Conference Proceedings Paper

The RADARSAT Constellation Mission in Support of Environmental Applications

Mohammed Dabboor [1,*], Steve Iris [2] and Vern Singhroy [3]

[1] Science and Technology Branch, Environment and Climate Change Canada; Mohammed.Dabboor@canada.ca
[2] Canadian Space Agency; Steve.Iris@canada.ca
[3] Canada Center for Mapping and Earth Observation, Natural Resources Canada; Vern.Singhroy@canada.ca
* Correspondence: Mohammed.Dabboor@canada.ca; Tel.: +1-514-421-4756

Published: date
Academic Editor: name

Abstract: The RADARSAT Constellation Mission (RCM) is a future Canadian spaceborne Synthetic Aperture Radar (SAR) mission, which comes to support the operational use of SAR imagery for different Earth observation applications. The mission with its three identical satellites will provide average daily complete coverage of Canada's land and oceans. In this paper, we provide an overview on the RCM and its characteristics and advancements over the previous Canadian SAR missions. However, emphasis is given on the expected potential of the RCM related to environmental applications. Experimental results of environmental applications using simulated RCM data showed promising performance of the mission.

Keywords: Synthetic Aperture Radar; RADARSAT Constellation Mission; Environment

1. Introduction

The RADARSAT-1 (launched in 1995), RADARSAT-2 (launched in 2007) and the RADARSAT Constellation Mission (to be launched in late 2018) are three past, current, and future SAR space missions which consist the Canadian RADARSAT program [1]. The RADARSAT Constellation Mission (RCM) is the evolution of the RADARSAT Program with the objective of ensuring data continuity, improved operational use of SAR data and enhanced system reliability [2]. Canada is developing the RCM using small satellites to further maximize the capability to carry out round-the-clock surveillance from space [2]. The Canadian Space Agency (CSA), in collaboration with other government-of-Canada departments and Canadian industry, is leading the design, development and operation of the RCM to help addressing key priorities. The RCM will provide all-weather day and night imagery in support of Canadian sovereignty and security, environmental monitoring, natural resources management, and other government priorities [3]. The RCM will have three identical small satellites, providing SAR imagery over the entire Canada's land and oceans every day. The short revisit frequency of the mission combined with accurate orbital control affords a range of applications that are based on regular collection of data and creation of composite images that highlight changes over time, such as those induced by climate change, land use evolution, coastal modifications, urban subsidence and even human impacts on local environments [2,4].

The RCM is being designed to address three main core applications; maritime surveillance (ice mapping, pollution monitoring, ship and iceberg detection, marine winds), ecosystem monitoring (forestry, agriculture, wetlands, coastal change), and disaster management (flood monitoring, windstorms, earthquakes, landslides, volcanic activities) [3]. Simulated RCM products are made available to help users become familiar with the new format and adapt their processing chains

accordingly [5,6]. The simulated RCM products are derived from an RCM simulator developed at the Canada Center for Mapping and Earth Observation (CCMEO). The RCM simulator uses RADARSAT-2 imagery as input to simulate RCM data at its respective nominal spatial resolution and noise floor. In this paper, we provide an overview of the main characteristics of the RCM. Focus of the paper is on the RCM applications related to the environment. Environmental applications of the RCM are of high interest since Environment and Climate Change Canada is the biggest user of SAR imagery within the Government of Canada.

2. RCM Characteristics

The RCM is a constellation of three identical C-band SAR satellites. In contrary to RADARSAT-1&2, the RCM satellites will be small in mass (~ 1430kg) with a lifetime of 7 years. Also, the RCM satellites will fly in a lower orbit (600 km) than that of RADARSAT-1&2 (800 km) with an inclination angle of 97.74° and a satellite Earth circling equal to 96.4 minutes. Increased satellite repeat cycle of 12 days for each satellite is expected. The 12-day repeat cycle provides a coherent change detection (CCD) period of 4 days (taking into account the three satellites), enabling enhanced interferometric SAR applications, e.g. coherent change detection for disaster management, landslide estimation, flooding monitoring, etc.

The RCM satellite will operate in ten difference SAR modes with different nominal spatial resolutions and Noise Equivalent Sigma Zero (NESZ). Table 1 presents an overview of the characteristics of the ten RCM SAR modes [3].

Table 1. Characteristics of RCM SAR modes

Beam Mode	Nom. Res. (m)	Swath (km)	Looks (rng x az)	NESZ (dB)
Low Resolution 100m (LR)	100	500	8x1	-22
Medium Resolution 50m (MR50)	50	350	4x1	-22
Medium Resolution 16m (MR16)	16	30	1x4	-25
Medium Resolution 30m (MR30)	30	125	2x2	-24
High Resolution 5m (HR)	5	30	1x1	-19
Very High Resolution 3m (VHR)	3	20	1x1	-17
Ice/oil Low Noise (LN)	100	350	4x2	-25
Ship Detection	var.	350	var.	var.
Quad-Polarization	9	20	1x1	-25

The constellation will have the capability to provide all the polarization options, including the new SAR configuration called compact polarimetric (CP) polarization. The RCM satellites will transmit a right-circular polarization and receives two mutually coherent orthogonal linear polarizations (RH and RV), enabling the use of CP SAR data in wide swath imagery [5-7]. The CP option will be available at all RCM imaging modes, except for the quad polarization SAR mode.

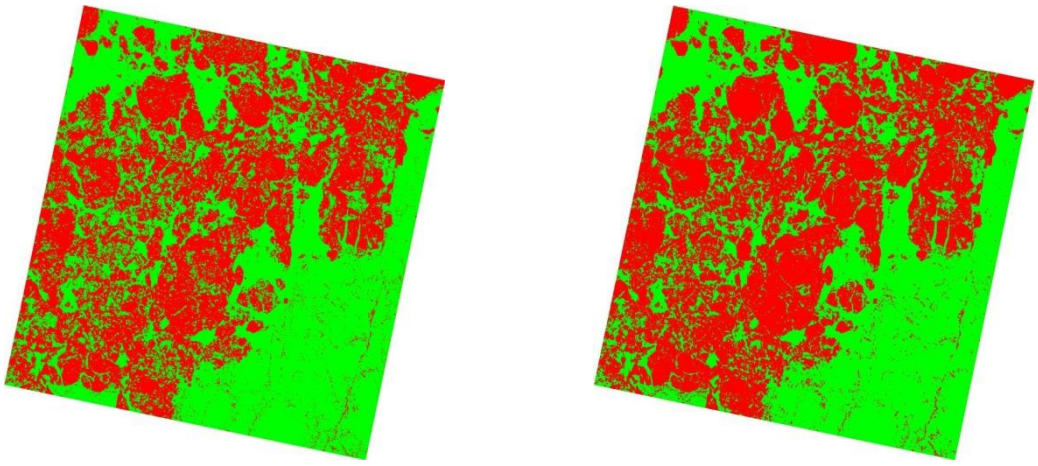
3. Environmental Applications

The constellation specifications and characteristics are expected to open wide prospects for environmental applications in Canada and worldwide.

3.1. Sea Ice Mapping

Sea ice monitoring and mapping is one of the mandatory SAR applications to be addressed by the constellation [5]. The RCM will support the operations of the Canadian Ice Service (CIS), with primary objective the improvement of the sea ice monitoring in the Canadian Arctic. The RCM modes most likely to be used operationally are the LN, LR, and MR50 modes. Two studies have investigated the potential of these three modes for sea ice classification [5,8]. In [5], simulated CP SAR data of the three RCM SAR modes were evaluated for the classification of First Year Ice (FYI), Multiyear Ice

(MYI), and open water in dry ice winter conditions. Results showed promising performance of the tested RCM SAR modes in the discrimination of sea ice types and open water. The expected performance of the three tested RCM SAR modes in [5] was further validated in [8] using a larger set of simulated RCM CP SAR data with different sea ice types, during all sea ice seasons. Herein, the effect of the radar incidence angle in the discrimination between sea ice types was also examined. We conducted additional experiments to validate the potential of the RCM for sea ice classification using simulated CP SAR data of the RCM HR SAR mode. The classification accuracy of the simulated RCM data (96.13%) was found to be comparable to the accuracy of real full polarimetric RADARSAT-2 SAR data (98.99%). Figure 1 shows the classification results of MYI (red) and FYI (green) using simulated RCM data (Figure 1a) and full polarimetric RADARSAT-2 data (Figure 1b).



(a) (b)

Figure 1. Classification of FYI and MYI in Victoria Strait in the Canadian Arctic using a) simulated RCM CP data and b) RADARSAT-2 full polarimetric SAR data.

3.2. Wetland Monitoring

Canada's wetlands are diverse and cover about 14 per cent of the land area of Canada. Wetlands are an essential part of the environment and can take the form of marshes, bogs, fens, swamps and open water. Spaceborne remote sensing is an essential tool for the continuous monitoring of wetlands. The RCM with its rapid revisit time is expected to play an important role in monitoring wetlands within Canada, allowing the detection and tracking of changes in wetlands and the identification of possible impacts of these changes on species of plants, animals, and insects. The potential of the RCM for wetland monitoring was evaluated in [9]. Simulated CP SAR data of the RCM MR16 mode were derived and evaluated for flagging changes within wetlands. Changes within wetland could be crop or flooded vegetation to open water or open water to wet soil. In [9] the promising performance of the RCM for detecting both interannual (Figure 2a) and seasonal (Figure 2b) changes within wetlands was indicated. Change detection results using simulated RCM data were found comparable to those obtained using full polarimetric RADARSAT-2 data.

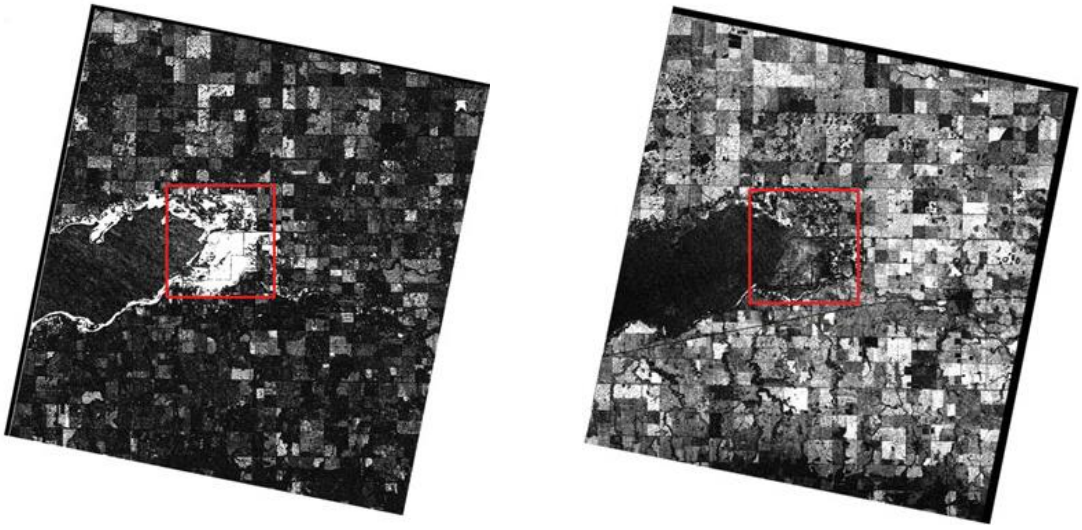
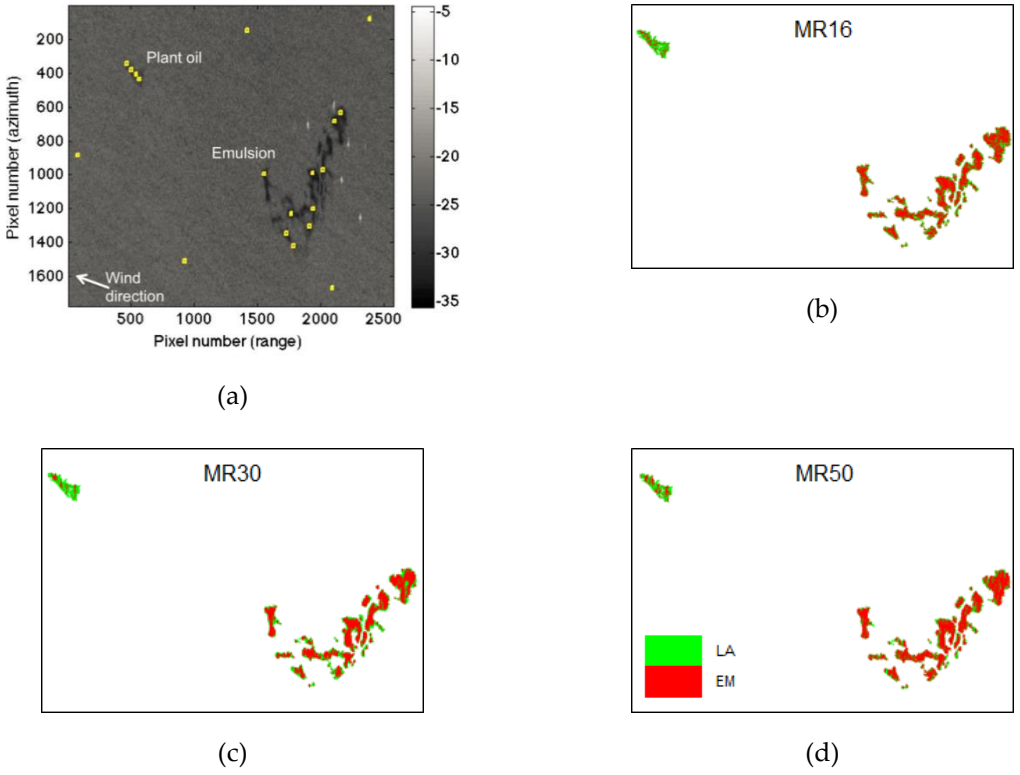


Figure 2. Detected a) interannual (May 2010 to July 2013) and b) seasonal (May 2012 to September 2012) changes in Whitewater Lake, Manitoba. Red box indicates test site within the study area. Bright regions within the red box indicate regions with changes.

3.1. Maritime Pollusion Monitoring

The RCM with its frequent revisit capability will make it possible to monitor oil spills more closely, offering enhanced potential to support oil spill control and cleaning. Near real-time SAR data will be provided to meet the requirements of the Canadian Integrated Satellite Tracking of Pollution (ISTOP) program for both effective oil and ship detection. The RCM LN mode is expected to be used for the oil spill monitoring. However, other RCM modes, such as those of medium resolutions, are being evaluated for their potential to monitor oil spills.



(a) (b) (c) (d)

Figure 3. a) RADARSAT-2 VV SAR image with spilled plant oil (to be treated as lookalike) and emulsion [10]. Classification of Emulsion and lookalike using simulated CP SAR data of the RCM modes b) MR16, c) MR30, and d) MR50.

Example results of the performance of the medium resolution RCM SAR modes in the detection and classification of Emulsion (EM) which is a mixture of oil and water and plant oil which was treated as Lookalike (LA) are shown in Figure 3. Evaluation of the classification results indicated that the RCM MR 30 (Figure 3c) provides the highest overall classification accuracy (84.05%) of EM and LA in comparison to the RCM MR16 (Figure 3b) and MR50 (Figure 3d) modes (74.30% and 83.70%, respectively).

4. Conclusions

The RCM is the evolution of the RADARSAT Program and is expected to address many different applications within the public and private sectors, both in Canada and internationally. The increase in the revisit frequency of the mission introduces a range of applications that are based on regular collection of SAR imagery. Preliminary experimental results with simulated RCM CP data showed promising performance capability of the RCM in different environmental applications, including sea ice mapping, change detection in wetlands, and maritime pollution monitoring.

Acknowledgments: RADARSAT-2 data and products © MacDonald, Dettwiler and Associates Ltd. (2013) – All Rights Reserved. RADARSAT is an official mark of the Canadian Space Agency.

Author Contributions: Mohammed Dabboor conducted the experiments on the RCM potential for sea ice mapping, change detection in wetlands, and oil spill detection. All authors contributed to the writing of the paper.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

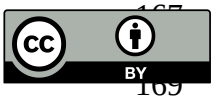
The following abbreviations are used in this manuscript:

SAR: Synthetic Aperture Radar
RCM: RADARSAT Constellation Mission
ISTOP: Integrated Satellite Tracking of Pollution
EM: Emulsion
LA: Lookalike

References

1. Singhroy, V.; Charbonneau, F. RADARSAT: science and applications. *Phys. in Canada* **2014**, 70 (4), 212-217.
2. Séguin, G.; Ahmed, S. RADARSAT constellation, project objectives and status. In Proceeding of the IEEE International Geoscience and Remote Sensing Symposium, Cape Town, South Africa, 12-17 July 2009; pp II-894-II-897.
3. De Lisle, D.; Iris, S.; Chalifoux, S. RADARSAT constellation mission serving Canadians. In Proceedings of the Spatial Knowledge and Information Canada Conference, Montreal, Canada, 23-26 February 2017.
4. De Lisle, D.; Iris, S. RADARSAT constellation mission status update. In Proceedings of the 11th European Conference on Synthetic Aperture Radar, Hamburg, Germany, 6-9 June 2016; pp 1-3.
5. Dabboor, M.; Geldsetzer, T. Towards sea ice classification using simulated RADARSAT constellation mission compact polarimetric SAR imagery. *Remote Sens. Environ.* **2014**, 140, 189–195.
6. Dabboor, M.; White, L.; Brisco, B.; Charbonneau, F. Change detection with compact polarimetric SAR for monitoring wetlands. *Can. J. Remote Sens.* **2015**, 41, 408-417.
7. Charbonneau, F.; Brian, B.; Raney, K.; McNairn, H.; Liu, C.; Vachon, P.; Shang, J.; De Abreu, R.; Champagne, C.; Merzouki, A.; Geldsetzer, T. Compact polarimetry overview and applications assessment. *Can. J. Remote Sens.* **2010**, 36 (2), S298–S315.
8. Geldsetzer, T.; Arkett, M.; Zagon, T.; Charbonneau, F.; Yackel, J.; Scharien, R. All-season compact-polarimetry C-band SAR observations of sea ice. *Can. J. Remote Sens.* **2015**, 41 (5), 485-504.

9. Dabboor, M.; White, L.; Brisco, B.; Charbonneau, F. Change detection with compact polarimetric SAR for monitoring wetlands. *Can. J. Remote Sens.* **2015**, 41(5), 408-417.
10. Skrunes, S.; Brekke, C.; and Eltoft, T. Characterization of marine surface slicks by RADARSAT-2 multipolarization features. *IEEE Trans. Geosci. Remote Sens.* **2013**. 52(9), 5302–5319.



© 2017 by the authors; licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC-BY) license (http://creativecommons.org/licenses/by/4.0/).