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OIL SPILLS AND THEIR DETECTION

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Abstract- **This paper presents the state of the art for oil spill detection in the world oceans. We discuss different satellite sensors and oil spill detectability under varying conditions. In particular, we concentrate on the use of manual and automaticapproaches to discriminate between oil slicks and look-alikes based on pattern recognition. We conclude with a discussion of suggestions for further research with respect tooil spill detection systems.**

Key words: **Oil spills; detection; Satellite sensors; SAR;KSAT**

1. INTRODUCTION

There are many oil spills that occur every year. They harm the environment, the plants, the animals, and the people who live near it. People can clean up the spill. The environment takes the disaster of an oil spill and the follow a natural process to clean itself. Oil spills are dangerous to everything and cost a lot to clean up. In France an oil spill occurred that leaked ten million liters of oil into the ocean on December twelfth. The spill cost seven million dollars to clean up. After all the clean up attempts three hundred and fifty kilometers of coastline was covered in oil. The oil will stay in the sand for almost thirty years. Other things affected would include the sea birds. All the clean up crews estimate that up to one hundred thousand sea birds died. The oil killed them when it coated their bodies so they could not fly away and they drowned . One of the worst places in the world for an oil spill to occur is in Alaska. On March 1989 the Exxon Valdez grounded itself in Alaska. The tanker spilled eleven million gallons of oil into the waters of south central Alaska. The spill affected many different animals, the land, and the people living near the spill site. Many people responded to the spill and quickly went to the site to help clean it up. The oil shipping company contributed nearly two million to help clean the spill up. The spill damaged the tundra. The damaged spots will take up to fifty years for the tundra to repair. The fish, that the spill damaged are still recovering. Two major types of fish were damaged. They were salmon and herring. The oil will cover the fish and the fish will suffocate to death. The oil also damages the eggs the fish lay. It makes the baby fish deformed or not born at all. The decline in the fish population is what hurt the people the most. Ten years later the fish are still returning to their point of stability.

Observed oil spills correlate very well with the major shipping routes (e.g. in the Southeast Asian Waters (Lu, 2003 and Lu et al., 1999), and in the Yellow and East China Sea (Ivanov et al., 2002) and commonly appear in connection with offshore installations (e.g. in the North Sea (Esped al & Joh annessen, 2000). Annually, 48% of the oil pollution in the oceans are fuels and 29% are crude oil. Tanker accidents contribute with only 5% of all pollution entering into the sea (Fingas, 2001). After analysing 190 ERS-1[1] SAR images of the Mediterranean Sea, Pavlakis et al. (1996) found that "deliberate" oil spills appear with considerably higher frequency than oil spills corresponding to reported ship accidents. According to the European Space Agency (1998), 45% of the oil pollution comes from operative discharges from ships. When taking into account how frequent such spillages occur, controlled regular oil spills can be a much greater threat to the marine environment and the ecosystem than larger oil spill accidents like the Prestige tanker (carrying >77,000 ton of fuel oil (Oceanides Web-site, 2004) accident at Galice, northwest coast of Spain in 2002. The impact of not monitoring oil spills is presently unknown, but the main environmental impact is assumed to be sea birds mistakenly landing on them and the damage to the coastal ecology as spills hit the beach (Shepherd, 2004). Sime cek-Beatty and Clemente-Colón (2004) describes how oiled birds lead to the use of SAR for locating a sunken vessel leaking oil.

Active microwave sensors like Synthetic Aperture Radar (SAR) capture two-dimensional images. The image brightness is a reflection of the microwave backscattering properties of the surface. SAR deployed on satellites is today an important tool in oil spill monitoring due to its wide area coverage and day and night all-weather capabilities.Satellite-ba sed oil pollution monitoring capabilities in the Norwegian waters were demonstrated in the early 1990s by using images from the ERS -1 satellite (e.g. Bern et al., 1992b, Skøelv & Wahl, 1993 and Wahl et a l., 1994b). A demonstrator system based on ERS for the Spanish coast was presented by Martinez and Moreno (1996). Today, R ADARSAT-1 and ENVISAT are the two main providers of satellite SAR images for oil spill monitoring.

2. SATELLITE SENSORS FOR OIL SPILL DETECTION

Microwaves are commonly used for ocean pollution monitoring by remote sensing. They are often preferred to optical sensors due to the all-weather and all -day capabilities. Mainly spaceborne instruments are covered here, but airborne Side -Looking Airborne Radar (SL AR) is another possibility. SLAR is a n older but less expensive technology than SAR, but SAR has greater range and resolution (Fingas & Bro wn, 1997). Airborne surveillance is limited by the high costs and is less efficient for wide area surveillance due to its limited coverage. While spaceborne SAR can be used for a first warning, aircrafts are more suitable to be brought into action to identify the polluter, the extent, and the type of spill. An example is the German aerial surveillance, which locates oil discharges by SLAR, infrared/ultra violet (IR/UV) scanning is used to quantify the extent of the film, a microwave radiometer (MWR) is used to quantify the thickness and a laser-fluor o-sensor (LFS) is used for oil type classification (Trieschmann et al., 2003).

With more than 200 wavelengths provided by a hyperspectral sensor, the spectral signature of oil can be exploited and used to distinguish between different oil types (crude or light oil). This can also eliminate the false alarm rate of ocean features that have the same colour and appearance as oil. Salem and Kafatos (2001) found that a signature matching method based on airborne hyperspectral imaging (looking at chemical composition) is more accurate than the conventional techniques, where analysis is based on visual interpretation of the oils colour and its appearance in the satellite image. There is currently no commercial spaceborne hyperspectral sensor in orbit. The NASA EO-1 Hyperi on hyperspectral sensor is an example of a spaceborne technology demonstrator that was launched in 2000. However, its major drawback is its small swath width of only 7.5×100 km.

UV technology can be used to detect oil spills as the spill displays high reflectivity of UV radiation even at thin layers. The UV instrument is not usable at night, and wind slicks, sun glints and biogenic material can cause false alarms in the UV data. These interferences are often different from those for IR, and a combination of IR and UV can provide a more reliable indication of oil and can be used for estimating oil thickness (Fingas & Brown, 1997).

In conclusion, SAR is still the most efficient and superior satellite sensor for oil spills detection, th ough it does not have capabilities for oil spill thickness estimation and oil type recognition. SAR is useful particularly for searching large areas and observing oceans at night and at cloudy weather conditions. Usually even small volumes of oil cover large areas (several hundred meters) and thus the need for very high spatial resolution in SAR images is not crucial. Bern et al. (1992a), Wahl et al., 1994a and Wa hl et al., 1996 found Low Resolution ERS -1 SAR images with a spatial resolution of 100 m sufficient for oil spill detection. The original ERS images were filtered using a 5×5 mean filter, which gave better noise characteristics than the full resolution images, and they were therefore easier to analyse. SAR also has some limitations, as a number of natural phenomena can give false oil spill detections. In addition, SAR is only applicable for oil spill monitoring in a certain range of wind speeds. The usefulness of SAR in terms of responding to oil spills at various conditions is covered in more detail in the next section.

3. SAR FOR OIL SPILLS

The wind vector SAR instruments have the advantage over optical sensors that they can acquire images of the oceans and coastal areas day and night and despite any weather conditions. However, the wind level influences the backscatter level and the visibility of slicks on the sea surface. Oil slicks are visible only for a limited range of wind speeds. They compared data from airborne surveillance with ERS SAR data. For both sensors they found that the maximum number of detected pollutions was found during summer time, April to September. A reason for this could possibly be that the average wind speed is higher at wintertime at all test sights (e.g. mean wind speed in the North Sea is above 10 m/s). A wind speed between 12 m/s and 14 m/s should possibly be considered as the upper limit for all spaceborne SAR imagery of oil spills (Litovchenko et al., 1999), but the maximum wind speed for slick detection depends on oil type and the age (i.e. time since release) of the spill (Bern et al., 1992a). Thus, an estimate of the wind speed is valuable information for oil spill detection.For the oil spill detection algorithm described by Solberg et al. (1999), the wind level is set manually based on inspecting the image visually and it is used as input to a threshold procedure.

Other possibilities are to incorporate wind information delivered by an external source (e.g. a forecasting centre) or to use automatic methods. With automatic methods for wind estimation, the wind speed can be derived directly from the SAR image. Salvatori et al. (2003) estimate the wind speed from the SAR image by applying an inverted CMOD4[5] model. The wind vector appeared useful in knowing the evolution of the spill and to obtain correct classification.

4. METHODOLOGY

Methodology for oil spill detection in SAR images.
We distinguish between manual approaches and automatic algorithms for oil spill detection. Detection of oil spills can be divided in (Indregard et al., 2004):

- Detection of suspected slicks.
- Manual verification of the slicks (oil/look-alike) and assignment of confidence levels.

Since 1994 KSAT in Norway has provided a manual oil spill detection service. Here operators are trained to analyse SAR images for the detection of oil pollution. The KSAT approach is described by Indregard et al. (2004). External information about wind speed and direction, location of oilrigs and pipelines, national territory borders and coastlines are used as support during the analysis. The operator uses an image viewer that can calculate some spot attributes, but he/she still has to go through the whole image manually. This is time consuming. Possible oil spills found are assigned either high, medium or low confidence levels. The assignment is based on the following features: the contrast level to the surroundings, homogeneity of the surroundings, wind speed, nearby oilrigs and ships, natural slicks nearby, and edge and shape characteristics of the spot. The determination of a confidence level is not exact science and there will always be an uncertainty connected to the results from manual inspection.

During manual inspection, contextual information is an important factor in classifying oil spills and look-alikes. A challenge is to somehow incorporate the “expert knowledge” into the automatic algorithm. In Solberg and Volden (1997), a set of rules and knowledge about external conditions (e.g. wind speed) are used to adjust prior probabilities of oil slicks in the scene. This information is incorporated into a classifier based on a multivariate probability distribution function. Fiscella et al. (2000) found that a human image interpreter and a classification algorithm have similar ability to discriminate oil spills from look-alikes, but the image set used contained only 21 oil spill candidates.

A study of best practise, based on a comparison of KSAT's manual approach, NR's automatic algorithm (described in Bjerde et al., 1993, Solberg & Solberg, 1996 and Solberg & Volden, 1997 and lately in Solberg et al., 1999 and Solberg et al., 2003) and QinetiQ's semi-automatic oil spill detection approach, has been performed by the ongoing Oceanides project (Indregard et al., 2004). QinetiQ's semi-automatic approach covers only the first step of an automatic algorithm, dark spot detection, and therefore the output targets must be classified visually by an operator. In this study the three satellite-based approaches were compared to airborne verifications in a satellite-airborne campaign. The study was done without the operators or the algorithms knowing of the aircraft verifications. (The benchmark set consisted of 32 RADA RSAT -1 images.) This data set contained 17 verified oil spills. KSAT detected 15 of these slicks, NR's algorithm detected 14, and QinetiQ detected 12. The results show that a challenge is to have all operators pick out the same spots and assign the same confidence levels. NR's algorithm is objective (with one exception of manual wind level assignment, see Section 3.2) and produces the same result repeatedly. Good agreement was found for high-contrast slicks among the various methods, but there were some differences on low-contrast slicks. The operators at KSAT use 3–25 min to analyse a scene (on average 9 min), the NR's algorithm used about 3 min and QinetiQ's algorithm used 20 min per scene in average. This shows that automatic approaches are more feasible as the volume of SAR data grows.

In conclusion, A study of best practice of manual versus automatic oil spill systems showed that operators show some variance in detecting spills, particularly in assigning an oil spill confidence estimate. An automatic algorithm with a reliable and objective oil spill confidence estimate would be highly desirable. The need for automatic algorithms depend on the number of images to be analysed, but for monitoring large ocean areas it is a cost-effective alternative to manual inspection.

5. CONCLUSION

More work on the direct comparison of the performance of manual versus automatic methods for oil spill detecti on is needed. Up to now, the automatic systems have been tested off-line, thus, additional spills reported by the automatic systems cannot be verified. We still believe that the slicks classified as oil by automatic algorithms should go through a manual inspection prior to sending out aircrafts. In that case, inspection of a couple of slicks per scene would be much more efficient than inspection of the complete scene as currently done. As part of the ESA project Northern View, NR's automatic algorithm will be deployed in KSAT's operational environment.

Automatic oil spill detection algorithms are normally divided into three steps, dark spot detection, dark spot feature extraction, and dark spot classification. Few papers are published on automatic algorithms for classification of oil spills and its look-alikes as most authors focus on the detection step. Large-scale classification studies with acceptable classification performance are reported based on statistical classification (Fiscella et al.,2000 a nd Solberg et al., 1999), and neural nets (Frate et al., 2000). An extensive comparison of the classifiers used by the different approaches, based on the same data set of features, would be desirable.

To increase the performance further, incorporation of more knowledge is needed. We believe that the future oil spill system should be an integrated system, including automatic algorithms, a data base of “hotspots” (e.g. oilrigs, sunken ships and seepages), ship lanes, alga information, and more extensive use of wind information.

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