The RADARSAT Constellation Mission (RCM): Extending Operational Marine Surveillance for Environment Canada

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Abstract

Environment Canada is the largest Government of Canada user of Synthetic Aperture Radar (SAR) data produced by the Canadian RADARSAT missions. Near real-time imagery from both RADARSAT-1 and RADARSAT-2 are used operationally for daily ice monitoring and oil pollution detection programs. Additionally, Environment Canada is assessing the use of marine wind information extracted from SAR data to support operational marine forecasters and numerical weather prediction.

The launch of the RADARSAT Constellation Mission (RCM) will more that just ensure continued access to SAR data to support Environment Canada's operational marine surveillance programs.
The RCM will also improve on both the geographic coverage and timeliness of the data acquired in Canada's coastal waters. New modes, like compact polarimetry, also have the potential to provide new and improved ice information.

Introduction

The Canadian RADARSAT Constellation Mission (RCM) will be the successor to the current RADARSAT-1 and RADARSAT-2 missions. While RCM will ensure continued access to dual-channel C-Band Synthetic Aperture RADAR (SAR) data, the addition of new modes like compact polarimetry and the three-satellite constellation approach is fully anticipated to extend the capabilities of SAR to support Environment Canada's (EC) operational marine surveillance programs

EC has been actively engaged and provided leadership in the development of RCM User Requirements to ensure RCM will meet its current and future needs and have already begun preparations to ensure a smooth transition that will maximize the exploitation of the new opportunities offered by RCM. This paper summarizes how three EC marine surveillance programs (Ice and Iceberg Monitoring, Oil Pollution Monitoring and SAR Winds Monitoring) are preparing for the transition from the current RADARSAT-1 and RADARSAT-2 missions to the RCM Mission.

Sea Ice and Iceberg Monitoring

Environment Canada's Canadian Ice Service (CIS) is responsible for the daily monitoring of Canadian coastal waters for the presence and condition of sea ice, icebergs, and lake ice. The provision of regular ice information promotes safe and efficient maritime operations and protects Canada's Exclusive Economic Zone (EEZ) by providing reliable and timely information to marine clients. The CIS relies on a suite of both airborne and satellite sensors to detect and characterize ice. Canada's RADARSAT program is the cornerstone of operational ice monitoring. The integration of RADARSAT-1 into its daily monitoring not only provided the CIS with significant cost savings (due to reduced aircraft flight hours), it has also resulted in more accurate, timely ice charts for its marine clients. Specifically, the limits of ice

(i.e. ice edges), its concentration and its typing were significantly improved. It's successor, RADARSAT-2, has recently been operationalized at CIS. For the first time, CIS analysts are using dual channel SAR information, HH+HV, to detect and monitor sea ice and icebergs. RADARSAT-2's dual polarization capability is resulting in more accurate ice detection and monitoring.

Within the era of the RADARSAT Constellation Mission, the potential for lighter ice conditions and increased economic activity in the Arctic will increase the requirement for operational ice information. Importantly, the RCM represents continuity of dual channel C-band SAR for ice monitoring from previous RADARSAT missions. This will allow unbroken operational monitoring of Canada's coastal waters for sea ice throughout this decade. Also important, is the fact that, at full phase, there will be three SAR satellites in orbit. This provides the CIS will good within-mission backup in case of spacecraft failure and provides its clients with better service/business continuity. Another key benefit of the constellation is the near daily coverage of all of Canada's coastal waters. Today, in southerly domains like the Gulf of St. Lawrence, aircraft is required to fill in the gaps between the incomplete coverage offered by a single, polar-orbiting SAR satellite.

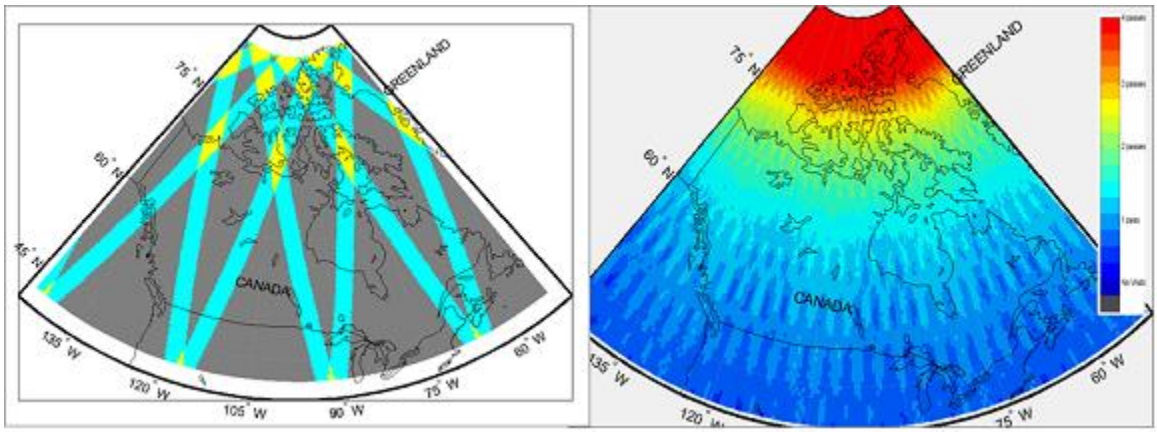

Figure 1: Left – RADARSAT-2 Daily Coverage vs. Right – RCM expected daily coverage.

With three satellites, the RCM will provide CIS ice analysts with a SAR snapshot of ice conditions in all southerly waters on a daily basis in support ice charting. This should reduce the reliance on aircraft and could lead to further cost savings. In the Arctic, due to the precession of orbits, multiple daily snapshots will be available. This should also improve the monitoring of high arctic dynamic ice regimes (Figure 1).

In order to support ice (and oil) monitoring, specific modes which feature improved noise floor characteristics have been included in the RCM. It is anticipated that these Low Noise modes will permit monitoring of those ice types that have low signal to noise characteristics (e.g. new, smooth ice). Through its inclusion of a Compact Polarimetry (CP) mode, the RCM also has the potential to provide improved ice information. It is understood that fully polarimetric SAR modes and associated analyses have the ability to fully explain and describe sea ice scattering. These high power modes on existing missions (e.g., RADARSAT-2), however useful for providing improved ice information, are of little operational value to the CIS and other ice services due to their narrow swath widths. RCM's CP mode has the potential to provide polarimetric-like ice information at surveillance swath widths (i.e. over 100's kms) (Figure 2). This experimental mode may represent an important improvement over the range and type of ice information that can be extracted over large operational areas. CIS will be working with the Canadian Space Agency and Natural Resource Canada's Canada Centre for Remote Sensing to establish a pre-launch understanding of the potential of this new mode for operational ice monitoring.

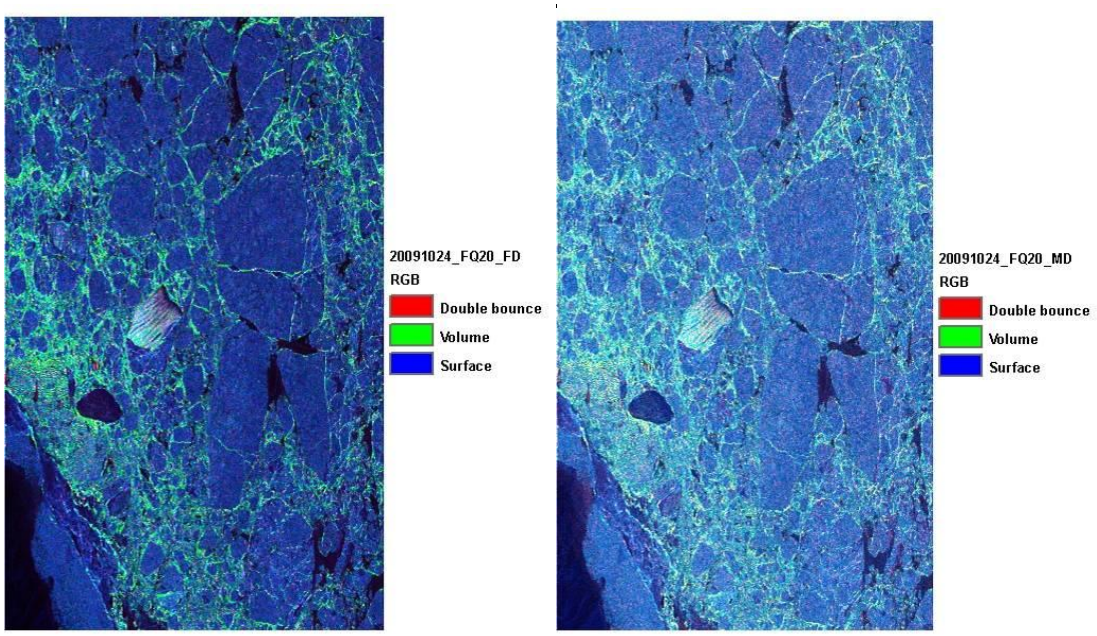

Figure 2. R-2 Polarimetic image (left) and simulated CP image (right). RCM CP mode should provide information similar to a fully polarimetric SAR (Source Geldsetzer, NRCAN)

Oil Pollution Monitoring

In 2006, Environment Canada's Canadian Ice Service assumed responsibility for the space-based monitoring of discharged oil pollution in Canadian coastal waters, as well as in the Gulf of St. Lawrence and Great Lakes. The Integrated Satellite Tracking of Pollution (ISTOP) program streamlines government response by guiding patrol aircraft to areas where oil spills are suspected, and by focusing any necessary prosecution and/or cleanup efforts.

Currently, the ISTOP program uses single-polarization (HH) RADARSAT-1 data to monitor its operational areas. Through the use of SAR data, ISTOP analysts not only attempt to locate potential oil slicks but also those vessels in the spill's vicinity that may be responsible for the pollution event. Oil slicks tend to be more visible in SAR imagery at steeper incidence angles where the ocean backscatter is typically higher, thus providing better contrast with the much darker oil target. As the incidence angle increases, ocean backscatter decreases and the detection of oil slicks is more difficult. Contrarily, ship detection success rates are better when larger incidence angle modes are used. For these reasons, the ScanSAR Narrow A beam was deemed the best compromise mode for oil and ship detection from the choices available on the RADARSAT-1 platform. It provides a generous swath width (300km), adequate incidence angle range (20°-40°), and respectable nominal resolution (50m). It should also be mentioned that the system noise floor (NESZ) for this single-polarization ScanSAR mode is quite low (~ -26dB) which permits easier detection of low signal oil targets.

Advancements in RADARSAT-now permit users to acquire dual-polarization (HH/HV & VV/VH) imagery at ScanSAR swaths. There is an agreement in the literature that (VV) polarized images provide better contrast than either HH or HV polarized images when detecting oil. For ship surveillance, Defence Research and Development Canada (DRDC) Ottawa has observed that (HH) co-pol outperforms (VV) co-pol [1]. The use of RADARSAT-2's dual-pol mode should help the ISTOP program diminish the oil slick

– ship detection conflict as it provides both co-pol (VV) and cross-pol (VH). Another critical issue for the non-hard-target applications is the sensor noise floor. RADARSAT-2, with an NESZ of approximately -28dB for ScanSAR modes, provides good signal to noise ratio for oil spill detection. Oil detection is easiest when SNR (i.e. oil slick signal to ocean clutter) is > 5 dB [1], [2].

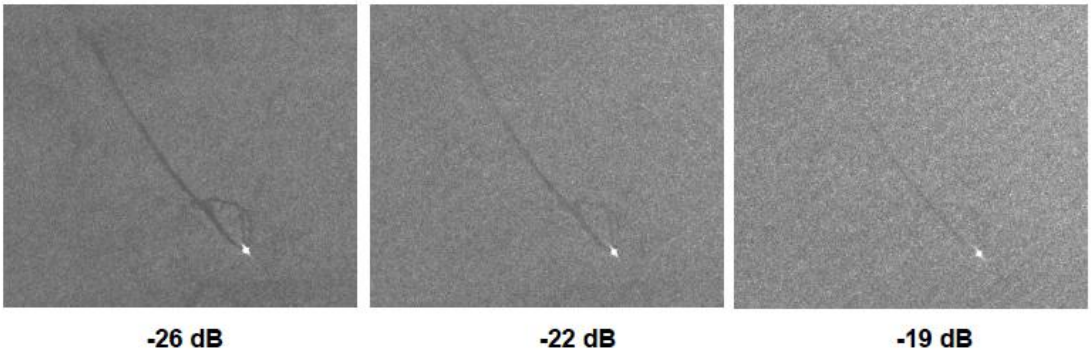

Figure 3. Appearance of oil-like signature at various levels of NESZ injected into RADARSAT-1 ScanSAR Narrow data

Most importantly, the RADARSAT Constellation mission (RCM) provides SAR data continuity for the oil spill monitoring program. The constellation's biggest advantage over previous RADARSAT missions is the increased temporal and spatial coverage it will provide (see Figure 1). At full phase, there will be 3 SAR satellites in orbit which will enable faster revisit and better coverage for the ISTOP regions of interest. Based on current information, it appears that the "Low Noise" mode on board the RCM will be optimum for the ISTOP program. With its 350km swath, 100m resolution and proposed NESZ of < -25dB, it looks to be the most promising choice. Its beam width is slightly larger than the current ScanSAR Narrow mode, while the noise floor estimate remains consistent with RADARSAT-1. However, the mode's lower resolution of 100m will adversely affect the detectability of certain ship targets. RCM's "Medium Resolution" and "Low Resolution" modes are possible alternatives but their current NESZ estimates of < -22dB will hinder detection of the low noise oil targets. At this early stage, the benefits of any RCM compact polarimetry modes for oil spill monitoring are unknown.

SAR Wind Monitoring

The extraction of ocean surface wind speed and direction from SAR imagery has been demonstrated from several SAR satellite missions, but has only limited operational implementation worldwide. Following a successful pilot during 2006-2008 in the Pacific and Yukon Region, Environment Canada's Meteorological Service (MSC) is now conducting a two-year project (National SAR Winds) to assess the utility of these data to support operational marine forecasting needs across all five forecast regions of Canada, and to evaluate and plan for possible future implementation within the operational marine weather monitoring network. The project is sponsored by the Canadian Space Agency GRIP program, and aims to evaluate the operational use of large quantities of SAR data by marine forecasters, the numerical weather prediction system, and other multidisciplinary science users. The project will recommend an optimum system architecture for a proposed operational national SAR Winds processing and dissemination system - not only EC's forecast needs, but to serve the full range of potential users of high-resolution marine surface winds in Canada.

The operationalization of this capability is contingent on the continuity of spaceborne SAR data, for which RCM will be critical. A key advantage of RCM for this application will be increased revisit

frequency, particularly at southern latitudes. However even daily coverage in fixed dawn/dusk windows will not fully met the observation frequency and time-of-day diversity requirements for a marine winds monitoring system, especially in coastal areas there the diurnal cycle is usually more pronounced. Only a virtual constellation of several SAR missions with diverse overpass timing will address this need. The potential of the advanced features of the RCM mission, such as the Doppler Anomaly product and different cross-polarization modes, may also extend the capabilities of a future operational implementation.

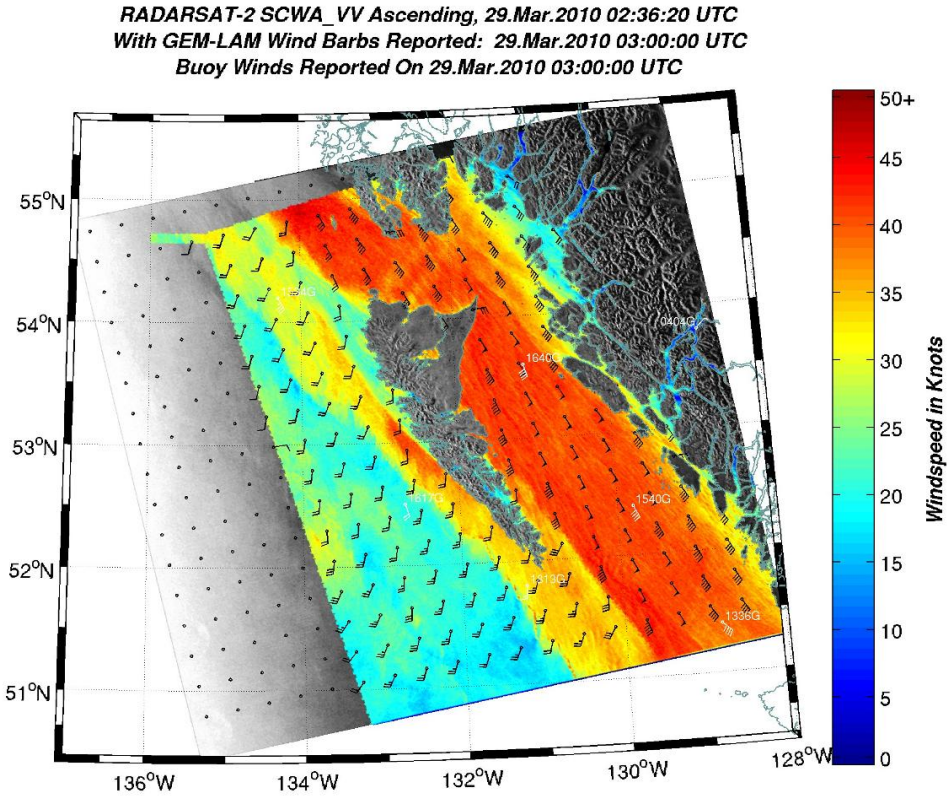

Figure 4: RADARSAT-2 SAR derived wind speed with Barrier Jets

The SAR Winds application has the potential to consume significant quantities of data. An evaluation of marine meteorologists' requirements demonstrates than for the minimal coverage of the oceans and large inland lakes more than 15,000 scenes/yr from RADARSAT missions will be required. This is a significant increase over current EC consumption of approximately 7,000 scenes/yr currently consumed for ice and oil applications. To be ready to ingest and use this volume of data, partnerships are being developed between all MSC Regions, the Canadian Meteorological Centre in Dorval, and the Canadian Ice Service to ensure readiness and optimal coordination for the exploitation of RADARSAT-2, ENVISAT ASAR, ESA Sentinel-1, and RCM.

The National SAR Winds Project includes operational demonstration, training, science, and coordination components. The retrieved wind vectors are being evaluated for operational utility in two ways – for visualization by the marine desk forecaster in the preparation of warnings and forecasts (human analysis), and for assimilation into the numerical weather prediction model. On the science side, the investigation

of optimal imaging modes and extraction algorithms for both uses is being conducted. There are early promising results related to use cross-polarization modes which could lead to wind retrieval without knowledge of the wind direction, thus simplifying the processing algorithm and reducing sources of error. Throughout the project EC staff from the forecast and science communities are working together to provide mutual learning, and to provide as comprehensive an assessment as possible of the impact of these data on forecast skill. The end result will be a well-documented science assessment and business case which will permit a well informed decision on the operationalization of SAR Winds in Canada.

Summary

The RADARSAT Constellation Mission will more that just ensure continued access to dual-band C-Band SAR data to support EC's operational marine surveillance programs. With three satellites in orbit, the RCM will be able to provide near-daily coverage over all of EC's areas of interest, thus improving the service that EC is able to provide. The addition of new modes, like compact polarimetry, offers the potential for additional ice, oil and wind information to be extracted from the SAR.

By the time RCM is launched, the monitoring of the marine domain with SAR is going to be very busy. In addition to the established ice, iceberg and oil pollution programs, we will see the emergence of new applications like SAR winds and Department of national Defence ship detection. Each of these operational programs will have requirements for repetitive coverage of large marine areas with optimized beam modes and polarizations, and these requirements will often be in direct conflict. Faced with these significant challenges of conflicting requirements, Federal Government Departments (FGDs) who will be active in the marine domain have already begun to coordinate their future SAR data requirements through the creation of an Enhanced Marine Ordering Coordination (EMOC) working group which will look to create standard coverages and use compromise beam modes to ensure RCM is best utilized to meet all FGD mandates. To further resolve conflicts, EC promotes coordination for the exploitation of current and future SAR missions such as RADARSAT-1/2, ENVISAT ASAR, ESA Sentinel-1, and RCM.

References

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