# Oil slick detection by SAR imagery: algorithms comparison

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*Abstract*— **C-band SAR is well adapted to detect ocean pollution because backscatter is reduced by oil slicks. They appear as dark patches on the image as the increase of viscosity due to the presence of oil damps gravity-capillarity waves. In order to detect these dark patches, we use algorithms based on filters, gradients, and morphological mathematics, and a new approach based on ocean surface characterization. We have tested these methods on ERS and ENVISAT images acquired during *Prestige* tanker wreckage and the results are compared with aircraft surveys. We conclude that slicks with high contrast and simple shape are easily detected using basic algorithms, but most of the time, other methods are needed. The ocean characterization method is a way to follow for improving oil slick detection and providing decision aids for classification step.**

***Keywords*: *Synthetic Aperture Radar, oil slick, pollution detection.***

## I. INTRODUCTION

Ocean pollution has been recently highlighted by the *Prestige* tanker accident in Europe, like those of *Exxon Valdez*, *Erika* or *Aegean Sea* previously. These oil tanker accidents only account for 5% of total oil pollution worldwide and hide the regular pollution in important traffic zones like the Mediterranean [1], the Baltic seas [2], the Atlantic ocean [3] and the Malacca strait (around Singapore), generated by oil drillings or illegal discharges. Natural slicks are also common, of biological origin by photo-oxidation process or bacterial decomposition (fecal material, plankton, algae…) or of geological origin (bottom oil seeping). With regular passes over oceans, satellites are useful to get statistical information about slicks all over the world ocean. Counting all kinds of slicks, 10% of the ocean surface is estimated to be covered by slicks [4].

The objectives of slick detection are the followings. When accidents occur, polluted areas must be determined precisely in order to evaluate slick drift and to protect coastlines. At present, this work is done on request by airborne surveys; an automatic detection by satellite would be helpful and would provide means to fight against illegal discharges. Besides, slicks reduce air-sea exchanges processes, such as surface evaporation, formation of whitecaps and spray, yielding a significant reduction of $CO_2$ fluxes and heat transfers [4]. Thus, the slicks must be taken into account in climate change models. In other ways, natural slicks are of interest for biologists and fishermen since they show intense biological activity in the water column. For these reasons, efficient detection means have been implemented, with airborne and satellite measurements.

Satellite detection is well adapted since it regularly produces images in difficult access areas. Furthermore, they allow instantaneous coverage of areas as wide as 500 x 500 km. Slicks modify seawater viscosity and surface tension, therefore having a strong impact on short waves measured by radars [5, 6]. Backscatter level is decreased by slicks, which appear as dark patches in comparison with their surroundings. Synthetic Aperture Radar (SAR) seems to be one of the most suitable instruments for this kind of study since it does not depend on weather (clouds) nor sunshine and allows high resolution imaging of the ocean surface with pixel size of about 10 to 75 m. SAR measurements are mainly limited by wind and sea state [7]. Satellite surveys by ERS SAR have been used complementary to airborne survey after the *Aegean Sea* wreckage in 1992 for example [8], and ENVISAT ASAR satellite images have been analyzed during the *Prestige* disaster in 2002.

Tracking oil slick using SAR images is done in two steps: detection and classification, presented in section II. We focus on the detection part here, evaluating the possibilities offered by segmentation algorithms to detect slick contours on SAR images: section III presents some algorithms and their applications on a SAR image of *Prestige* tanker accident. Conclusions follow in Section IV.

## II. IMAGE ANALYSIS

Several approaches exist for slick analysis from satellite images. Automatic analysis of SAR images is not applied routinely yet. Most of tanker accidents have shown that analysis must still be supervised. In cases of such disasters, quick results have to be obtained. In order to obtain operational analysis, the first step consists of locating slicks in the image and of detecting contours, which can be performed with several methods: filters, gradients, morphological mathematics, etc...

Second, classification determines the nature of the slicks: oil slick, low wind area, biological trash favored by upwelling areas, etc... For that, statistical methods have been tested successfully, it consists of assigning probability for each slick to be due to pollution [9]. As a complementary layer of analysis, ancillary data should be systematically used to understand meteorological and oceanic conditions [10, 11].

We will focus here on detection step, using simple and complex algorithms.

## III. APPLICATION

### A. *Case study*

In 2002, the *Prestige* tanker accident off spanish coasts has been a major environmental disaster because of the huge quantity of oil-dumped in the ocean, drifting over large distances. We chose this example for two main reasons: first, daily aircraft surveys were performed, giving maps of detected surface oil slicks; second, many images have been acquired over the region during the oil spill drift (ESA provided ENVISAT and ERS images over the area of the *Prestige* wreckage during months).

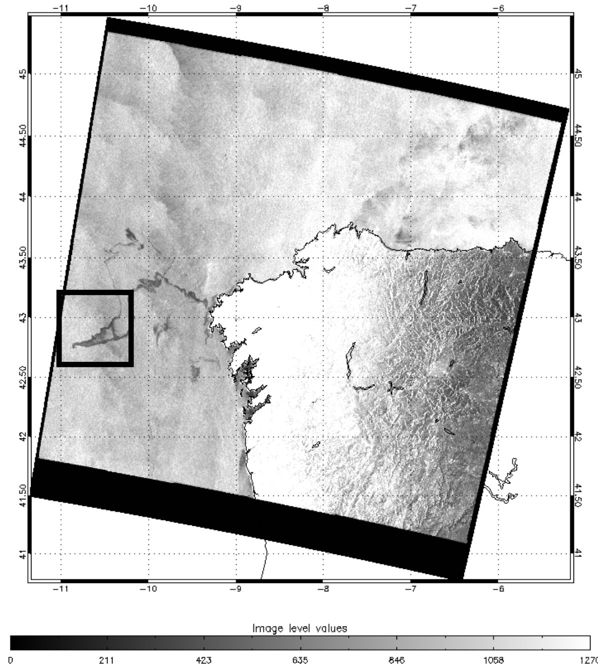


Figure 1. ENVISAT ASAR image, November, 17th, 2002 acquired at 10h45 UTC (Wide Swath mode, orbit 3741, polarization VV) off spanish coast after *Prestige* tanker wreck on November 13th. The square shows the study area ©*ESA*.

### B. *Algorithms*

We have tested four algorithms:

*1)* First, a succession of median and Sobel filters followed by a morphological mathematics combination of dilatation and erosion was used.

*2)* The second method is also a simple algorithm using smoothing followed by thresholding and Sobel filter, this method is used for the Mediterannean sea pollution detection by the NCMR (Greece).

*3)* Next algorithm is a combination of gradient and attenuation relative to background level followed by morphological filters. It is used in the SARTool software of BOOST Technologies (*http://www.boost-technologies.com*).

*4)* The last method is a complex algorithm of ocean surface characterization, developped at ENSTB. It is based on multi-scale analysis of the observed data because oil and sea spectra have different distribution signatures [12].

### C. *Analysis*

Our study is based on 46 areas of 14 SAR images (ENVISAT and ERS), we present one example here.

We propose to analyze a part of ASAR ENVISAT image acquired on November 17th, 2002 near spanish coast (Fig. 1).

This image has been acquired by ENVISAT satellite, four days after the beginning of the *Prestige* tanker drift and two days before its final wreck. Slicks are visible from the tanker over an area of about a hundred kilometers. This case is very interesting in order to test segmentation methods because of the ambiguity of the study area (Fig. 2a).

*Prestige* tanker appears as a bright point southwest of the slick (Fig. 2a). From this point, two polluted “arms” drift towards north and east, probably caused by the spread of two kinds of oil mixed in the tanker [13]. Although slick is clearly defined around the tanker, because outlines are sharply stood out, the drift part is more complex.

We have applied the algorithms presented in section III.B on this study area (Fig. 2b to 2f). Method 2 is not efficient for this image: Fig. 2c presents blurred slick boundaries and no pollution near the tanker. Methods 1 and 3 highlight top and bottom slick outlines and shows a non-polluted area in the middle of the two principal polluted “arms”, smaller with method 1 (Fig. 2b) than with method 3 (Fig 2d). Method 4 applied with two classes (Fig. 2e) presents the same slick shape as Fig. 2b and 2d, except another polluted area from north to south at the east of the study area. This method is applied with three classes (Fig. 2f): grey corresponds to oil, white to clean sea and black an intermediate between these two first classes. The synergetic data study of this area reveals that the ambiguous zone from north to south (black in Fig. 2f) is probably not due to pollution but related to a weak wind

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area with low radar backscattering due to atmospheric phenomenon [11].

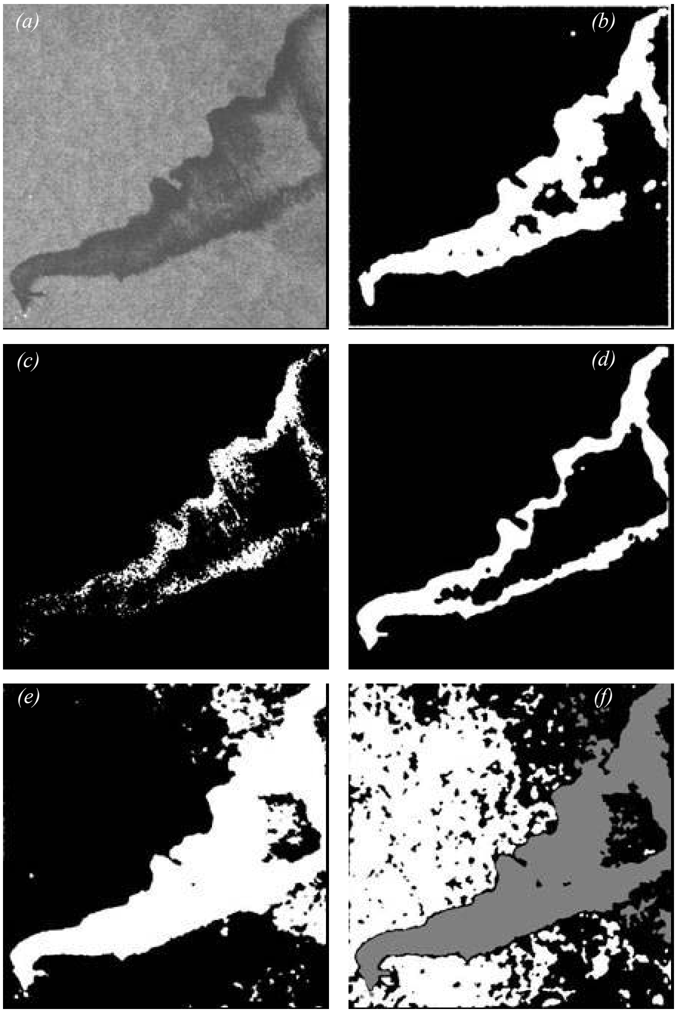


Figure 2. a) Study area shown in Fig. 1 (size: 38 km x 38 km). Study area analysis of a) with methods described in section IIIB: b) method 1, c) method 2, d) method 3, e) method 4 with 2 classes, f) method 4 with 3 classes.

The two polluted « arms » are well detected with the tested methods except method 2, which is efficient with basic examples only. Method 4 used with three classes is a promising technique, bringing additional information as it yields statistical characterization of each class.

The ambiguity of the area between the two polluted "arms" is revealed by the different results of segmentation: is it an area where oil is in sub-surface or is it a mixture between oil and water? Expert report is needed in order to process the classification step.

For the year 2004, these oil slick detection algorithms are used systematically on Wide Swath SAR images of the Mediterranean ecological protected zone (ZPE), the analysis is done in collaboration with *CEntre de Documentation de Recherche et d'Expérimentations sur les pollutions accidentelles des eaux* (CEDRE) experts for the classification step.

## IV. Conclusion

SAR appears to be a suitable instrument for the study of ocean pollution, well adapted because it does no depend on weather nor sunshine, which is an advantage when compared to optical measurements, also used for pollution study. Furthermore, it allows instantaneous coverage of areas as wide as 500 x 500 km. The constraints related to SAR measurements are mainly atmospheric and oceanic conditions, secondly the image will be reliable only if pollution is still on the ocean surface, *i.e.* the measurement must be made just after slick generation, before it goes down in sub-surface layer [7].

SAR images analysis is done in two steps: detection and classification, which can be done with several methods. We have focused here on detection part, applying several algorithms on 46 areas of 14 SAR images. We have evaluated the possibilities offered by these algorithms to detect slick contours.

The segmentation methods give good results with simple images, but for complex and ambiguous areas, other methods are needed as shown on the example presented in this paper. Some algorithms have been proposed, and their tests show that basic methods (filters, gradients, morphological mathematics) are efficient with simple images without ambiguity. For complex areas (and only for them), the original approach based on ocean surface characterization is better than other methods, allowing characterizing each class and then better understanding ambiguous areas of the image.

This study presented a qualitative comparison of detection algorithms. Next step will be to present a quantitative study: criteria have to be found in order to compare algorithms, for example contrast values, slick shapes, etc...

This is the first step towards operational monitoring. Fast detection before the following classification step is critical for providing decision aids to authorities.

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