Eye in the sky

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McHugh-Warren and Simms describe some of the challenges in using information derived from satellite remote sensing as evidence in a court of law.

Who should read this paper?

This paper should be of interest to persons with an interest in remote sensing, maritime law and/or ocean policy. The work represents a unique perspective, insofar as it considers the demands placed on remote sensing technology by the legal community.

Why is it important?

Release of oil at sea by ships, accidental or otherwise, is a significant environmental problem. According to the IMO, ships transport some 2,400 million tonnes of crude oil and oil products annually. While the number of 'major' spills (greater than 700 tonnes) has been reduced in recent years, there are still a significant number of small releases each year. Satellite-borne synthetic aperture radar sensors that can 'see' in darkness and through cloud and fog are well known for their ability to detect oil on the surface of the ocean and therefore represent the best available technology for monitoring vast expanses of ocean. However, there are a number of challenges when attempting to use synthetic aperture radar image data as evidence in a court of law. These challenges stem from the fact that radar response, like all other remote sensing data, is a surrogate measure of the feature of interest. Differences in the intensity and pattern of response observed in the radar image are inferred to represent, in this case, oil on water. But, unless the ship is literally caught in the act, the correlation is never 100%. There is always the possibility that some other phenomenon could cause the same variation in intensity and pattern of response.

This work investigates how satellite radar image data might be used in court as legal evidence in the prosecution of illegal ship discharges. Legal chain of custody, clearly documented data processing methodologies and accuracy, precision, reliability and repeatability of results are all key considerations. If, through careful application, remote sensing data can gain more widespread use as bona fide legal evidence, then it could help not only to catch maritime polluters, but to deter others.

About the authors

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RADAR IMAGES IN THE PROSECUTION OF ILLEGAL OIL DISCHARGES: OPPORTUNITIES AND A CASE STUDY

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ABSTRACT

Illegal oil discharges from ships are harmful to the world's oceans. Earth observation satellites such as Synthetic Aperture Radar (SAR) offer many advantages in the collection of data for use in the prosecution of illegal discharges. However, the process by which radar images can be used in court is yet to be ascertained, especially with regards to the admissibility and authentication of the data as evidence. It was determined that expert witness qualifications and the reliability of SAR images for oil spill detection address the concept of admissibility of the information presented in court. Conversely, authentication relies on quality metadata. A case study is presented that uses a RADARSAT-1 (R-1) SAR image as the main evidence and oblique aerial photographs as supporting documentation of an offshore oil spill incident in the waters south of Newfoundland and Labrador, Canada. This case helps highlight the legal chain of custody involved with using remote sensing images. The research reveals that satellite SAR imagery can be used operationally to extract information about oil spills and the ocean environment. The main difficulties with the use of these images in the prosecution of illegal oil discharges lie with tracking the analysis process, the coordination of aerial photograph recording as supporting evidence and the overall evidence gathering protocol.

KEY WORDS

Oil discharges; Synthetic Aperture Radar (SAR); Aerial photographs; Evidence; Admissibility; Authentication; Integrated Satellite Tracking of Polluters (I-STOP)

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INTRODUCTION

For much of the last century, the degradation of the world's oceans from ship operations has been recognized as a major concern to the coastal wildlife, fishing and tourism industries, and the entire marine ecosystem [Wiese, 2002]. Oil from ships can enter the water through accidental spills caused by malfunctioning equipment, negligence, or illegal actions such as tank washings, dirty ballasts, and bilge pumping [CEOS Disaster Management Support Group, 1997].

Several maritime nations initially agreed to develop measures for oil pollution in the ocean in the 1930s. Twenty years later, in 1954, the 'Marine Pollution 73/78' agreement was reached, which sets standards that allowed oil to be released at certain distances from land and in very small amounts. Under this agreement the highest legal concentration of oil that can be released into the ocean is 15 parts per million (ppm), which for example is the consequence of running bilge water through an oily-water separator before disposal at sea.

Since 1968, aerial photography has been the main remote sensing tool for detecting oil slicks, and has proven effective in many prosecutions for illegal ship discharges in Canadian waters [Armstrong, 2007]. In Canada, the Fisheries Act [Justice Canada, 1985], Canada Shipping Act [Justice Canada, 2001] and the Migratory Birds Convention Act [Justice Canada, 1994] are applied when illegal oil discharges are presented in court. High-oblique photographs captured from the aircraft's window during oil pollution surveillance flights have been used as evidence in the prosecution of illegal discharges, while satellite images and particularly the capabilities of SAR data [Bern et al., 1993] has remained under-exploited.

Limitations of the application of satellite SAR images in the prosecution of illegal oil discharges concern their admissibility and authentication as evidence. Evidence is admissible when the court is satisfied that it has been validated. Authentication consists of establishing the identity of the evidence by assuring that appropriate standards were applied in the collection and preparation of the data presented in court.

The following section reviews court case applications of remote sensing for oil spill detection and identifies documentation by which aerial photographic evidence is gathered to facilitate its admissibility in court. The third section illustrates how SAR images address the concepts of admissibility and authentication as evidence; followed in the fourth section by a case study where a SAR image is used during a response effort to an oil spill event.

REMOTE SENSING FOR OIL SPILL DETECTION

Remote sensing technologies have been used in litigation mainly for documentation of conditions over large or inaccessible geographic areas and to provide a synoptic view of conditions under which traditional evidence had been recorded. During the early 1970s, the United States Environmental Protection Agency began to routinely apply remote sensing in law enforcement related activities [Latin et al., 1976].

Aerial photographs can be used to detect oil slicks by capturing the sun's incident visible light it reflects, which contrasts with the low

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reflectance from the ocean's surface. However, visible band remote sensing systems have limited detection capabilities in oil spill surveillance, mainly due to their sensitivity to fog and clouds, and limited autonomy. The Canadian National Aerial Surveillance Program has presented oblique aerial photography as evidence in court cases related to illegal oil spills. From 1968 to 2007, visual aerial surveillance, in conjunction with testimonials from crews, has resulted in several prosecutions with the highest fine of $170,000 [Armstrong, 2007].

SAR is an active remote sensing system that exploits centimetre-scale microwave wavelength electromagnetic energy. Clouds minimally affect microwave energy due to its longer wavelength. This quality is desirable in coastal and oceanic regions that are particularly affected by occurrences of fog and cloud conditions. In addition, given that most illegal ship dumping occurs at night [Wiese, 2002], SAR is an ideal candidate to help with oil slick detection on the ocean's surface. The identification of oil slicks with radar images relies upon the ocean's surface backscattering, which is dependent on the density and type of oil, and sea state. Typically, oil slicks dampen the sea surface, reducing the amount of energy backscattered to the satellite [Lewis, 1998].

Satellite SAR has been used to locate and identify oil slicks since the 1990s; however, objective validation awaits additional records of oil slick occurrences [Robinson and Ufermann, 2003] and more examples of operational monitoring of shipping activities, offshore engineering industry, and marine pollution [Johannessen et al., 2001]. In law enforcement cases where satellite remote sensing has been used, lawyers feel a stronger case can be built on evidence collected in situ [Davies et al., 1999].

One of the constraints with the admissibility of earth observation imagery is that it has not been used without coincident data from airborne surveillance missions [Armstrong, 2007], probably because radar is a relatively new technology (in civilian applications) and that it produces the representation of a 'non-visible' interaction of electromagnetic radiations.

Accepted Remote Sensing Evidence

Evidence building and law enforcement cases have relied on remote sensing technologies such as radar speed guns, video cameras, [R. v. Nikolovski, 1996] and Forward-Looking InfraRed (FLIR) sensors [R. v. Tessling, 2004]. Common traits between these systems and SAR imagery include that they are digital products, some operate in non-visible spectral bands and others can record data without an operator present.

Non-imaging radar systems may be hand-held, or mounted on a land-based tripod, ship, aircraft, or spacecraft. Speed guns are normally used to determine the velocity of a moving single target. Radar speed guns exploit the X-, K-, or Ka-band (overall wavelength range of 2.4 to 1.1 cm). They are active systems that operate with radiation wavelengths of the same order as those of the C-band (5.6 cm) imaging radar.

Business owners rely on video cameras for surveillance of their premises. Videotape has been shown to be an effective tool, mainly due to the fact that people can easily relate to the visible band images they produce [Gillen, 1986]. However, when this new technology was first introduced as evidence, it faced legal

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challenges related to admissibility and authentication. One of these challenges was the fact that a person did not operate the video camera, and therefore the data could not be authenticated. This further affected admissibility until evidence recorded by a device without the assistance of a human operator made precedent in a first successful court case [R.v. Nikolovski, 1996].

FLIR systems and other heat detecting sensors are routinely used to locate illegal marijuana drug growing operations. This data has been controversial, yet it has met acceptance as evidence in court [Smith, 1996]. Also, near infraRed colour aerial photographs helped settle insurance claims related to the accidental release of chemicals into the environment [Polet et al., 1986; Dams et al., 1986]. A problem with presenting these data as evidence in court is that they record non-visible electromagnetic radiation.

Gathering of Photographic Evidence

The purpose of presenting aerial photographs in a court case is to increase the visual comprehension of facts [Gillen, 1986] and to provide demonstrative evidences of crime scenes. Since the introduction of SAR-based oil slick detection, the role of oblique aerial photographs has been of supporting evidence, rather than primary evidence. They are a visible-band representation of the ocean surface synchronized (or nearly coincident) with the radar image [Armstrong, 2007] for the location of an alleged oil spill. The photographs captured during aerial surveillance missions normally meet the legal requirements for admissibility, as they have been, in previous cases, accepted as evidence in court [Transport Canada, 2007]. Transport Canada [2007], the Bonn Agreement [2004], and the International Tanker Owners Pollution Federation [ITOPF, 2001] have published substantive instructions on how to determine oil spill characteristics from visual observation and colour aerial photographs. The gathering of photographic evidence and ancillary data must follow a strict protocol in order to address some issues that have influenced cases to fail in the past [Armstrong, 2007].

SAR IN THE COURT OF LAW

In order to consider remote sensing data in the court of law, the criteria of admissibility and authentication must be specifically addressed. This section presents the aspects by which SAR images are a justified source of data for the investigation and prosecution of alleged oil spills.

Admissibility of Evidence

The admissibility of evidence closely depends on the ability of an expert witness to exhibit information that aerial photographs or satellite images contain and demonstrate the reliability of SAR images to represent an oil slick on the surface of the ocean.

The role of an expert witness is to explain the type of evidence presented in court and that the information it contains is relevant to the case [Latin et al., 1976]. The oil spill observer, the person who took photographs, or any other person on board a surveillance aircraft that responded to the oil spill event in question may be called as an expert witness. Unlike the oblique photograph taken with a hand-held camera, the SAR image is recorded from an unmanned satellite platform. The introduction of such type of image evidence implies that

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the remote sensing expert should be prepared to explain the SAR image technology, analysis methods and interpretation that led to the produced evidence. In addition, they should be able to verify that the satellite image was not tampered with and that the oil spill product can be reproduced.

The reliability of SAR for slick detection has to be shown through the repeatability of the data recording technology and the analysis method to produce the same results within a defined level of accuracy. The analysis of aerial photographs and SAR for slick detection complies with the legal requirement of repeatability in that the applications have transited from the experimental to the operational phase. The following examples show that the interest to demonstrate the reliability of images for oil spill detection is a matter of constant progress.

SAR satellites have been used in oil spill detection programs in Europe since the early 1990s [Bern et al., 1993]. Shortly after, Johannessen et al. [1995] demonstrated the first version of a SAR image classification routine for extracting oil slicks features. Since then, surveillance and oil spill volume estimate protocols were developed for the Mediterranean [Fusco and Vizzari, 1998], North and Baltic [Johannessen et al., 2001; Tufte et al., 2004] seas. In Canada, the Integrated Satellite Tracking of Polluters (I-STOP) program has built an expertise with the analysis of over 5,000 SAR images a year for ice monitoring and other marine applications [DeAbreu et al., 2006]. This program integrates realtime satellite SAR imagery, airborne oblique colour photography, and surveillance reports. The European and Canadian initiatives have tightly defined input parameters, analysis routines, and expected output products.

Studies have yielded estimates applicable to the validation of SAR images for oil slick detection. On the one hand, Brekke and Solberg [2005] report a 88% classification accuracy with a dataset of 17 verified oil slicks. On the other hand, Fiscella et al. [2000] evaluated a dataset containing 80 oil slick samples and 43 non-polluted samples showing oil slick look-alike features and found that more than 80% of the samples were correctly classified. These figures of accuracies are indicative, but incomplete for attesting to consistent and robust oil spill identification procedures. The lack of documented accuracy assessments is due to inadequate validation datasets, as there are not enough sufficient oil slick occurrences to perform objective validation of SAR slick detection [Robinson and Ufermann, 2003].

Authentication of Evidence

Authentication is met by establishing the identity of the evidence submitted in court. This implies, for example, that an image must illustrate the specific target area of interest and produce a representation that is in fact equivalent to the information the camera or sensor originally captured. The chain of custody serves this aspect of the authentication of evidence. Likewise, one must be able to make the demonstration that a standard protocol has been followed while preparing an oil slick product. The concept of standardization is defined in reference with the realm of the discipline from which the application draws. For example, a standard remote sensing process may consist of four elements: statement of the problem, data collection, data-to-information

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conversion and information presentation [Jensen, 2007].

Metadata and archiving protocols fit with the data collection element of the remote sensing process and they address the chain of custody obligations. The data-to-information conversion and information presentation are probably the most challenging parts of the process because they alter the images, but at the same time they are essential for providing comprehension of the information relevant to a case. This more specifically concerns numerical analysis, because it modifies, often irreversibly, digital images for the purpose of presenting comprehensible documents as evidence to the court. Image analysis processes can be verified as part of 'analytical' chain of custody.

A standard photo- or image-interpretation process is intuitively organized hierarchically by using the tone, or colour, and location as primary elements. The spatial structure (i.e., size, shape, texture and pattern) is a secondary interpretation element and more complex information belongs with higher order elements. The latter may include site, situation, association, non-image data sources (or collateral data), convergence of evidence, and multi-concept interpretation [Konecny, 2003]. The interpretation process is compatible with the legal requirements for authentication, considering it provides a comprehensive suite of interconnected tasks, which are presented in a logical progression. The high order elements, which are derived from collateral data, have a critical role in the validation of evidence because they bring independently recorded data that can either support, or contradict, the information extracted from the images introduced as main evidence.

CASE STUDY

The case study first consists of preparing a radar image and photographic documents that meet the legal requirements of admissibility and authenticity. It focuses on an alleged oil slick from the McHugh ship (a pseudonym) that was detected on a RADARSAT-1 (R-1) image and verified from aerial surveillance in 2002 as part of the I-STOP program. The incident occurred about 300 km south of Newfoundland and Labrador. The case nearly made it to court, but was not prosecuted.

R-1 is equipped with a C-band radar system that transmits and receives horizontally polarized electromagnetic radiation [RADARSAT International, 2000]. The image was recorded from a ScanSAR narrow beam mode that covers a 20 to 46° incident angle range and produces a 300 km swath width. The nominal spatial resolution is 50 m, resampled to a pixel spacing of 25 m.

The Canadian Coast Guard travelled to the alleged spill site approximately 5.30 hours after the R-1 image was captured. The oil spill report indicated four separate oil slicks had been observed within the imaged area. During the airborne operation, the pollution prevention officer took 26 oblique colour photographs using a 35 mm analog hand-held camera and confirmed that two ships were in the area of an oil slick.

The steps that follow are applicable to a SAR image and are potentially complementary to the initial oil spill report. They include pre-processing, information extraction, validation, and preparation of an oil slick product for presentation in court. As part of the case study,

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these steps are executed and documented to illustrate their importance for meeting the legal requirements.

Pre-Processing

Relevant pre-processing steps involve radiometric calibration, geometric correction and image enhancement. Radiometrically-calibrated image pixels represent the strength of the backscattered signal in physical unit of decibel. The calibration also accounts for some of the backscattering variation associated with the increasing incidence angle [Raney et al., 1991]. The relationship between the raw image and the calibrated values can be documented as part of the processed image metadata.

An image analyst has the option of using a path image or to apply geometric corrections to conform to a standard map datum and reference system. The image provider normally produces a geometric correction report that specifies the projection parameters of essence to the validation of the geographical location of targets (i.e., oil spill, vessels, and coastline) represented on an image.

Image enhancements increase the backscattering contrasts and make an image easier to interpret. When using an image for legal evidence, all enhancement functions and the sequence by which they were applied must be known. Typical low-pass filters are recommended for oil spill applications, which should suppress speckle, but still preserve small size and thin oil spill-related contrasts [Brekke and Solberg, 2005].

Image Interpretation

The visual image interpretation process was applied to the SAR image to identify potential oil slicks. The image interpretation elements applicable to the identification of oil slicks include tone, shape, texture, size, site, situation, association and location.

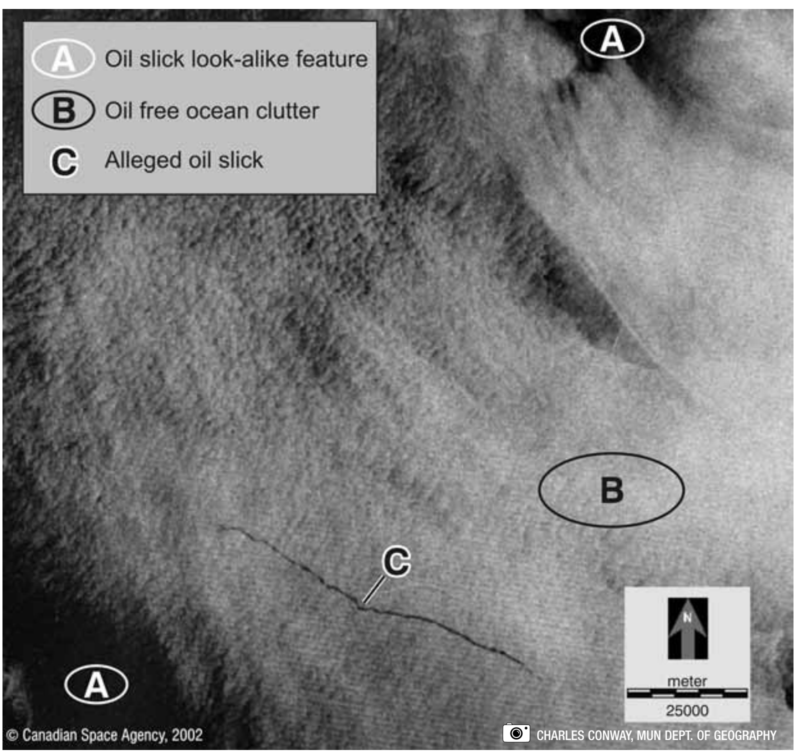

Figure 1: Portion of RADARSAT-1 SAR image with (A) oil slick look-alike features, (B) oil free ocean clutter, and (C) alleged oil slick.

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Dark-toned areas, potentially oil slicks, were identified on the R-1 image (Figure 1). The dampening of the capillary waves on the ocean and the creation of a thin narrow film smoothing the ocean surface is an outstanding characteristic of an oil slick, which causes specular backscattering and results in homogeneous dark tones on the SAR image [Lewis, 1998]. This contrasts with the bright tone from diffused backscattering of ocean clutter. Oil slicks from ships are typically linear in shape, with a very high length-to-width ratio, because they are shaped as a trail in the wake of the ship. The area of the oil slick segment on the R-1 image, based on multiplying the length (75 km) by the width (0.5 km in the widest part), is 37.5 km^2. However, this generalized measurement is an overestimation as the width of the spill is uneven. The automatic classification produced an oil slick area estimate of 21 km^2, based on the number of pixels it encompasses and the spatial resolution of the image (Figure 2).

An identifying site element for the identification of oil slick features is that they are located in an offshore commercial shipping lane [Turpin, 2003], unless a spill was triggered by a wreck onshore or accident while the ship is docked in port. The situation elements consist of two bright tone point shape features, possibly ships, approximately 15 km north of the potential oil slick, but not consistently aligned with it. The absolute location of the oil slick was taken from the R-1 image at halfway along the alleged spill.

Wind-affected water surfaces and algal blooms can also produce a specular backscattering [Alpers and Huhnerfuss, 1989], but they can be ruled out as oil slick features based on their wider and irregular shapes and on other, higher order, interpretation elements.

Validation

Collateral data, such as weather records and aerial photographs collected during a synchronized aerial surveillance mission can support the validation of the satellite image-derived information. Wind data were obtained from independent sources (recorded with instrumentation that was not controlled through the oil spill surveillance effort). The

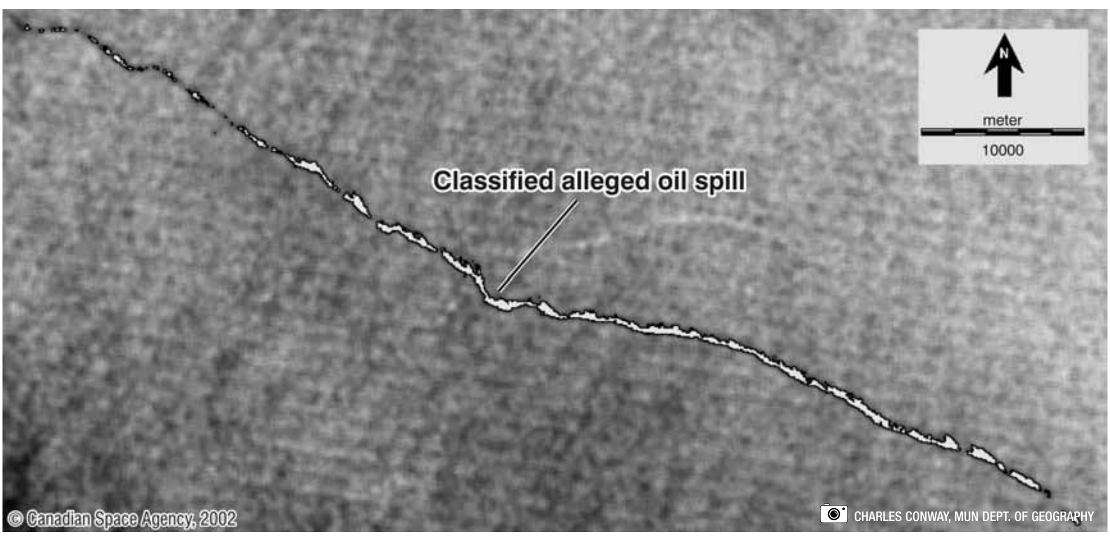

Figure 2: Portion of RADARSAT-1 SAR image with classified alleged oil slick.

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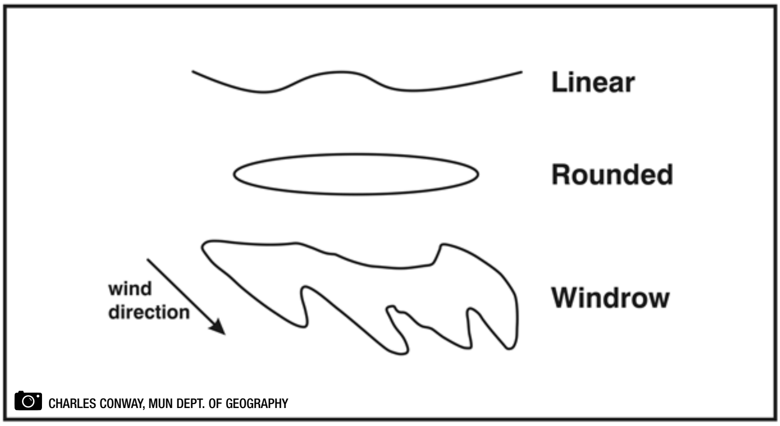

Figure 3: Graphical representation of typical oil slick shapes.

Meteorological Service of Canada (MSC) 12-hour forecast and historical Sea State and Buoy Status Reports estimated a 25-kn wind speed and a 35-kn easterly wind, respectively. The land-based stations that are nearest to the alleged incident recorded southeasterly wind velocities of 12 and 13 kn (22 and 24 km/h), respectively, at the time the R-1 image was recorded [Environment Canada, 2011].

High oblique colour aerial photographs constitute a visual data source onto which the validation of the satellite images can rely because it is, with direct observation, one of the most traditional means of reporting oil spill events. However, technical specifications presented through flight and event observation reports [Canadian Coast Guard, 2002a; 2002b; Environment Canada, 2002; MDA, 2002] must accompany the presentation of aerial photographs for these to be admissible as evidence.

The remainder of this section presents the interpretation results of the oblique aerial photographs that coincide in time and location with the R-1 image acquisition. The presence of oil slicks was recorded on all photographs and some of them also showed a ship in the immediate area. The colour of the oil slicks varies from silvery-grey sheen and rainbow to metallic. The shapes of these features appeared discontinuous and continuous. About half the photographs contained linear and elongated oil slicks while other photos showed round and windrow shaped oil spills (Figure 3). The texture of the oil identified in two photographs is smooth, while the majority of the other photos reveal a rippled pattern associated with the wind-induced surface waves. Since the visual characteristics of the features match the oil spill interpretation codes of the Bonn Agreement [2004], there is a strong argument that the oblique photographs can be used as supportive documentation to prove there were in fact oil slicks on the ocean surface.

An estimate of the volume of oil that was allegedly spilled was made from one of the photographs. The slick in this particular photograph is silvery-grey sheen, a colour class that corresponds to a volume estimate of 40 to 300 L/km^2 [Bonn Agreement, 2004]. As a result, the total volume estimated for the area of the oil slick represented by the single photograph is in the range of 0.27 and 2.01 L. These values are based on one of the photographs; therefore, they correspond to only a small portion of the 600-L estimate made by the Canadian Coast Guard [2002b] at the time of the incident.

The area estimate obtained from image classification is 21 km^2 (see the section 'Image

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Interpretation' above). An extrapolation based on the colour photo-derived volume of 40 to 300 L/km^2 yields a total volume of 840 to 6,300 L. The volume expresses the amount of oil that was released and links with an equivalent concentration. The legally allowable spill concentration of 15 ppm [Pavlakis et al., 2001] is equivalent to approximately 90 L of oil [Committee on Oil in the Sea, 2003]. The SAR image suggests that this limit was exceeded.

The pollution prevention officer on board the surveillance aircraft documented the GPS-recorded absolute location of the four segments of the oil slick. The sighted oil slick coordinates were manually entered into a point vector file geo-referenced to the R-1 image and the corresponding Universal Transverse Mercator reference system. The R-1-detected oil spill is located within the latitude and longitude range of the aerial oil sightings. However, three of the four oil spill segment sightings are away from the R-1-derived oil slick by distances of 6, 17 and 32 km. These discrepancies are significant, since they exceed the 750-m positional accuracy of the R-1 path image. However, given the wind speed recorded at the time of the event (22 to 24 km/h), the oil patches could have migrated by the time (5.30 hours later) the aircraft arrived to the site.

The SAR image provides an initial event location and the aircraft surveillance response time is critical. More than five hours after the R-1 image was recorded, the oil slick appeared to be in smaller segments. A continuous slick usually divides into fragments and forms windrow patterns mainly due to the surface currents and turbulence [ITOPF, 2001]. Prevailing wind on that day would have displaced the oil after the SAR image was recorded.

SAR Legal Preparation

The radar image preparation followed guidelines developed by Gillen [1986], Quinn [1979], Bonn Agreement [2004], and ITOPF [2001]. A relevant visual hard-copy product includes a print of the image in a map-and-graphic composition of the radar image, aerial photographs, sighting locations and annotations.

A strong argumentation for building the acceptance of radar images as evidence in court can be made by streamlining the tasks that expert witnesses are to address in order to be prepared for the presentation of radar image as evidence to the court. The process of using a SAR image for oil slick detection begins when the image is delivered to the remote sensing analyst. The handling and analysis normally require several steps and may involve more than one person. Expert witnesses must be prepared to present to the court parts or the whole remote sensing image and ancillary data analysis process. Information collection must not be limited to the specifics of an alleged oil spill, but also must include all phases of image processing, analyst identity, host hardware, analysis software, data storage facilities and data security measures.

CONCLUSION

The parameters for the admissibility of remote sensing imagery evidence were presented. Both the oblique aerial photographs and SAR images are operational data acquisition methods. They are potentially admissible in court, pending the reliability of the data has been established. A strong asset to this is that as expert witnesses they are able to explain the SAR image characteristics, analysis process and interpretation elements to the court and this is done more

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effectively if they had some involvement with the preparation of the evidences presented to the court. The dependability of SAR detection also relies on the concept of repeatability of results in using these types of data. The outcome of this research shows the acceptance of the feasibility of SAR image-based oil spill detection within the remote sensing discipline.

A case study using a SAR image and high oblique aerial photographs from a pollution incident off the south coast of Newfoundland and Labrador (Canada) demonstrated that these data could help identify, investigate and potentially prosecute illegal oil discharges. The technological parameters for the validation of SAR imagery were applied by using oblique aerial photographs to verify an alleged oil slick. The authentication of a SAR imagery and oblique aerial photographs as evidence was demonstrated through the case study by outlining the accepted image interpretation process and applying known legal and metadata standards.

The efficiency of satellite SAR imagery as a sound data source for the collection of evidence to prosecute illegal oil discharges is strengthened when used in conjunction with aerial surveillance-based observer and photographic records, and ancillary information. The interpretation of remote sensing images follows established processes that are compatible with the concepts of admissibility and authentication.

Issues related to the credibility of SAR data and to the evidence building process are possible sources of failures in using remote sensing data as image evidence. First, SAR imagery is perceived as a new technology that law practitioners may not be readily inclined to adopt. Previously, when other new technologies were initially introduced, such as surveillance video, it only took one case for these to be accepted as evidence and set a precedent. Second, the analysis of digital data implies a modification of the initial product. This process may jeopardize the authentication if it is not properly documented. Finally, ancillary and contextual data gathering protocols must be minutely respected, particularly if the process is not fully automated.

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