SAR-Based Oil Pollution Surveillance in Canada: Operational Implementation and Research Priorities

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ABSTRACT

In November 2006, Canada began to operationally monitor marine coastal areas for oil pollution with satellite SAR. The implementation of this program by the Canadian Ice Service follows the highly successful ISTOP project sponsored by the Canadian Space Agency. The operational ISTOP program uses RADARSAT-1 data to identify potential oil spills to vector aerial and surface response efforts. The CIS has established research priorities that will help ensure that the ISTOP program will continue to play an effective role in the mitigation of marine oil pollution today and in the years to come.

Keywords: oil spill detection, ship detection, marine pollution, SAR.1 Introduction

1 BACKGROUND

Oily waste illegally discharged by a small percentage of ocean traveling vessels into coastal waters is having a severe impact on Canada's marine ecosystem, specifically on the mortality of marine birds. In Canada, it is estimated that over 300 000 birds are oiled annually in just the Atlantic waters. Without mitigation of this pollution, it is expected that the seabird population in Canada will be severely impacted. With the passage of Bill C-15 in 2005, the Government of Canada moved to strengthen its approach to oil releases at sea through a comprehensive set of enforcement tools. Improved surveillance was seen as key plank for the Government of Canada to meets its goals and obligations under this new act. Towards this, the government moved to operationalize the highly successful ISTOP (Integrated Satellite Tracking of Pollution) program which had been operating in a prototype mode since 2002.

With support from the Canadian Space Agency, Environment Canada and Transport Canada partnered with MDA Geospatial (formally RADARSAT International) to demonstrate the use of RADARSAT-1 to optimize oil pollution monitoring and surveillance in Canada. The utility of space-borne SAR to detect oil on water had shown promise in coastal areas around the world. Between 2002 and 2005, MDA ordered and received near real time RADARSAT-1 data over Canada's east and west coast. Image analysts used a GIS interface to visually identify potential oil targets and candidate sources (e.g. nearby ships, offshore platforms). Results were immediately forwarded to surveillance, response and enforcement clients for follow-up. The primary ISTOP client was Canada's National Aerial Surveillance Program (NASP). NASP aircraft regularly survey Canada's coastline for marine oil pollution. The ISTOP program was found to be a very useful complement to the NASP, helping vector its aircraft to high potential targets. In the fall of 2005, the Canadian Ice Service was given the directive to operationalize the ISTOP program by the fall of 2006.

2 OPERATIONALIZATION OF ISTOP

Given its mandate to operationally monitor and report on ice conditions in Canada's coastal waters, the Canadian Ice Service was well positioned to implement ISTOP in a short time period. CIS ice operations receive and analyze over 5000 near real time SAR images (RADARSAT-1, ASAR) each year. CIS ice analysts are trained in SAR image interpretation and, through its own airborne reconnaissance program, have worked closely with aircraft teams. With further support from the Canadian Space Agency and MDA Geospatial, the CIS developed and implemented an operational ISTOP workflow and production system on November 1, 2006.

The ISTOP workflow and production system is shown in Figure 1. Thirty minutes after acquisition by Canadian ground stations, satellite SAR data is processed by MDA at the Canadian Data Processing Facility in Gatineau, Quebec and forwarded to the CIS in Ottawa . Upon arrival at CIS, the Level 1 CEOS data is split into two streams. In the first stream, the data is immediately re-projected, converted to an Erdas Imagine file format and stored in a customized geodatabase -- the ISIS (Ice Service Integrated System) catalogue. A second stream of CEOS data is ingested by the Ocean Monitoring Workstation (OMW). Satlantic Ltd.'s OMW [1] has proven itself capable of automatically detecting oil and ships in SAR imagery. Automated target detection was implemented in the ISTOP workflow to provide analysts with an accurate and objective first guess at the presence of oil and ships in incoming imagery. The OMW also produces an estimate of the surface wind vector over the RADARSAT scene. The OMW XML outputs are converted to shape files which are sent to the ISIS catalogue. The ISIS catalogue also contains a variety of visible, infrared and microwave imagery, as well as other related data layers, e.g. coast lines, bathymetry.

CIS ice analysts were trained in oil and ship detection in SAR. Given their extensive experience with interpreting sea ice against an ocean *background* in SAR imagery, the ice analysts quickly grasped the fundamentals of SAR oil and ship detection. An ISTOP workstation was developed to provide the analysts with a geospatial workspace where they could review and overlay the SAR imagery, the OMW outputs and relevant environmental fields (e.g. wind information). This customized ARCView application also allows the analysts to create the required ISTOP products when a potential slick is detected.

ISTOP products are distributed automatically to subscribed clients via the CIS Product Distribution System (PDS). When a spill is detected, a preliminary bulletin is issued to alert subscribers that a potential slick has been found. This is done to provide the pollution aircraft maximum ready time to respond if capable. After a full image analysis (approx. 15-20 mins.), the analyst will issue final reports to PDS on the location of potential oil slicks and any nearby vessels. Armed with this information, pollution aircraft will respond to identify the spill and any potential nearby sources.

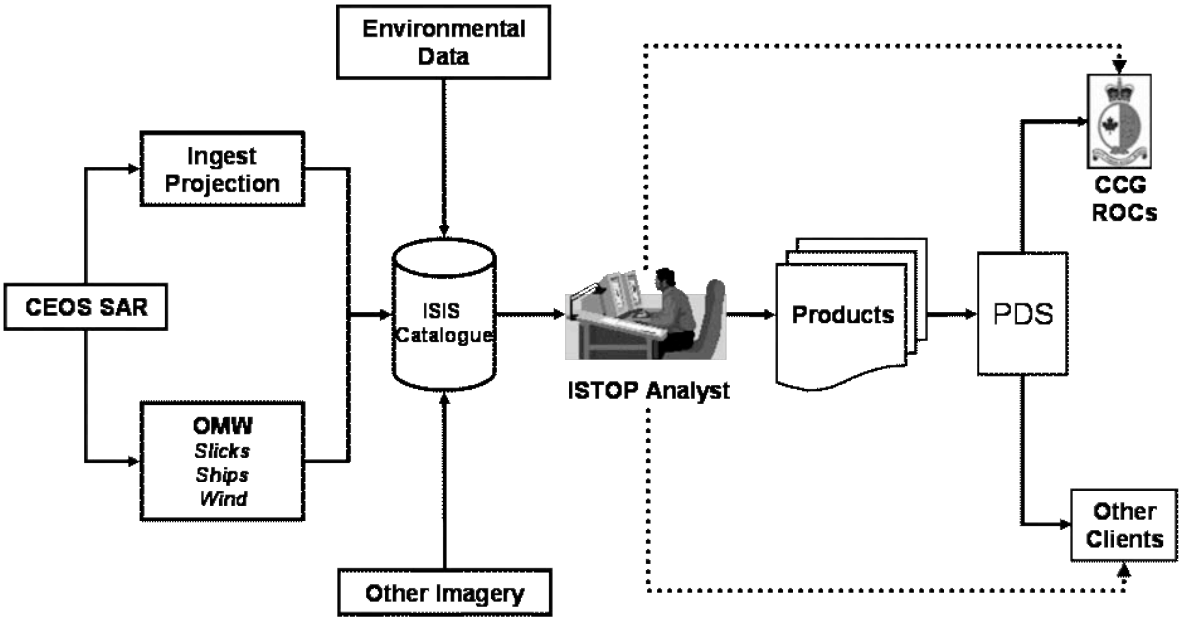

Figure 1. ISTOP workflow and production system.

3 ISTOP RESEARCH PRIORITIES

CIS has dedicated resources to ensure that ISTOP is well positioned to improve its performance in oil and ship detection today and in the years to come. Research and development at the CIS will focus on improving the automated detection of oil through the incorporation of the ISTOP database. The ISTOP database contains 3 years of spill events detected and logged through the ISTOP program and is growing with the recent operationalization at the CIS. Focus will be on filtering out false slick positives through slick classification and filtering techniques.

Understanding the sensitivity of ISTOP performance to system NESZ is also a priority as the follow-on SAR constellations are specified and designed for launch the next decade. Of interest to ISTOP is the expected poorer sensitivity of these systems compared to RADARSAT-1 and likely RADARSAT-2. Recent research at the CIS has shown that increasing the noise floor to -22 dB would have unacceptable impacts on ISTOP slick detection capabilities. At this NESZ level, there would be inadequate clutter to noise ratio (CNR) to support the consistent detection and mapping of oil with the high confidence required by ISTOP (Figure 2). On the other hand, evidence suggests that -22 dB may be an acceptable NESZ for ISTOP at VV polarization offered by RADARSAT-2 and Envisat ASAR.

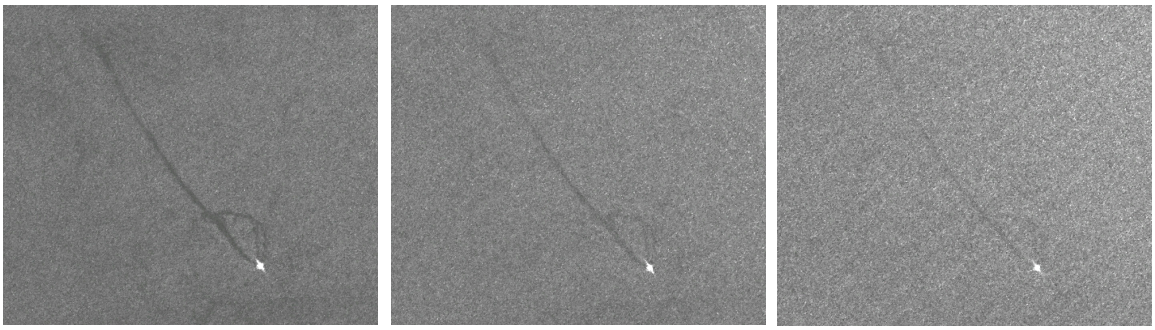

Figure 2. Appearance of oil-like signature at various levels of NESZ injected into RADARSAT-1 ScanSAR Narrow data

Another research priority is to assess the utility of RADARSAT-2 VV/VH dual channel ScanSAR data for the ISTOP program. It is known that VV polarization provides superior CNR for oil detection over HH polarization. On the other hand, VV is less appropriate for ship detection. However, VH polarization has shown promise in detecting ships (figure 3)[2]. ISTOP will be working with others to investigate more fully whether the VH channel of RADARSAT-2 can perform adequately for ship detection. If so, VV/VH will be likely replace HH as the default ISTOP acquisition mode after the launch of RADARSAT-2.

Finally, the CIS is interested in determining the impact of RADARSAT product quantization on ISTOP automated and visual detection of potential slicks. It is suspected that moving from 8 bit to 16 bit or 32 bit ScanSAR products would lead to improved detection of slicks. However, this would result in increased data volumes and transfer rates. The related cost-benefits will be investigated after the launch of RADARSAT-2. Somewhat related to image quantization is the application of product look up tables (LUTs). The CIS routinely requests a post-processing LUT enhancement be applied to the RADARSAT data during processing to provide a radimetrically balanced image across range. It is evident that the current LUT is far from optimal for ISTOP. The CIS hopes to develop a more appropriate LUT for both oil and ship detection to be applied on RADARSAT-2 data to support ISTOP visual analysis.

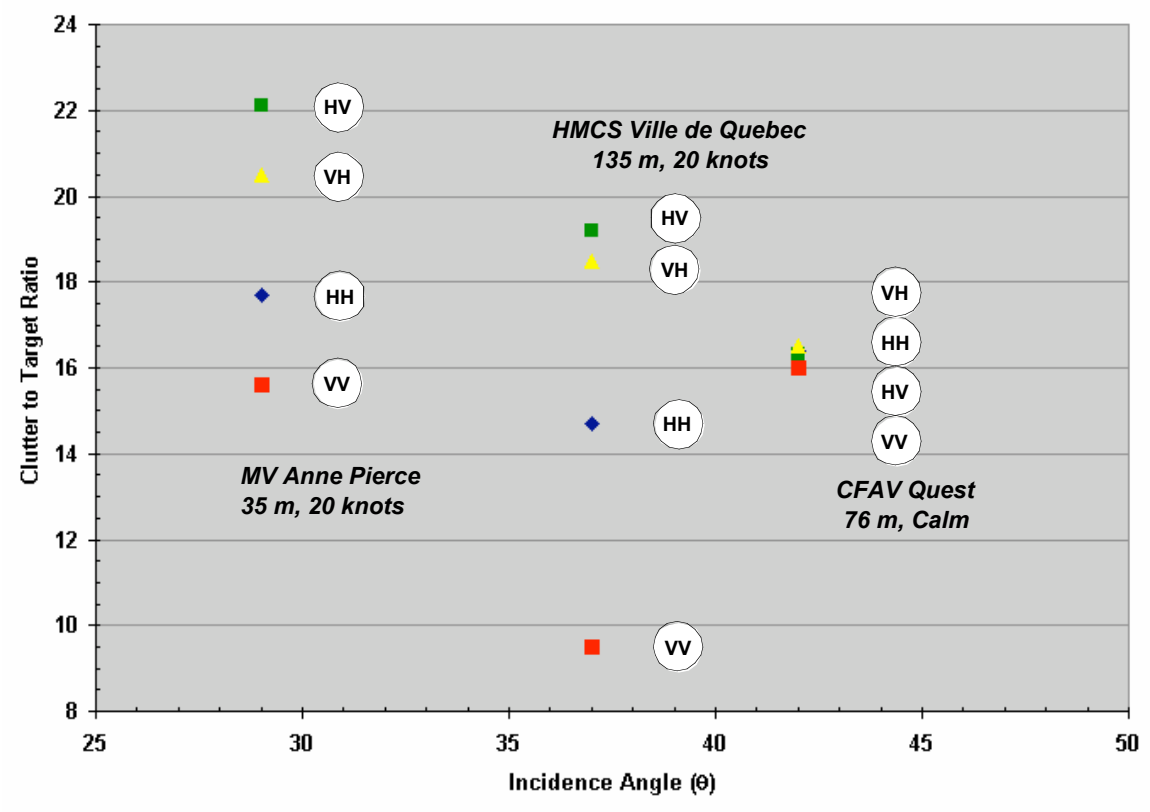

Figure 3. Clutter to target ratios for three ships at various airborne SAR polarizations. VH polarization shows good potential for ship detection over a wide range of incidence angles (Source data from [2]).

4 CONCLUSIONS

The ISTOP program has been successfully implemented at the Canadian Ice Service. RADARSAT-1 imagery of both Canada's east and west coast are now acquired daily and analyzed shortly after image acquisition for the presence of marine pollution. The operational workflow developed over the last year builds on CIS ice expertise, is robust and scalable. ISTOP research and development will continue at the CIS with the focus on improving current operations and ensuring that future satellite missions are well positioned to serve ISTOP oil and ship detection requirements. The operationalization of ISTOP, and the concurrent investments in the national aerial surveillance program, has significantly improved Canada's ability to detect, investigate and enforce against marine oil pollution in its coastal areas.

5 REFERENCES

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