
A NEAR-REAL TIME OIL SLICK MONITORING DEMONSTRATOR FOR THE MEDITERRANEAN

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ABSTRACT

A demonstration service has been set up which provides near-real time information on oil slicks in support of national coast guards surveillance. From a 2-year continuous monitoring of busy ship route locations in the Mediterranean, it has been found that every fifth ERS-SAR image contains at least one man-made slick of several kilometers length. At night, the percentage of images showing slicks, increases to about 22%. Due to the many features visible on SAR images from sea areas the correct attribution of dark patches to oil slicks is not easy and needs considerable experience. Useful assistance is provided by semi-automatic image processing tools, those, based on neural network techniques, assess the probability of an operator-proposed object to be an oil slick.

1 INTRODUCTION

Coastal and sea surface monitoring at large scale is performed generally by air. However, as a complement to airborne surveys, spaceborne imaging radar has already been proofed to be cost-effective for providing a much-enlarged coverage in time and space.

Such combined surveillance is successfully applied in northern European waters and more recently has also been tested in the Mediterranean basin, mainly along the coasts of Italy, France, Spain and Greece. In this region only a few countries, aside of institutional anti-pollution preparedness, have implemented a monitoring system. This is due to primarily not affordable costs but also due to other priorities.

With the willingness to pursue rigorous enforcement of international and national laws and regulations as a deterrent towards polluters, frequent sea area surveillance can be achieved using such an integrated airborne-spaceborne surveillance system. This approach could well be also the basis of a collection of statistic information on the status of pollution in relevant areas of special interest (touristic sites, protected areas, etc.).

With regard to the Mediterranean it also has to be considered a closed sea area with reduced exchange of water and therefore highly vulnerable. For this reason International law do not tolerated any pollution, neither as river discharge nor from ships, while elsewhere in open ocean waters ship waste disposal is regulated. Our preliminary experience as well other works confirm that the Mediterranean is pollution-wise probably one of the worst treated area in the world, and in places comparable to the heavily polluted waters of the Caspian Sea, the Black Sea and certain areas in Southeast Asia (Gadimova 2000). In all those areas international solidarity needs urgently to be developed, and as first concerted action at least a satellite monitoring service to be install. It can be expected that only based on reality, i.e. by demonstrating the horrendous level of daily pollution through a data base of mapped oil slicks, a political awareness can be developed.

The presented paper aims to give an overview of the experiences made in setting up an oil spill monitoring demonstrator for the Mediterranean. It also reports on contacts with coast guards and on the difficulty to communicate with operational entities. It finally reports on the results achieved by a cautious acceptance of satellite technology. It has to be stated already at this point that today the aim of running an integrated service is still not reached, but the achievements so-far are encouraging to continue the work.

2 REQUIREMENTS OF THE COAST GUARDS

Within the Mediterranean region the approach of the different countries to survey their proper territorial waters or even the open sea area can be described as widely divers. It ranges from intentions and plans to fully operational procedures. The level of service development and equipment in use is accordingly. The range is between apparent total absence of means for monitoring and for intervention up to a well structured organisation with a variety of equipment to survey and also to combat, analyse and treat polluting substances.

It has to be admitted that collecting such information in the countries around the Mediterranean is not a straightforward task and also subject of politics and confidentiality. It is assumed that in the southern and eastern part of the region, much more procedure and equipment are in place, but due to its connection to the military, relevant information can not be accessed. At various conferences within the region, the practical aspects of combating oil pollution is seldom treated since discussions include more general statements and good intentions than procedures and their enforcement. However, ESA/ESRIN as a promoter for the use of ERS-SAR data took the initiative to convene operational entities on various occasions to discuss the topic (G.Calabresi Ed.,1996).

Today only Italy, France and Spain have developed and established an organisation that would allow an efficient monitoring of their national coastal area. All these countries have available a park of aircraft or helicopters for monitoring and immediate intervention as well as a fleet of ships for clean-up operations. They have developed well structured and functional entities of staff operating around the clock. However only France performs regular patrolling flights, while in general, the other two countries intervene only upon requests or messages of sightings of oil slicks in the vicinity of the coast.

The interest of these operational entities towards satellite remote sensing can be judge as to be ambiguous. On the one hand the advantage of the much enlarged observation zone in time and space has been recognized, as well as the quality in terms of reliability to correctly identify oil slicks from satellite data. On the other, the many unknown factor such the impact of high technology, the worry of substituting aircraft operations by satellites but also the complexity of joint operations produce a rather strong hesitation in accepting a new approach.

An often expressed requirement of coast guards regards data availability. Frequencies requested range from hourly coverage to at least one scene per day. Today's systems are far from offering this. Only after the launch of ENVISAT and by joining the acquisitions with RADARSAT, a nearly daily coverage of the Mediterranean can be achieved. A further obstacle is the pricing policy of the satellite data. Current prices are mostly based on single frames, which are hardly acceptable for a regular monitoring service. What needs to be achieved is an accounting for a surface/time based monitoring, which financially is not only supported by the entity responsible but also by one or several countries of the region. However most of responsible entities for oil pollution do not foresee expenses arising from purchasing satellite data, therefore a change in budget preparation is needed as well.

In discussions with the coast guards, the concept of random coverage in time and space is difficult to accept, even when planned well ahead in time. But taking into account the availability of aircraft or fast ships, (which is the case in most countries in the Mediterranean) and near-real time satellite products would already allow a wide coverage of active monitoring.

Experiences made with the Italian Coast guard confirm this approach. By regulations this institution is obliged to check any incoming report regarding oil pollution. During a test-phase using ERS SAR images they received oil spill sightings a few hours after acquisition of the data. Whenever an aircraft or ship was available for reaching the spill out in the sea, a sortie was programmed. In practical all cases the reported spill could be confirmed. However this encouraging result had also the disadvantage that since there are very many slicks of considerable size, too often verifications needed to be made. In order to use satellite data in a cost-effective way a new procedure needs to be worked out. It could include that an intervention by the coast guard is necessary only in the following two cases:

- an observed spill can potentially pollute a coast (close monitoring and eventual clean-up operation) or
- a ship in action of spilling is observed (identification of the ship for legal procecuton).

In all other cases, the oil spill reports can serve for statistical purposes to provide environmental ministries or agencies with material on the status of pollution in respective areas.

3. INTERPRETATION OF SAR SCENES OF SEA AREA

A reliable detection of oil slicks is based on a good understanding and correct interpretation of features appearing in images of sea areas. Such features are linked to sea current, atmospheric phenomena, coastal interaction, man-made or man-induced objects. Furthermore a good knowledge of the actual weather situation, i.e. weather observations and analysis charts, wind and atmospheric conditions forecasts, as well as ocean-current maps are prerequisites for a successful application of remote sensing data.

An experienced operator can retrieve a great amount of qualitative information and, in case of the availability of calibrated data, also quantities can be derived directly from a SAR image. The existence or absence of certain phenomena often helps to a great extent to judge the environmental conditions. This is crucial for distinguishing so-called look-alike (oil spills) from real spills. It is well known that spills are only visible in wind-speeds higher than about 3m/sec and probably not above 12 to 15 m/sec.

In general: the higher the wind speed the fewer look-alikes appear. Windspeeds can be judge quite well by observing co-lateral effects, such as vortices, current fronts and different atmospheric effects including windfronts and convective air masses. Since ships are in general well visible, their wakes can also be often taken as an indicator for wind-direction and windspeed. Pollution originating at oil-platforms can (under appropriate wind conditions) also be spotted. In some cases the duration of the spilling could be estimate by measuring the length and the direction of wind-drifting pollutant.

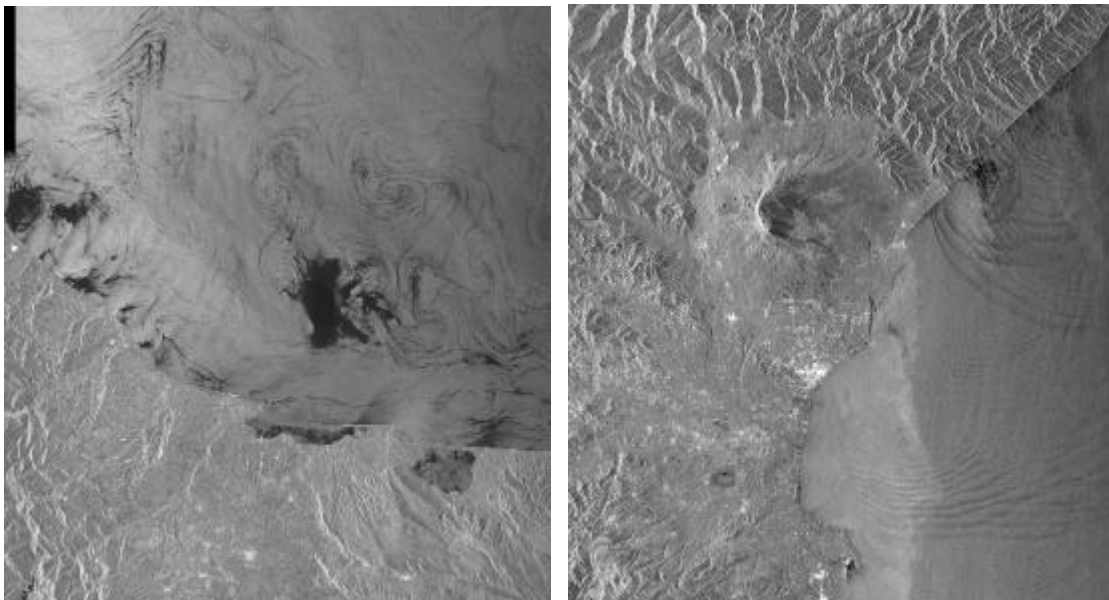
However it is equal important to judge the form of the slick and its internal consistency. Again co-lateral observations are important. They should concentrate on the presence of internal waves and other current features, as well as on atmospheric gravity waves. Changing characteristics due to aging and drifting have also to be considered.

In all, experiences in ocean-feature interpretation is needed to operationally use Radar images for this type of application. To avoid any wrong reporting, the following two possibilities have to be considered: If the information is provided by a value adding companies, highly specialised staff need to be involved for satellite image analyses. As alternative the coast guards themselves take care of analysing the data. This would mean that investments in hardware and software as well as propre training of operators need to be provided.

4. APPROPRIATE IMAGE ANALYSING TOOLS

It has been found that non on the commercially available image processing software is adapted for an immediate use in this domain. In fact, the different projects for oil spill detection had to largely adapt existing software or built new tools. The requirements include to quickly get a new image displayed and oriented (positioning of objects, distance measurements) and to immediately activate analysis tools. The display tool should also allow for incidence angle correction and easy-to-handle continuous manipulation of the Look-up Table. This is necessary to explore also the very dark and the very bright sea areas in a fast and user-friendly manner.

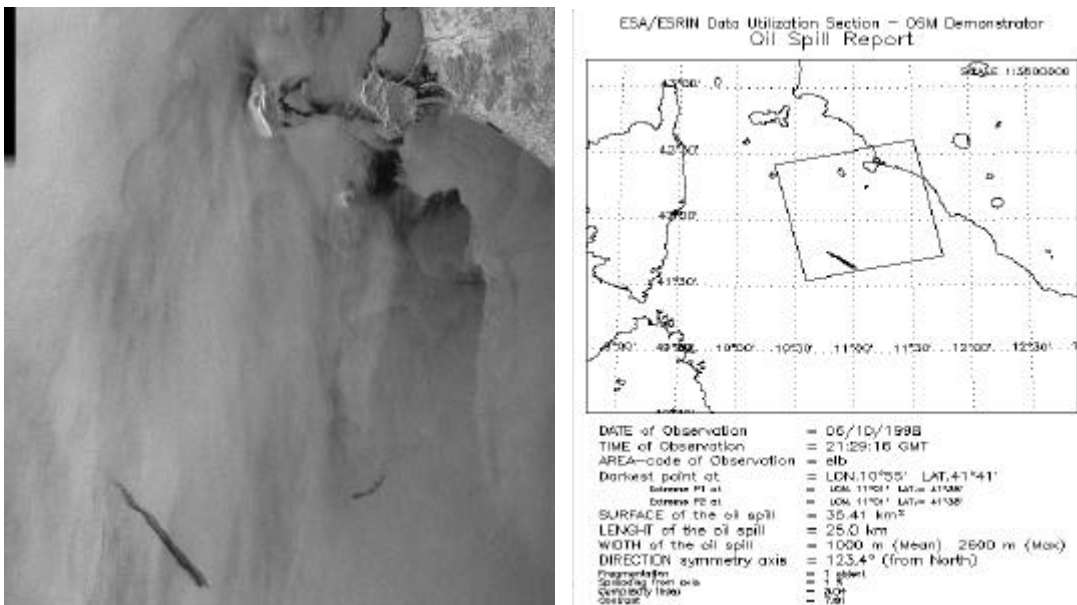
There is an on-going discussion on the implementation of automatic slick detectors. We think that a good piece of software of this kind would be useful. However it has to be considered as an additional



a) b)

Figure 1. SAR Ocean features

- a) Apulian coast, southern Italy 1/3/1998, 21.11gmt: Low wind situation, sea current generating vortices and look alike (dark streaks), local land-see winds near the coast (bright bands at the outlet of valleys), calm or very low wind areas (dark areas)
- b) East Sicilian Coast 5/5/1999 09.41gmt: Low wind situation, land-sea wind producing a wind front, internal waves generated at the Strait of Messina



a) b)

Figure 2. Oil spill detection and reporting

- a) ERS SAR of 6/10/1998 21.29gmt, Italian Western coast, large (very recent) and small (slightly older) oil slick altered by northerly winds
- b) Oil slick report faxed to the Italian Coast Guard early morning of 7/10/1998.

help in guiding the attention of an operator, and should not mislead an interpreter to consider just the automatically proposed slicks.

Once an operator has spotted a potential feature, the measurement of a slick should be largely supported by software tools. Most important parameters are the central and extreme geographic co-ordinates, distance to the next coast, size, surface and complexity, as well as radiometric statistics in and around the polluted zones. In case of the availability of calibrated data, also wind-speed and direction should be computed (wind direction to be determined through image interpretation).

It is also useful and often desirable to include a tool for automatically or semi-automatically detecting ships and for computing speed and heading. The availability of an underlying GIS is also very practical. A digital nautical chart of appropriate scale would be the ideal data set.

Finally, the product containing the results of the image analysis has to be carefully developed. Depending on the requirements of the end-user the relevant information can just be sent in fax-form, perhaps including the geographic situation and a table of parameters as described above, or as an email with attached file. Such a file could serve as an input to a data-base for the generation of further products (Figure 4).

We have to stress again, that the image processing and analysing tools need to have a user-friendly, straightforward but also robust user-interface, in order to be accepted either by a value adder or by an operational oil spill response entity.

5. A DEMONSTRATOR AT ESRIN

Based on requirements and initial assumptions, as well as on experiences with commercial software for oil spill detection application, a new approach was attempted, using IDL routines. The flexibility of the associated programming language and the richness of the algorithms as well as the linear way to generate new applications led to satisfactory results.

With the experiences gained in the many contacts and working sessions with the Italian and French coast guard the tools were more and more enriched. Essential input also came from studies done in the framework of master thesis at the Universities in Rome (automatic slick detection, ship detection, etc.). But the system has kept its simplicity, supporting also less-experienced computer-user, by offering a user-interface of just one tool-window and the assistance by help-messages whenever needed. For practical demonstrations, a direct link to a server was established to immediately get new data from the satellite receiving-station. The input procedure is largely automatic and presents to the operator an already enhanced, correctly oriented image. The mouse-position is shown as geographic co-ordinates and the corresponding digital value (or value in decibel) appears. Any mouse-click within the image display window enters the corresponding position into a protocol page. A double mouse-click provides a zoomed window. Distance measurement, histogram-display and spontaneous update during interactive LUT manipulation, as well as graphical cross-section display, are among others the most important tools available.

The slick-analysis tool works either automatic or semi-automatic. In the second case the operator has to roughly encircle a potential slick and to click inside. Now the program searches for dark features, and assesses the gradients to outline the dark areas. An image section with these borders as well as a list of parameters is presented to the operator. This result is also compared with a database of typical oil slicks and look-alikes and a probability of the result being a real oil slick is computed. This analysis is based on neural network techniques (F. Del Frate et al., 2000). At this point the operator is also given the possibility to further elaborate on the result interactively.

The application also includes a ship detection and characterization tool. It provides an operator with ship speed and course estimation.

The system provides different type of output such as a fax-page with an graphical overview, showing the coast line, co-ordinates, the SAR scene outline and the form of the slick, and a table below contains all

necessary information concerning the observation (Figure 2b). The same information can also be exported as GIS file and attached to an e-mail. A protocol of the analysis is also generated and is kept in a data base together with the image and its inventory file.

5.1. Experiences with the ESRIN demonstrator

The flow of the data from the satellite to the user and the related information is given in Figure 3. It consists of an immediate transfer of acquired data to a processing centre where an image is georeferenced and analysed on a dedicated workstation and a fax-report is generated to be dispatched to the coast guards of the zone.

From a 2-year continuous monitoring activity over busy ship route locations in the Mediterranean, it has been found that every fifth ERS-SAR image in the total amount considered contains at least one man-made slick of several kilometers length. At night, the percentage of images showing slicks increases slightly to about 22%.

In comparison, a similar monitoring service provided by the Tromsø Satellite Station shows different figures. In the North Sea and the along the Atlantic coastal water of Norway it has been found that only 2 to 3 % of the image include oil slicks, either from ships or from oil-producing platforms. It has to be admitted that due to on an average increased wind speed, the detection of slicks is reduced and also the tolerated amount of waste water or drilling oil released by platforms has to be accounted for. The overall ship traffic might also be denser in the Mediterranean but not the amount of platforms.

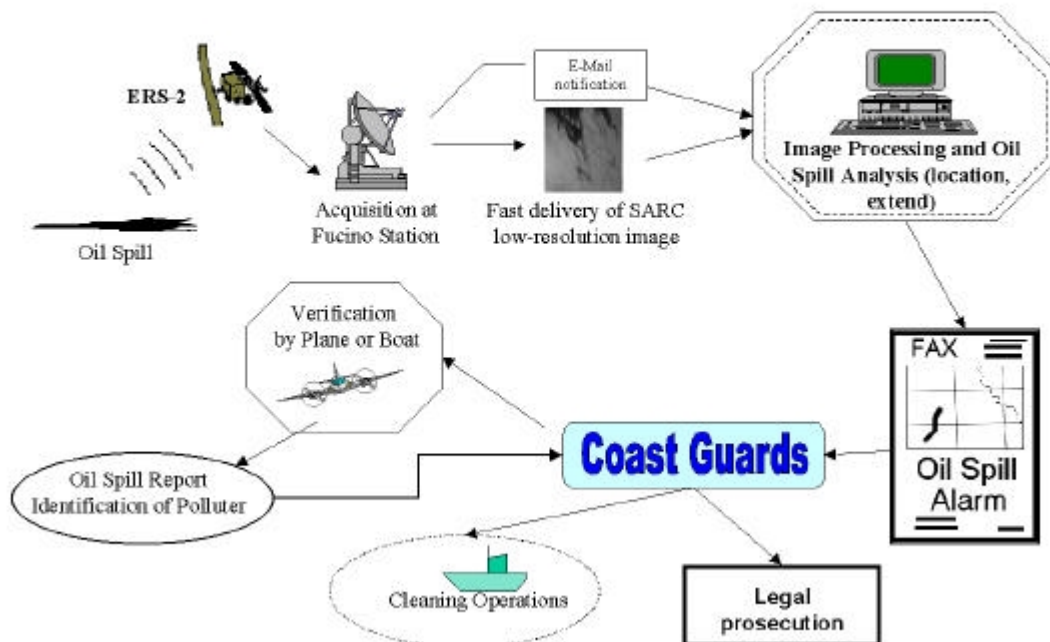


Figure 3. Flow chart of data from satellite acquisition to end-user

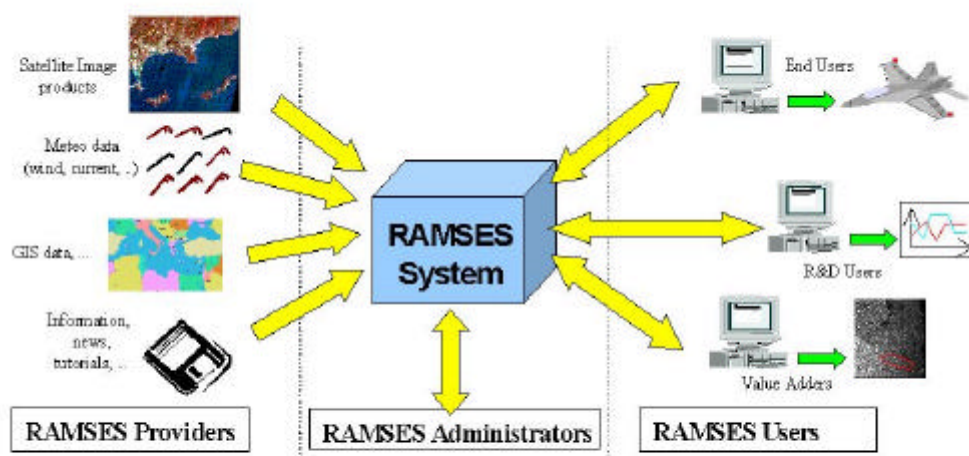


Figure 4. Overview of the RAMSES project for oil spill monitoring in the Mediterranean

5.2. Connection of the ESRIN Demonstrator to other Oil Spill Monitoring Projects

Since the launch of ERS-1 several initiatives have been started in Europe to use SAR data for detection of surface damping pollution at sea. The first has been the Norwegian Project, which was largely supported by the Norwegian Space Agency. Subsequently, the Dutch expressed interest. In the Mediterranean an initiative by ESA/ESRIN led to the development of the Demonstrator. This project was realized based substantially on Norwegian experiences, both in terms of data processing and image interpretation. However the ESRIN Demonstrator as it is today, is more evolved than the operational system at Tromsø Satellite Station and conceptually it is also more flexible. Built on IDL routines and language, user demands for extra functions or display arrangements can be accounted for rather easily.

There is also a connection to the EU-Project ENVISYS, coordinated by the Norwegian Computing Centre, for which the ESRIN team has prepared and delivered the near-real time data. The core of ENVISYS is the commercial ERDAS image processing and the Oracle data base software. Further developments were necessary for running specific applications.

At present a strong collaboration is on-going in support to the EU-Project RAMSES (Figure 4.). This project foresees a central server containing different kind of products, including SAR scenes, derived oil slick reports in different forms, marine and meteo data, and GIS based oil slick statistics. Different data providers and users are grouped around this server. Data provider include satellite operators or commercial data distributors, value adding companies delivering interpretations, and institutions offering forecasts of atmospheric elements, sea current and temperature. End-users retrieve information from the server as non-expert, expert or scientific user. At the end of the project an accounting system should allow to pay or charge each provider or user. Important contributions of the ESRIN-team to RAMSES include the set up of the requirements for the system and the products, and for the migration of technical know-how to a newly developed image management and analyzing tool. This tool is not based on IDL but on Java. The structure of the server is based on CORBA. A further task of the ESRIN-team for the upcoming operation of the RAMSES system is the training of operators and interested end-users for SAR

image interpretation and the use of the display and analyzing software tool.

6. OUTLOOK

As defined from the start the activity in ESA/ESRIN concerning oil slick detection and monitoring will remain a demonstration and research opportunity. But the developed system is adapted to serve very well as an operational tool to analyse SAR images for sea pollution, ships and other ocean features. Thanks to its conceptual flexibility there is ample room for improvements, such as to accept information from other satellite sensors or from aircraft and ship campaigns, as well as GIS files to enhance the information of remote sensing data. Concerning the analysing tools, among others, improvements in wind speed and direction estimation as well as for ship and ship-wake detection and analyses are planned.

References

G.Calabresi (Ed.), 1996. ERS SAR Contribution to Oil Pollution Monitoring in the Mediterranean, Spill Science & Technology Bulletin Vol3, Number 1/2.

S. Gadimova, 2000. Towards the Development of an Operational Strategy for Oil Spill Detection and Monitoring in the Caspian Sea based upon a Technical Evaluation of Satellite SAR Observations in Southeast Asia, submitted to IAPRS, Vol. XXXXIII, Amsterdam.

F.Del Frate, A.Petrocchi, J.Lichtenegger, G.Calabresi, 2000. Neural networks for oil spill detection using ERS-SAR data, accepted as S99-11 for IGARS'99 Special Issue..