

SATELLITE MONITORING OF OIL POLLUTION IN THE EUROPEAN SEAS

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ABSTRACT: Ships and industries damage the delicate coastal ecosystem in many parts of the world by releasing oil or pollutants into rivers, coastal and offshore waters. After a tanker accident the biggest problem is to get a clear idea of the extent of the oil slick and predict the way it will move. For natural and man-made oil spills it is necessary to operate a regular and operational monitoring. In the Mediterranean, North and Baltic seas aircrafts or ships normally carry it out. This is expensive and is constrained by the limited availability of these resources, borders between countries, daylight hours, good weather conditions, etc. Satellite imagery can help greatly identifying probable spills over large areas and then guiding aerial surveys for precise observation of specific locations. The Synthetic Aperture Radar (SAR) instrument, which can collect data almost independently of weather and light conditions, is an excellent tool to monitor and detect oil on water surfaces. SAR is currently on board the ENVISAT, ERS-2 and RADARSAT satellites. The application of this technology to the investigation of oil pollution in the Caspian, Black, Mediterranean, North and Baltic seas is shown.

KEY WORDS: Oil pollution, Satellite monitoring, ENVISAT, Caspian Sea, Black Sea, Mediterranean Sea, North Sea, Baltic Sea.

1. INTRODUCTION

As highlighted by Oceana in its report "The Other Side of Oil Slicks", chronic hydrocarbon contamination from washing out tanks and dumping bilge water and other oily waste represents a danger at least three times higher than that posed by the oil slicks resulting from oil tanker accidents (Oceana, 2003; 2004). For example, in the North Sea the volume of illegal hydrocarbon dumping is estimated at 15,000–60,000 tons per year, added to which are another 10–20,000 tons of authorized dumping. Oil and gas platforms account for 75% of the oil pollution in the North Sea via seepage and the intentional release of oil-based drilling muds (UNESCO, 2003). In the Mediterranean Sea it has been estimated at 400,000–1,000,000 tons a year. Of this about 50% comes from routine ship operations and the remaining 50% comes from land-based sources via surface runoff (UNESCO, 2003). In the Baltic Sea this volume is estimated at another 1,750–5,000 tons a year (Oceana, 2003; 2004). But, according to Finnish Environment Institute (<http://www.ymparisto.fi>, 2004), the total annual number of oil spills into the Baltic Sea may reach 10,000 and the total amount of oil running into the sea can be as much as 10,000 tons which is considerably more than the amount of oil pouring into the sea in accidents.

Detection of oil pollution is among most important goals of monitoring of the European seas. After a tanker accident or illegal oil discharge the biggest problem is to obtain an overall view of the phenomenon, getting a clear idea of the extent of the slick and predicting the way it will move. For natural and man-made oil spills it is necessary to operate a regular and operational monitoring. Oil pollution monitoring in the Mediterranean, North and Baltic Sea is normally carried

out by aircrafts or ships. This is expensive and is constrained by the limited availability of these resources. Aerial surveys over large areas of the seas to check for the presence of oil are limited to the daylight hours, good weather conditions and borders between countries. Satellite imagery can help greatly identifying probable spills simultaneously over very large areas and then guiding aerial surveys for precise observation of specific locations. The Synthetic Aperture Radar (SAR) instrument, which can collect data almost independently of weather and light conditions, is an excellent tool to monitor and detect oil on water surfaces. This type of instrument is currently on board the European Space Agency's ENVISAT and ERS-2 satellites, and the Canadian Space Agency's RADARSAT-1 satellite.

2. THE CASPIAN SEA

The Caspian Environment Programme (CEP) reports that the Caspian Sea is currently undergoing increasing anthropogenic pressure. As a result, there is an increase of eutrophication, water pollution by oil, heavy metals, chemicals and overexploitation of the Caspian biota (Kostianoy, Kosarev, 2005). Main sources of the Caspian Sea pollution are: (1) river run-off; (2) industrial and municipal waste waters; (3) offshore and onshore oil production; (4) oil transportation; and (5) flooded coastal zone due to sea level rise.

The Advanced Synthetic Aperture Radar (ASAR) image shows an area covering the Absheron Peninsula in Azerbaijan (Fig.1). Baku, appearing as a large bright area at the southern coast of peninsula, is the Azerbaijan's capital and one of the chief ports on the Caspian Sea. The oil platforms of Baku, built in the 1950s and 1960s appear as bright dots in the image. Some oil slicks (black patches) are visible in the image on the Caspian Sea. The

largest one of the size of the Baku City is related to Neftyanye Kamni oil rigs. The contamination of the Caspian Sea due to oil drilling in Baku has been a problem since the 19th century. There is no long-term statistics for oil spills in the Caspian Sea yet, because regular satellite monitoring of oil spills is absent in this region.

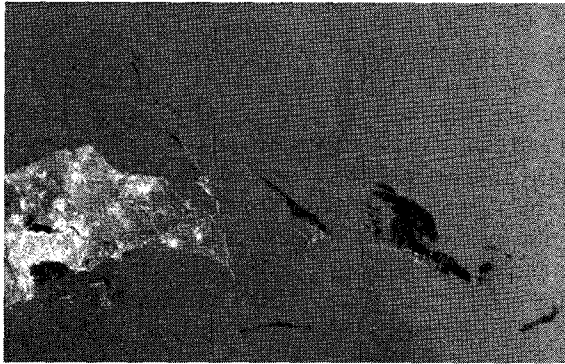


Figure 1. Oil pollution around Absheron Peninsula on 10 September 2004 (ASAR Envisat, 75-m resolution, ©ESA). Image courtesy: O.Yu. Lavrova, Russian Space Research Institute.

3. THE BLACK, MEDITERRANEAN AND NORTH SEAS

Increased oil exports from the Caspian Sea region to Russian and Georgian ports and across the Black Sea has led to increased oil tanker traffic (and risks of an accident) through the narrow, winding Turkish Straits (including the Dardanelles, Marmara Sea, and Bosphorus Straits). The result of this high level of traffic is a high risk of pollution and even ecological disaster in the Black and Mediterranean seas. According to Energy Information Administration (www.eia.doe.gov) around 50,000 vessels per year (nearly one every 10 minutes) now pass through Turkish Straits. Around one-tenth of these are oil or liquefied natural gas tankers. This increased congestion has led to a growing number of accidents; between 1988 and 1992, there were 155 collisions in the straits, some of them resulting in spilling thousands tons of oil into the straits.

The application of satellite SAR technology to the investigation of oil pollution in the Mediterranean, Black, North and Baltic seas was done in the OCEANIDES Project (2003-2005), which was an EC 5th Framework project and corresponded to the theme "Environmental Stress in Europe". The aim of OCEANIDES was to understand the number, location and impact of oil slicks deposited annually in European waters and to lay the foundations for a monitoring system that will provide this information in a continuous manner. In the Black Sea (Fig.2) it was detected about 200-250 oil spills yearly (in 2000-2002), in the Mediterranean Sea (Fig.3) – 1700 oil spills yearly (1999-2002) and in the North Sea (Fig.4) – 520 oil spills in 2000 (<http://oceanides.jrc.cec.eu.int/>).

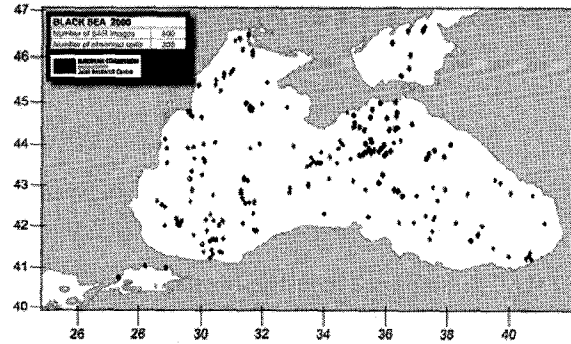


Figure 2. Oil spills detected in the Black Sea in 2000 by the analysis of SAR imagery (<http://oceanides.jrc.cec.eu.int/>).

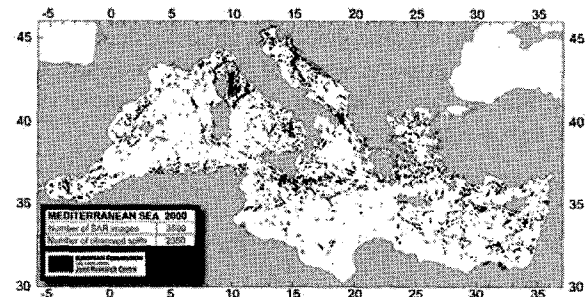


Figure 3. Oil spills detected in the Mediterranean Sea in 2000 by the analysis of SAR imagery (<http://oceanides.jrc.cec.eu.int/>).

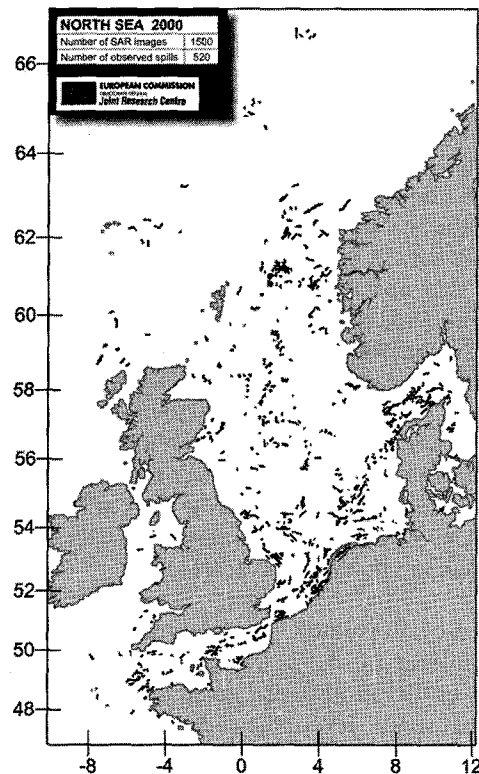


Figure 4. Oil spills detected in the North Sea in 2000 by the analysis of SAR imagery (<http://oceanides.jrc.cec.eu.int/>).

Under certain conditions it's possible to observe oil slicks in the visible band also. Such a case is shown in Fig. 5 where large oil spills were detected recently along the Lebanese coast from the analysis of MODIS-Aqua imagery. Damage to the Jiyeh Power Station in mid-July 2006 during military conflict between Israel and Lebanon spilled 15,000 tons of oil into the Mediterranean Sea. The slick spreads from the power plant northward of the city of Beirut as it easier to see in the enlarged areas (Fig. 5). The spill was expected to affect fishing and tourism industries, as well as local wildlife.

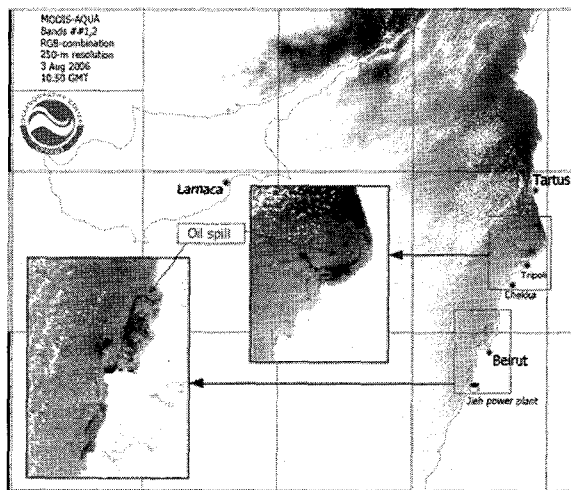


Figure 5. Oil spills along the Lebanese coast on 3 August 2006 derived from MODIS-Aqua. Image courtesy: D.M. Soloviev, Cyprus Oceanography Center.

4. THE BALTIC SEA

One of the main tasks in the ecological monitoring of the Baltic Sea is an operational satellite and aerial detection of oil spillages, determination of their characteristics, establishment of the pollution sources and forecast of probable trajectories of the oil spill transport. According to HELCOM (2002), a total yearly number of confirmed oil spills in the Baltic Sea detected by aerial surveys in 1989-2002 ranges between 350 and 750.

Since 1993 there is no more regular aerial surveillance of the oil spills in the Russian sector of the southeastern Baltic Sea and in the Gulf of Finland. In June 2004 we organized daily service for monitoring of oil spills in the southeastern Baltic Sea based on the operational receiving and analysis of ASAR ENVISAT and SAR RADARSAT data as well as of other satellite IR and VIS data, meteo information and numerical modelling of currents required for identification of slick nature in the sea and forecast of oil spills drift (Kostianoy, 2005; 2006; Kostianoy et al., 2004; 2005a,b,c; 2006). The principal difference with the above mentioned OCEANIDES Project was: (1) an operational regime of monitoring 24 hours/day, 7 days/week during 18 months; and (2) a complex approach to oil spills detection and forecast of their drift.

Operational monitoring of oil pollution in the sea was based on the processing and analysis of ASAR ENVISAT (every pass over the southeastern Baltic Sea, 400x400 km, 75 m/pixel resolution) and SAR RADARSAT (300x300 km, 25 m/pixel resolution) images received from KSAT Station (Kongsberg Satellite Services, Tromsø, Norway) in operational regime (1-2 hours after the satellite's overpass). For interpretation of ASAR ENVISAT imagery and forecast of oil spills drift IR and VIS AVHRR (NOAA) and MODIS (Terra and Aqua) images were received, processed and analyzed, as well as the QuikSCAT scatterometer and the JASON-1 altimeter data. Satellite receiving station at Marine Hydrophysical Institute (MHI) in Sevastopol (Ukraine) was used for operational 24 hours/day, 7 days/week receiving of AVHRR NOAA data for construction of sea surface temperature, optical characteristics of sea water and currents maps. SST variability and intensive algae bloom (high concentration of blue-green algae on the sea surface in the summertime) allow to highlight meso- and small-scale water dynamics in the Baltic Sea and to follow movements of currents, eddies, dipoles, jets, filaments, river plumes, and outflows from the Vistula and the Curonian bays. Sequence of daily MODIS IR and VIS imagery allows to reconstruct a real field of surface currents (direction and velocity) with 0.25-1 km resolution, which is very important for a forecast of a direction and velocity of potential pollution drift including oil spills and to predict their transport by currents.

Sea wind speed fields were derived from scatterometer data from every path of the QuikSCAT satellite over the Baltic Sea (twice a day). These data were combined with data from coastal meteorological stations in Russia, Lithuania, Latvia, Estonia, Sweden, Denmark, Germany, Poland, and numerical weather models. Satellite altimetry data from every track of Jason-1 over the Baltic Sea were used for compilation of sea wave height charts, which include the results of the FNMOCC (Fleet Numerical Meteorology and Oceanography Center) WW3 Model. Both data were used for the analysis of the ASAR ENVISAT imagery and estimates of oil spill drift direction and velocity.

In total 274 oil spills were detected in 230 ASAR ENVISAT images and 17 SAR RADARSAT images received from 12 June 2004 till 30 November 2005 (Fig. 6). Oil spills clearly revealed the main ship routes in the Baltic Sea directed to Ventspils, Liepaja, Klaipeda (routes from different directions), Kaliningrad, and along Gotland Island (Fig. 6). No spills originated from D-6 oil platform were observed. The interactive numerical model Seatrack Web SMHI (Ambjörn, 2006) was used for a forecast of the drift of (1) all large oil spills detected by ASAR ENVISAT in the southeastern Baltic Sea and (2) virtual (simulated) oil spills from the D-6 platform.

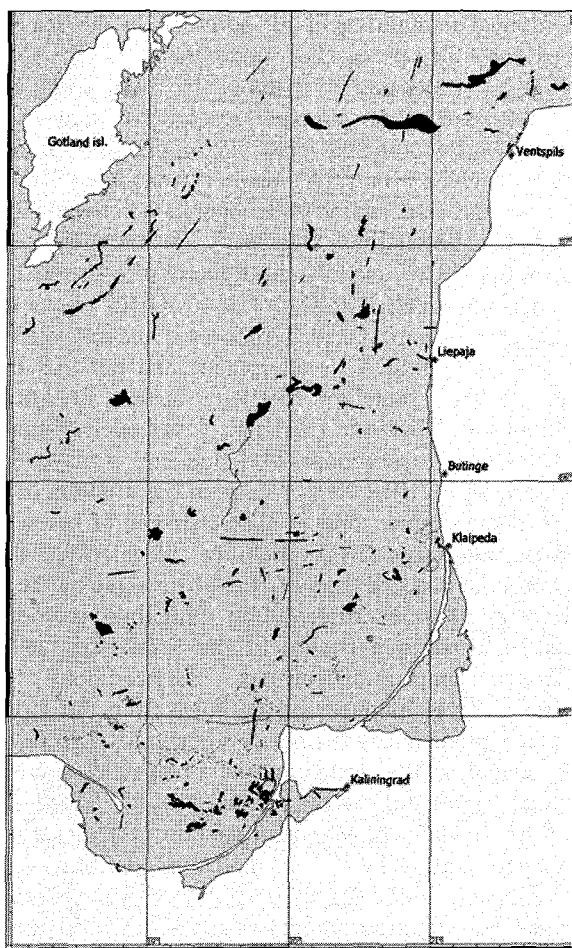


Figure 6. Map of all oil spills detected by the analysis of the ASAR ENVISAT and SAR RADARSAT imagery in June 2004 – November 2005.

5. CONCLUSIONS

ASAR ENVISAT and SAR RADARSAT provide effective capabilities to monitor oil spills, in particular, in the Baltic Sea, as well as in the other European seas. Combined with satellite remote sensing (AVHRR NOAA, MODIS-Terra and -Aqua, QuikSCAT, Jason-1) of SST, sea level, chlorophyll concentration, mesoscale dynamics, wind and waves, this observational system represents a powerful method for long-term monitoring of ecological state of semi-enclosed seas especially vulnerable to oil pollution. Our experience in operational monitoring could be easily transferred to the Caspian, Black, Mediterranean and other European seas.

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