# Emerging Practices in Oil Spill Preparedness and Response Using Space-Based Radar

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## Abstract

Space-based radar remote sensing is recognized as an essential tool for emergency response in the event of an offshore oil spill. Synthetic Aperture Radar (SAR) is capable of identifying the extents of oil on water over very broad offshore regions, at a low cost, and without putting people at risk.

The capabilities of SAR are complementary to other well established remote sensing technologies including aerial surveillance and platform- or vessel-based sensors. The correct combination and implementation of remote sensing technologies is critical to effective surveillance operations.

A better understanding of the technology, events such as the Macondo incident in 2010, industry efforts by the API and IOGP, and our own interactions with offshore operators are leading to the development and adoption of standard practices pertaining to space-based remote sensing in emergency planning and response activities.

This paper will introduce the basics of space-based radar monitoring for oil spills and will discuss our experience working with operators to integrate space-based monitoring into emergency preparedness and response activities and tools. Using examples and case studies, we demonstrate the benefits of adopting these emerging technologies and best practices.

Some of the practices discussed include:

- routine monitoring before an incident occurs;
- using multiple sensors to address coverage, revisit, and redundancy needs;
- integrating SAR in emergency preparedness activities; and
- integrating data and analysis in GIS systems and common operating pictures.

[1] Presented by David Gionet on March 25, 2015 at Interspill, Amsterdam

# Introduction

Developments and events over the past 10 years have established space-based radar remote sensing as an essential tool for emergency response in the event of an offshore oil spill. Synthetic Aperture Radar (SAR) is capable of identifying the extent of oil on water over very broad offshore regions, at a low cost, and without putting people at risk. Several SAR satellite missions are operational today offering commercial services (RADARSAT-2, TerraSAR-X, COSMO-SkyMed, and others). Each operates on a pre-determined orbit path with predictable imaging opportunities anywhere over the globe, making SAR ideally suited for both routine and emergency monitoring.

In the aftermath of the Deepwater Horizon (Macondo) incident in 2010, significant efforts by the IOGP (International Association of Oil & Gas Producers), IPIECA (International Petroleum Industry Environmental Conservation Association), and the API (American Petroleum Institute) have produced an excellent body of knowledge that has been shared with the oil and gas industry and satellite service providers.

The capabilities of SAR are complementary to other well-established remote sensing technologies including aerial surveillance and platform- or vessel-based sensors. The correct combination and implementation of remote sensing technologies is critical to effective surveillance operations.

This paper outlines how SAR is able to detect oil on water and discusses the range of information that can be derived from it. We then briefly look at how SAR integrates best within the range of monitoring strategies used by operators today. And finally, we will discuss emerging practices in the integration of SAR into oil spill preparedness and response.

# How SAR sees oil on water

SAR satellites are active sensors which emit energy pulses to illuminate the area under observation and measure the signals returned from Earth's surface. Unlike passive sensors such as those on optical satellites, radar sensors are not constrained by illumination or cloud cover.

Generally speaking, SAR measures the surface roughness of the observed area (see Figure 1). Oil on water dampens capillary waves on the surface of the sea and therefore creates a smoother surface that scatters the radar energy away from the source signal resulting in a dark area on the image.

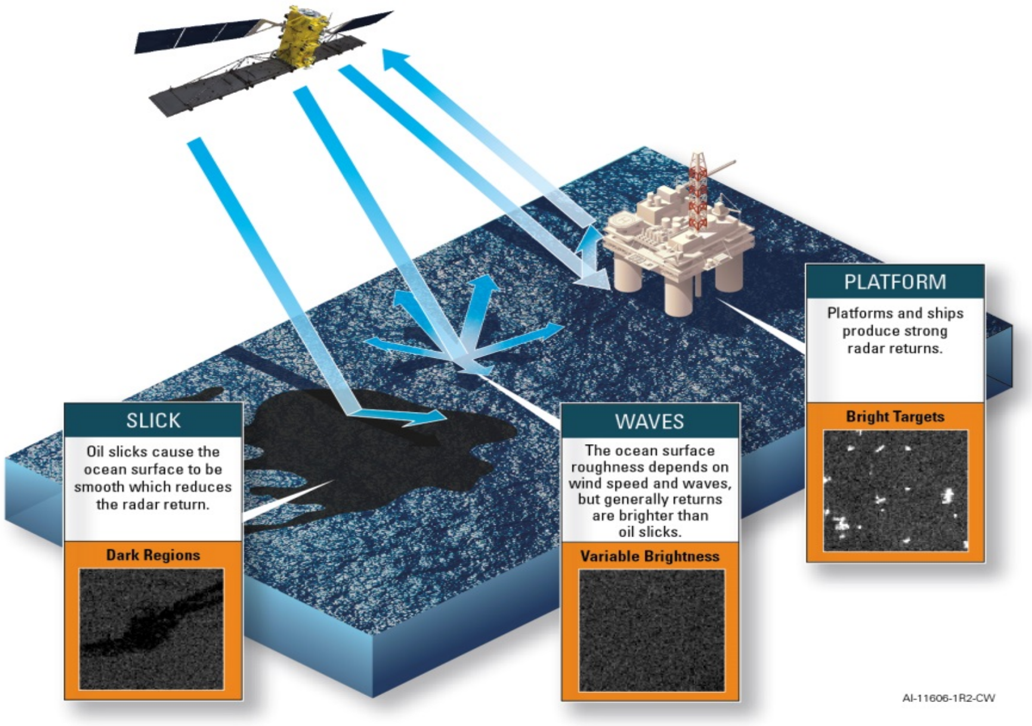




**Figure 1 - SAR satellites emits and measures energy pulses for the measurement of ocean surface characteristics. These measurements allow the detection of oil on water.**

It has been well documented that SAR is not immune to false positives. This is because there are other ocean features in satellite imagery that also dampen capillary waves and are therefore hard to distinguish from oil spill targets. These phenomena can include features such as:

- low sea surface wind;
- rain cells;
- turbulent wakes from ships;
- near shore wind shadows;
- fresh water from river flows into the ocean; and
- biological material such as algae and biogenic oils.

Naturally occurring oil seeps are another recurring phenomenon that can be misidentified as an oil spill. There are several strategies available that mitigate the impact of false positive detection. The three key approaches are:

1. routine monitoring of the area of interest to improve historical knowledge of coastal/offshore oceanographic features (including understanding patterns of natural seep activity),
2. employing well trained, experienced image analysts who follow a standardized protocol for the identification of features in the SAR image,
3. coordinating SAR monitoring with complementary technologies to corroborate and/or enhance the information derived from the satellite imagery.

## Information derived from SAR imagery

SAR satellites offer many benefits that enable them to provide a wide range of information about the area of interest. Benefits include:

- Consistent, reliable information delivery through the ability to observe day or night without relying on ambient light;
- All-weather monitoring in all offshore regions by seeing through clouds and fog;
- Predicable monitoring of very large ocean areas without putting anyone at risk (tens of thousands sq. km. in a single image, far in exceeding surveillance flight capabilities);
- Easy deployment of monitoring resources globally without the complexities associated with coordinating and preparing flight plans;
- Minimal reliance on local assets and infrastructure and minimal logistical support required.

Key information that SAR provides in the event of a spill include:

- location of the spill;
- size of the spill (surface area);
- wind speed and direction (directly derived from the satellite imagery);
- locations of vessels and other local/regional infrastructure to aid in response management.

With the use of repeat imaging and oil spill modelling tools, the outlines of the spill extent can help derive the path of the spill to enable the effective deployment of recovery resources and protect sensitive areas. As depicted in Figure 2, oil slick outlines from successive images can be overlaid on each other to provide a good indication of the spread and path of oil over time. Delineated oil outlines such as these, combined with data about winds and currents have been shown to be very useful in modelling the future size, shape, and location of the spill. Oil spill models can be updated with new spill extents derived from radar imagery to refine recovery plans and update estimates of areas at risk.

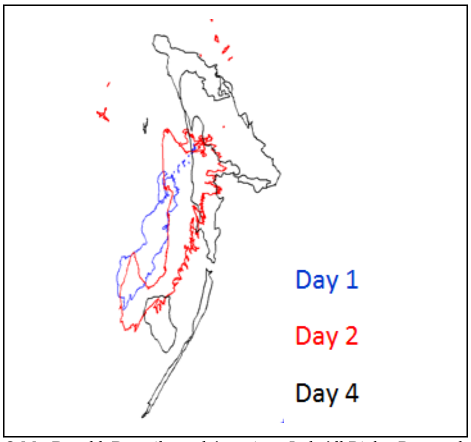




**Figure 2 – Satellite imaging over multiple days provides information about the spread and direction of a spill**

## SAR complements other monitoring technologies

The capabilities of SAR are complementary to other well-established remote sensing technologies including aerial surveillance and platform- or vessel-based sensors. Effectively combining and implementing remote sensing technologies enables effective surveillance and recovery operations.

A key strength of SAR is its ability to deploy anywhere and monitor larger areas than any of the other technologies day or night (areas over 90,000 sq. km. can be captured in a single image). While some planning is required there are fewer obstacles to leveraging the available assets than there are for aerial surveillance (e.g., no regulatory constraints or approvals required to access and observe areas of interest anywhere in the world). That said, SAR has limitations. For instance, its ability to discriminate between thick (i.e., recoverable) oil and thin oil sheens is limited although the use of RADARSAT-2 quad polarized data shows some promise in achieving this. To overcome the limitations, it is advisable to employ other sensing tools and technologies alongside SAR to capture a comprehensive picture and enable safe, efficient recovery operations.

Sensing technologies are often classified into three categories:

1. in situ (on platform, vessel, shore) – visual, IR (infrared), radar
2. aerial (aircraft, aerostat) – visual, IR, radar
3. space-based – multispectral (visual and IR), radar

The ideal role for satellite-based monitoring is providing a wide area view, which is an important element in developing situational awareness. This broad perspective is valuable in planning the deployment of more costly specialized resources, such as aerial surveillance and vessels. The integration of all sources of information into a Common Operating Picture (COP) enables response organizations to take a strategic view of the situation and make effective tactical plans for near-term recovery operations.

## Emerging Practices

In the wake of the 2010 Macondo incident, industry-led efforts have compiled a wealth of information to help oil and gas companies and oil spill response organisations. These resources provide detailed information about the wide range of tools and techniques available and provide guidance on suggested approaches to leverage remote sensing.

Some of the key outputs of recent industry initiatives include:

- *An Assessment of Surface Surveillance Capabilities for Oil Spill Response using Satellite Remote Sensing* – 2014 (IOGP/IPIECA)[2]
- *An Assessment of Surface Surveillance Capabilities for Oil Spill Response using Airborne Remote Sensing* – 2014 (IOGP/IPIECA)[3]
- *Oil Spill Response Common Operating Picture Architecture – Recommended Practice REVIEW DRAFT* – 2014 (IOGP/IPIECA)[4]
- *Remote Sensing in Support of Oil Spill Response* – 2013 (API)[5]

Building on these lessons learned and our own experience as a satellite operator and service provider, we have identified some emerging practices in oil spill preparedness and response using space-based radar that we believe serve to strengthen the state of practice across the industry. The key practices discussed are:

- routine monitoring before an incident occurs;
- using multiple sensors to address coverage, revisit, and redundancy needs;
- integrating SAR in emergency preparedness activities; and
- integrating SAR data in GIS systems and Common Operating Pictures.

### Routine Monitoring

Historically, satellite-based monitoring has been called upon once an incident was suspected or identified. There are several challenges with this approach. During the first 24-48 hours after a spill, the need for actionable information is the greatest. Early intervention during a spill has a great impact on the outcome. It is very important to understand the scope of the incident, the location of the

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[2] http://oilspillresponseproject.org/completed-products
[3] Ibid
[4] http://www.opengeospatial.org/projects/initiatives/ogpoilspill
[5] http://www.oilspillprevention.org/

incident, and the likely path of the oil on water in order to effectively deploy resources to mitigate the impact on the environment.

Routine monitoring of an operational area helps to mitigate some of the challenges associated with SAR identified above, such as the possible detection of false positives and the lead time for the activation and reception of the first images. Routine monitoring is mitigation for these challenges.

As we have seen with multiple operators in various basins around the world, routine monitoring helps early detection of potential spills by providing a view that goes well beyond the horizon and therefore outside the reach of in-situ sensors and the path of routine flights. In addition, frequent monitoring increases the opportunity to acquire an image at the start of the event.

For example, in 2011 an operator in the Gulf of Mexico activated our 24/7 emergency monitoring response when they reported an incident at 12:45 local time. Based on the existing monitoring program, we were able to confirm immediately that an image would be available locally within five hours of their call. If the satellite had not been pre-programmed to monitor the company's assets, this imaging opportunity would not have been available. In addition, because we had been actively monitoring the region prior to the incident, we were also able to retrieve data acquired in the previous days and weeks to provide baseline information and pre-incident evidence.

More generally, through a simulation of emergency response timelines for an area in the Gulf of Mexico we found that routine monitoring enables delivery of the first image of an incident site an average of 24 hrs earlier than would be possible if the request came in once a spill was suspected.

Routine monitoring also helps establish an historical baseline of information that can serve multiple purposes. For example, to minimize the false identification of dark targets as oil spills, repeat imaging over the area helps understand the patterns of various phenomena occurring around the operating facilities. This facilitates faster and more accurate determination that a target is atypical in comparison to the patters of natural seepage, algae blooms, etc.

### Multiple Sensors

Repeat coverage by a single SAR satellite may not always meet an operator's needs. Despite advances such as left and right looking satellites and wider swath widths (including up to 500 km), revisit at lower latitudes while suitable for routine monitoring, may not be sufficient during an incident when daily imaging would be ideal. To meet that challenge, imaging can be provided by multiple satellites working in concert to provide the most effective coverage.

A common approach is to use a broad area sensor for primary coverage and a secondary sensor to fill schedule gaps or perform more focused imaging using alternate imaging modes. At any given time, the next available sensor for imaging a specific area will depend on the programming timelines/constrains of each operator, the satellite's current orbit, and availability of the sensor. However, it will always be more likely that greater frequency and coverage is available when combining the imaging of multiple sensors. For example, MDA offers services based on RADARSAT-2 as the primary satellite, but to meet specific customer requirements our services also include imagery acquired by other SAR satellites.

In a recent exercise conducted on behalf of the IOGP/IPIECA working with OSRL (Oil Spill Response Limited), MDA coordinated an emergency activation drill with multiple satellite operators to gain a better understanding of the lead times for image acquisition and latencies in product delivery in different locations. The details of the study will be published elsewhere but two key learnings included:

- the time from an emergency activation to first image ranged from 14.5 hrs to 51.5 hrs for northern latitudes and 23.5 hrs to58.0 hrs for equatorial latitudes, and
- routine monitoring with multiple satellites would have reduced the time gap between activation and image delivery.

### Integration of SAR in emergency preparedness activities

When a spill occurs, the first 24-48 hours are critical for information collection and making sense of the situation.

The traditional approach is to wait until the incident occurs to identify the needs and initiate contact. However, when faced with an active incident, operators are not in the best position to spare the time or have the focus required to support requirements gathering and documentation, drive a procurement process, or perform contract negotiations necessary to initiate the very monitoring they require at that critical time.

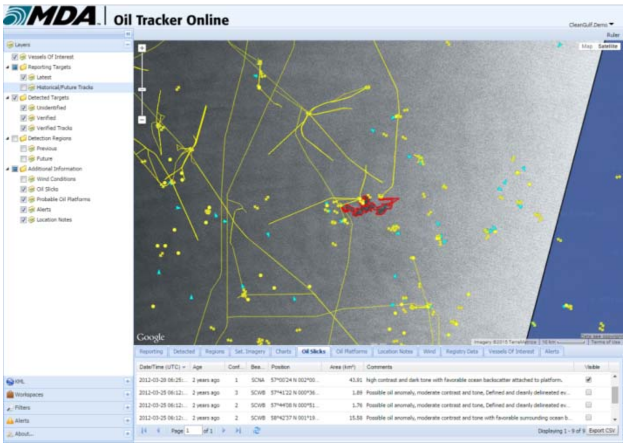
In addition to the activities required to setup data acquisition, the operator and response organization will be able to make the best use of the imagery if it has a defined workflow to feed the satellite data into recovery planning tools and operations. Incident response staff providing support to operation planners need to understand the data formats, delivery schedule and frequency, and data attributes to ensure that the information received from the SAR service provider is actionable as quickly as possible.

Emergency preparedness activities should include:

- training on SAR capabilities and limitations,
- integration of “real” data into the training exercises
- integration of data into the tools (COP and modelling software) and communication workflows to ensure the data is adapted to the available communication bandwidths used in the field
- the establishment of contractual arrangements and clear activation procedures with the satellite service provider
- all relevant static information is identified ahead of time and pre-loaded into the oil spill planning tools (sensitivity maps, infrastructure maps, etc.)

### Integrating data and analysis in GIS and COPs

The oil and gas industry is rapidly adopting a COP approach to integrating available information about oil spill response. Space-based SAR imagery is one of the only sources of data that can fairly quickly provide a complete overview of the situation. For example, Figure 3shows an incident in the North Sea (left) along with AIS-reporting and non-AIS reporting vessels detected in the SAR image. Additional information, such as pipeline locations, platform locations, lease boundary, etc., can be displayed in a COP. In this particular case, the detection of vessels was important so that the operator and response personnel could ensure that only authorized vessels were in the safety zone around the incident.



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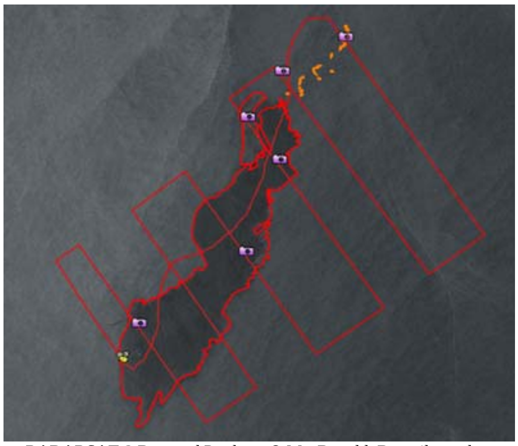
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**Figure 3 - RADARSAT-2 images viewed in a COP. First image (left) is displayed with pipelines, AIS reporting vessels and non-AIS reporting vessels detected in the radar image. Second image (right) showing the extent of an oil spill along with the recorded track from aerial reconnaissance flight.**

The second example depicted in Figure 3 (right) shows how the path of a reconnaissance flight could have been optimized had all the information available been shared with the response organisation prior to executing a flight to collect information about the spill. Integration in to a COP quickly allows aerial reconnaissance information (e.g., recorded flight path, geo-tagged aerial pictures, and geo-tagged video) to be viewed in context.

## Conclusion

This paper highlights that SAR satellites are a proven asset in support of oil spill recovery and are available to meet monitoring and emergency response needs today. SAR is effective in detecting oil on water day or night and under a wide range of weather conditions. Utilizing information derived from SAR to guide the use complementary technologies results in a complete situational picture that help guide effective recovery actions.

Emerging practices resulting from our work with operators and oil spill response organizations were introduced and discussed. Implementing industry best practices and these emerging practices will help mitigate some of the known challenges and maximize the utility of space-based radar in oil spill preparedness and response.

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