The Role of Remote Sensing to Detect Oil Pollution

Tugsan ISIACIK COLAK,
Istanbul Technical University Faculty of Maritime, Tuzla 34940, Turkey
isiacik@itu.edu.tr

Abstract

Remote sensing techniques play an important role for environmental applications. The study area of remote sensing in different fields varies wide such as agriculture, forestry, geology, hydrology, sea ice, land cover, land use, coastal monitoring, and ocean monitoring. Latter have an important factor for environment, when considering that Oceans cover %70 of Earth surface. The oceans provide valuable food and biophysical resource which are vitally important. Oceans are also the main element of world transportation. Major oil pollution inputs to the Marine Environment are industrial wastes, tankers accidents, explorations and oil from vessels during transportation. Besides ship collisions/accidents, ship operations cause illegal oil pollution. Oil spills floating on the sea surface are detectable by remote sensing. Remote sensing data and techniques play an important role to combat and to detect oil pollution from satellite and aerial observations. In an emergency case of any oil pollution disaster, it is possible to detect the spatial distribution and size of oil pollution using remotely sensed data. Based on information created satellite images, it is possible to generate an emergency contingency plan rapidly and support recovery actions.

This paper examines the role of remote sensing techniques to detect and combat oil spills, to minimize their impact and to mitigate oil pollution in case of an accident.

1. Introduction

Marine Pollution is great and very troublesome problem, marine pollution can be directly or indirectly by manmade source giving energy or substance to the marine environment. Marine pollution is created and results hazards to the marine environment, human, marine life (1). Marine Pollution Sources are oil pollution, heavy metals and their production, bioaccumulation, disposal of radioactive materials, discharge of sewage, harmful algal blooms (2). Shipping and maritime activities cause a great amount of marine pollution, generally. Oil is one of the most important pollutant resulting from maritime activities (1).

Marine Pollution Prevention from Ships (MARPOL) Convention defines oil as; petroleum in any form including crude oil, fuel oil, sludge, oil refuse and refined products (other than petrochemicals which are subject to the provisions of Annex II of the present Convention) and, without limiting the generality of the foregoing, includes the substances listed in appendix I to MARPOL Annex (3).

Possible sources of ship based oil pollution both tankers and all ships are shown in the Figure 1 below for example for all ships machinery space waste pure products for tankers both machinery space and cargo. Ship generates oily waste products due to usage of consuming heavy fuel oil, marine oil and lubricating oil for all types power driven vessels. On the other hand routine tanker operations cause oily waste water. Three categories of oily waste generally accumulate on board large vessels. These are bilge waste, sludge waste and oil cargo residue waste (slop) (1).

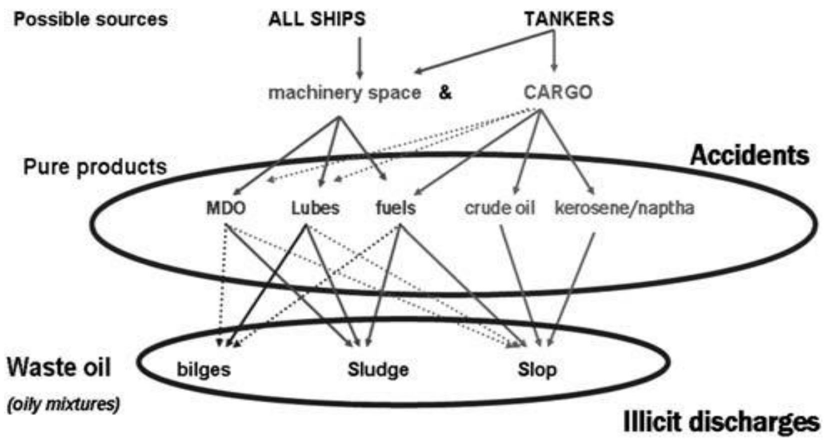


Figure 1: Possible sources of oil spills from different ship categories (4).

2. Oil Spill

Viscosity, volatility, and toxicity are the main differences between oil kinds. Viscosity can be described as oil's resistance to flow. Volatility refers to how quickly the oil evaporates. Toxicity refers to how poisonous; the oil is to human nature or other organisms. Spill of the various types of oil may affect the environment differently (5).The oil spill cleaning operations and methods may also differ. Spill responders categorize oil into four basic types. Very light oils (jet fuels, gasoline), Light oils (diesel, no. 2 fuel oil, light crudes), Medium oils (most of the crude oils), Heavy oils (heavy crude oils, no. 6 fuel oil, bunker) (5).

2.1 Effect and Behaviour of Oil

Important physical and chemical properties of oils that will affect the behaviour and effects of oil in water and aquatic environments are its surface tension, specific gravity, and viscosity. The composition and characteristics of an oil, together with a number of circumstances relating to the time and place of the spill, the amounts of oil, weather conditions etc. will determine how persistent the oil will be, how it will spread, whether it will evaporate or sink, etc (6).

- **Some Major Oil Spills Around World**

Amoco Cadiz Oil Spill – France, On March 16, 1978, the Amoco Cadiz ran aground on Portsall Rocks, three miles off the coast of Brittany due to steering failure. The vessel had been sailing from the Arabian Gulf to Le Havre, France. The entire cargo of 1,619,048 barrels, spilled into the sea. A slick 18 miles wide and 80 miles long polluted approximately 200 miles of Brittany coastline (7).

Exxon Valdez, the oil slick (blue areas) eventually extended 470 miles southwest from Bligh Reef. The spill area eventually totalled 11,000 square miles.(8). On March 24 1989, the tanker *Exxon Valdez*, en route from Valdez, Alaska to Los Angeles, California, ran aground on Bligh Reef in Prince William Sound, Alaska. The vessel was traveling outside normal shipping lanes in an attempt to avoid ice. Within six hours of the grounding, the *Exxon Valdez* spilled approximately 10.9 million gallons of its 53 million gallon cargo of Prudhoe Baycrude oil. Eight of the eleven tanks on board were damaged. The oil would eventually impact over 1,100 miles of non-continuous coastline in Alaska. Supertanker Exxon Valdez, 24 Mar 1989, 9:12 p.m. ran aground on Bligh Reef in Prince William Sound, Alaska (9).

M/T Prestige, suffered a fracture in the side shell on 14 November 2002 during a spell of very severe weather outside Spain. The M/T Prestige was a 1976 built Pre-Marpol single hull crude oil tanker. She sank releasing over 20 million gallons of oil into the sea.(10)

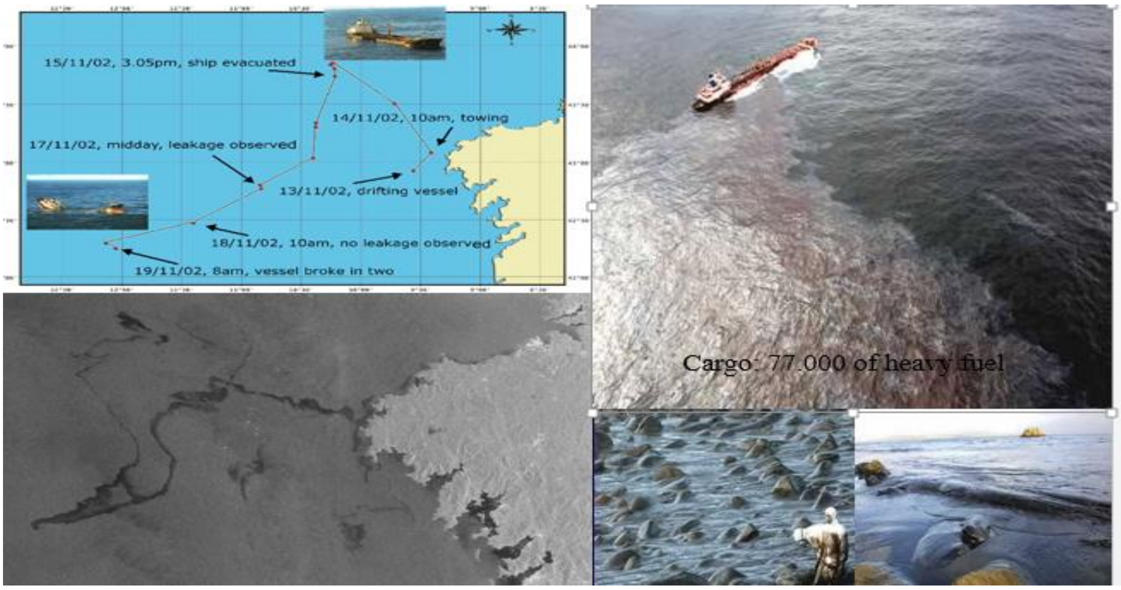


Fig 2: The prestige November 2002 sank off the coast of Galicia, Spain.

Deepwater Horizon, a semi-submersible drilling rig, sank on April 22, after an April 20th explosion on the vessel. Eleven people died in the blast. When the rig sank, the riser—the 5,000-foot-long pipe that connects the wellhead to the rig—became detached and began leaking oil. In addition, U.S. Coast Guard investigators discovered a leak in the wellhead itself. As much as 60,000 barrels of oil per day were leaking into the water, 125 miles of coast were affected (11).

On the other hand except ship accidents causing oil pollution, the essential problem is illegal oil discharges. The best method for dealing with bilge water, sludge and slop is storing and delivering ashore as disposal but storing these oily water and oily products on board causes less cargo transportation and too much cost for delivering the oily products a shore as disposal. These are the great reason why ships make illegal discharging (1).

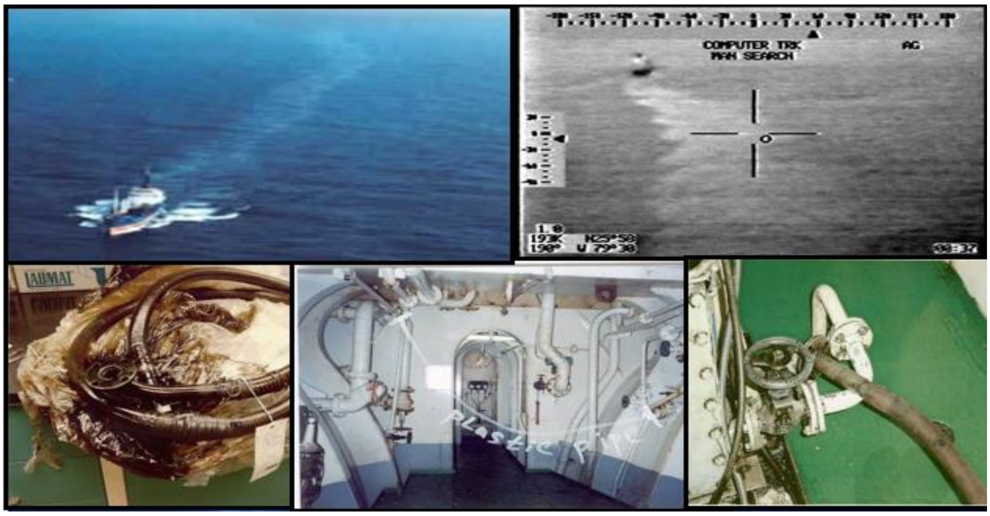
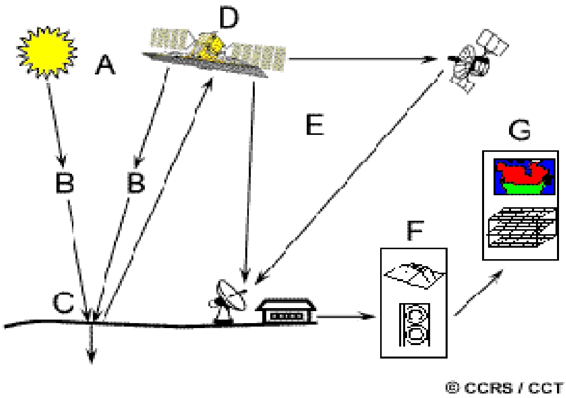


Figure 3: Illegal Oil Discharging from ships, bilge water (1)

3. REMOTE SENSING

"Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information" (12).



1. Energy Source or Illumination **(A)**
2. Radiation and the Atmosphere **(B)**
3. Interaction with the Target **(C)**
4. Recording of Energy by the Sensor **(D)**
5. Transmission, Reception, and Processing **(E)**
6. Interpretation and Analysis **(F)**
7. Application **(G)** (12).

Figure 4: Remote Sensing basic diagram

3.1 Remote Sensing Applications in General for Earth Observation

There can be many applications for remote sensing, in different fields, for agriculture mapping, forestry, environmental monitoring. geological applications, hydrological applications, land use applications, and ocean applications. One of the important ocean applications with remote sensing is oil spill. Oil spill monitoring**,** mapping and predicting oil spill extent and drift, strategic support for oil spill emergency response decisions, identification of natural oil seepage areas for exploration are study area for remote sensing.(12)

Figure 6: Monitoring Disaster, Tsunami 2004, Pre and Post Disaster of Thailand

In this study, remote sensing of oil spill monitoring subject will be studied. Oil spills no doubt destroy marine life, give fatal damage to habitat for animals and humans. To isolate the affected areas and organise clean up efforts properly, a number of factors should be identified when an oil spill generates. Spill location, Size and extent of the spill, Direction and magnitude of oil movement, Wind, current and wave information for predicting future oil movement.

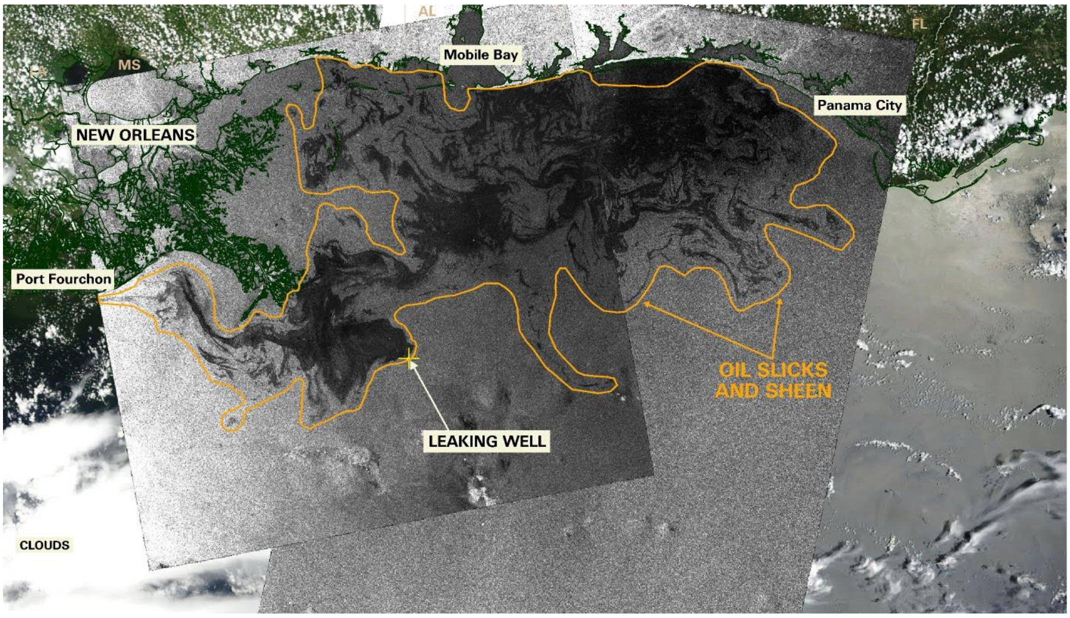


Figure 7: RADARSAT images aquired June 27, 2010, courtesy of CSTARS.

Remote sensing gives the advantage of observing events remotely and often inaccessible areas. It can be used to both detect and monitor spills. Remote sensing data gives rate and direction of oil movement for ocean spills through multi temporal imaging. By entering these data to drift prediction modelling which makes further control and clean up efforts more effective and easier (13).

4. Different Tools to Detect and Monitor Oil Spills

There are different remote sensing applications for detection of oil pollution/spills. These include ultraviolet, visible, infrared and microwave wavelength regions of the electromagnetic spectrum In the electromagnetic spectrum, oil gives different responses and signatures to radiation from different wavelengths. Ultraviolet (UV) technology can be used to detect oil spills which display high reflectivity of UV radiation even at thin layers. The UV instrument is not usable at night. Also wind slicks, sun glints and biogenic material can cause false alarms in the UV data (14).). Oil absorbs solar radiation and re-emits a portion of this energy as thermal energy mostly in the range between 8–14 μm and emissivity difference between oil (0.972 μm) and water (0.993 μm) leads to different brightness temperatures (15). Therefore, oil layers appear colder than water in thermal images. Infrared (IR) sensors are useful in evaluating the thickness of oil slicks as the thickness increases they appear hotter in the infrared images and they can be distinguished from thin ones. However very thin layers cannot be identified in TIR images (16). Microwave sensors are the most applicable tools for oil pollution monitoring since they are not affected by, weather conditions, clouds, haze, and day/night differences. Microwaves penetrate through atmosphere with very little absorption (17).

4.1 Air Borne Observation for Oil Spill Monitoring

Airborne observation for oil spill monitoring can be carried out routinely, to look for and suppress operational pollution by ships. In this case the aims are to detect the pollution, accurately locate and describe the pollution where possible, identify the polluter in order to assess the pollution (quantity and quality), anticipate the evolution of the situation and prosecute the polluter via a pollution observation report (18). Second aim of airborne observation is used in the event of an accident, to assist in recovery and dispersion operations at sea. The aims of the observation missions are to, locate the slicks, accurately describe the slicks, map the pollution in order to monitor the pollution, adjust drift models, guide response operations that day and prepare the response operations for the following days (19).

Image of the sea surface to the right of the aircraft, taken with the Side-looking Airborne Radar (SLAR). Image dimensions on the sea surface are approx. 3000 m along-track, 4000 m across-track (20)

5. Satellite Remote Sensing for Oil Spill Monitoring with RADAR

Infrared, visible and UV sensors will not be able to detect oil in inclement weather such as heavy rain or fog (21). The most common microwave sensor for oil detection on sea surface is the **Synthetic Aperture Radar (SAR**). SAR image is a measure of surface roughness depending on the backscatter. The main mechanism in detection of oil slicks is the dampening effect of oil on water. Dampening of sea waves results in reduced radar return from the affected area, so that oil slicks appear as relatively dark features on the SAR scenes.

5.1 The Principle of Oil Spill SAR Imaging

The presence of oil on the surface of sea causes damping effect on the short wind waves (Bragg Waves) and reduce the radar back scattering. In such cases the oil spilled areas can be seen as dark patches in SAR images. An oil spill is physically a low backscatter area and appears as a dark area in SAR images. The figure shows how SAR catch spills from sea surface (5)

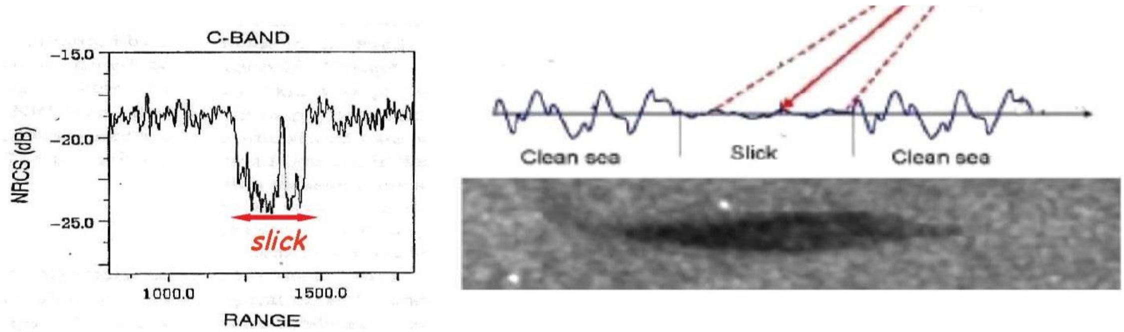


Figure 8: SAR Oil Spill Imaging

Neither very calm sea nor very rough sea surface is favourable conditions for oil slick detection for SAR. The figure shows optimum sea and wind condition (22);

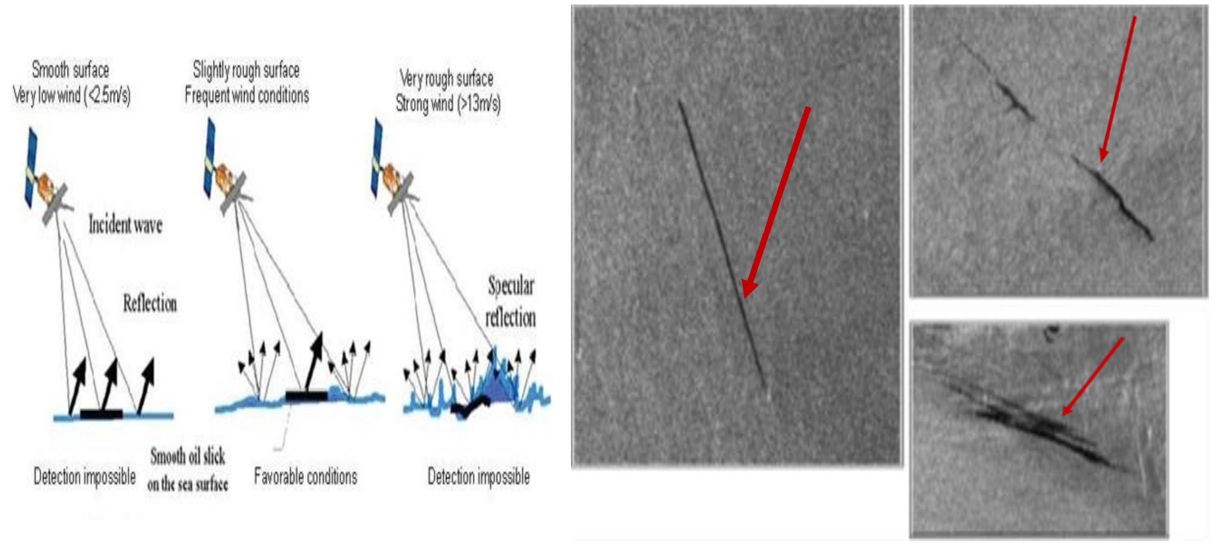


Fig 9: Slick detection condition.

SAR images require a number of processing steps before they can be interpreted properly. In the following picture, RADARSAT 1, 5 Agust 2012, this satellite picture is for the Northern Turkish Strait System, entry to Black Sea, before pre-processing. Processing starts with loading the SAR image into a software package which allows carrying out the pre-processing steps mentioned. Geo-referencing, radiometric and geometric corrections and filtering are the steps that carried out for the image processing. Then classification and further analysis are carried out and checked if there is an oil spill in the SAR satellite image or not. A trained analyst makes his decision. Because the dark area in the SAR picture can be a false alert like natural surface slick by turbulent mixing or bio-geo-chemical processes, and displacement,eddy currents or simply by the wind. Certain parameters will help trained analyst to make his decision. These parameters are total area, perimeter, roundness, general shape, degree of connectivity between patches, and more shape parameters.

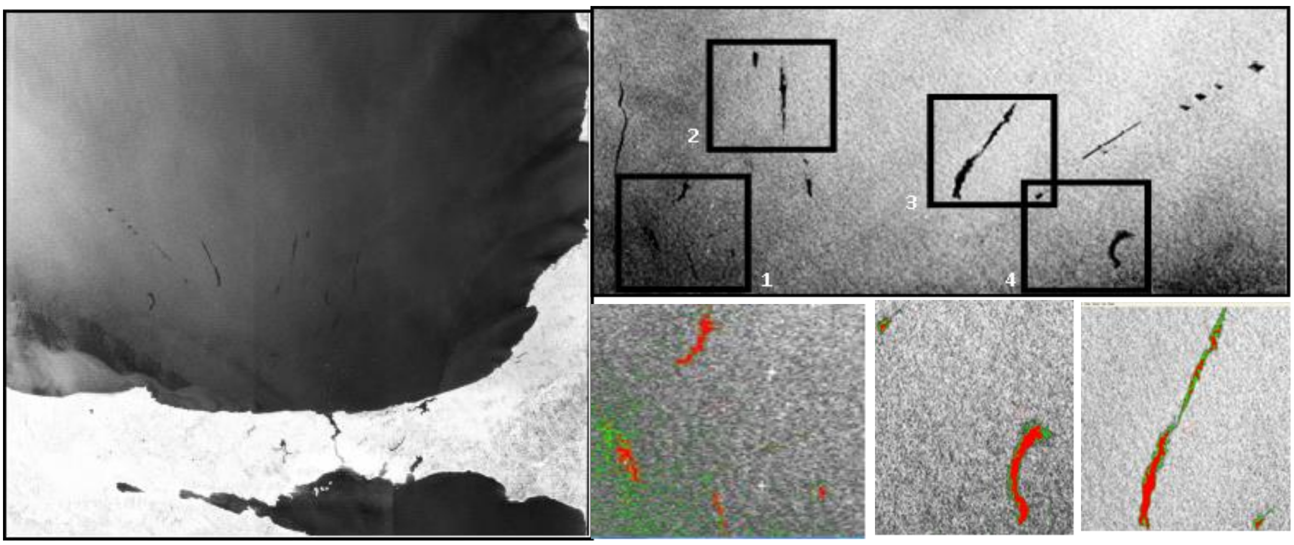


Figure 10: In the SAR image, black boxes are the possible oil spill area, RADARSAT, Agust 2012

6. Conclusion

With the increasing capacity of sea borne transportation, marine pollution especially ship based oil pollution has become one of the most important issue around world. Oil pollution with ship bilge water and sludge, or oil cargo residual and tank washing operations for tankers are called as ships illegal discharges by authorities, if these oily waters are discharges these oily waters directly to the sea. Another oil spill pollution source is ship accidents that cause oil pollution. One of the best effective instrument to detect and monitor oil pollution by maritime activities is satellite remote sensing because it allows us to detect oil pollution at the sea surface over a region of a few 100 kilometres at once. It is possible to monitor near-real time, continuously or periodically for the region of interest. SAR (Synthetic Aperture Radar) which is a microwave sensor is ideal for monitoring seas during day and night. It is also not affected by haze, clouds and dust. However satellite remote sensing equipment is great achievement for oil spill monitoring, it is not effective to mitigate an oil spill alone. The combined use of satellites, ships and aircraft for surveillance increases the chances of early detection of oil spills and fast clean-up operations, and preventing further environmental damage (23).

References

1. İşiacik T. Colak, Can., S., Monitroing Ship Based Oil Pollution for Black Sea, 1st International Symposium on Naval Architecture and Maritime, 2011, İstanbul
2. http://www.waterencyclopedia.com/Po-Re/Pollution-of-the-Ocean-by-Sewage-Nutrients-and-Chemicals.html, accessed at 20.01.2015
3. IMO, 1978-79. MARPOL Convention, Annex I, UK.
4. Ferraro, G. and Pavliha, M., The European and International legal framework on monitoring and response to oil pollution from ships, Journal of Environmental Monitoring.,2010
5. Remote Sensing of Ocean Oil-Spill Pollution, - Schistad H., Solberg, Vol. 100, No. 10, October 2012 | Proceedings of the IEEE
6. http://www.opec.org/opec_web/en/press_room/180.htm accessed at 15.01.2015.
7. http://response.restoration.noaa.gov/sites/default/files/Oil_Spill_Case_Histories.pdf, accessed at 15.01.2015
8. http://www.eoearth.org/view/article/152720/accessed at 17.01.2015
9. Oil in the Sea III:: Inputs, Fates, and Effects Committee on Oil in the Sea: Inputs, Fates, and Effects,National Research Council,Division on Earth and Life Studies,Transportation Research Board,Marine Board,Ocean Studies Board, 1989
10. http://heiwa http://heiwaco.com/prestige.htmco.com/prestige.htm, accessed at 20.01.2015
11. http://www.infoplease.com/ipa/A0001451.html#ixzz1Knvg5Vdh, accessed at 07.12.2014.
12. http://www.ccrs.nrcan.gc.ca/ccrs/eduref/tutorial/indexe.html> accessed at 14.01.2015.
13. https://earth.esa.int/handbooks/asar/CNTR1-1-6.html accessed at, 07.12.2014.
14. Brekke C., Solberg A. H.S. 2005, Oil spill detection by satellite remote sensing, Remote Sensing of Environment, Vol. 95, pp. 1–13.
15. Sabins, F. F., 1997, Remote Sensing: Principles and Interpretation, 3rd edn (New York: W. H. Freeman).
16. Nirchio F., Sorgente M., Giancaspro A., Biamino W., Parisato E., Ravera R., and Trivero P. 2005. Automatic detection of oil spills from SAR images,International Journal of Remote Sensing Vol. 26, No. 6, pp.1157–1174
17. Woodhouse, I. H. 2006, Introduction to microwave remote sensing, Taylor & Francis, 370 pages.

18. http://www.slideshare.net/tugsan/different-tools-to-detect-and-monitor-oil-spills-aerial-observation-tech
19. Aerial Observation of Oil Pollution At Sea Operational Guide, CEDRE, 2006
20. http://lms.seos-project.eu/learning_modules/marinepollution/marinepollution-c02-ws02-p02-t.html
21. Advances in Remote Sensing for Oil Spill Disaster Management: State-of-the-Art Sensors Technology for Oil Spill Surveillance, M.Nand Jha, Levy J, and Gao Y.,
22. Yonggang, J., First Institute of Oceanography SOA,ppt
23. http://www.monae.org/documents/Oil%20monitoring.pdf, accesed at 20.01.2015