OIL SPILL DETECTION USING SIMULATED RADARSAT CONSTELLATION MISSION COMPACT POLARIMETRIC SAR DATA

Mohammed Dabboor[1], Suman Singha[2], Konstantinos Topouzelis[3], Dean Flett[4]

[1]Science and Technology Branch, Environment and Climate Change Canada, Canada
[2]Remote Sensing Technology Institute (IMF), German Aerospace Center (DLR), Germany
[3]Department of Marine Sciences, University of the Aegean, Greece
[4]Canadian Ice Service, Environment and Climate Change Canada, Canada

ABSTRACT

Synthetic Aperture Radar (SAR) remote sensing has become a valuable tool for maritime pollution monitoring with three major requirements: 1) low noise floor, 2) large area coverage, and 3) polarization diversity to maximize detection and discrimination of pollution features. In order to reconcile the advantages of fully polarimetric SAR with larger area coverage, compact polarimetry (CP) acquisitions offer a trade-off between the above mentioned requirements. The future Canadian RADARSAT Constellation Mission (RCM) will enable the acquisition of CP SAR data in wide swath imagery, including ScanSAR modes. In this study, we investigate the potential of CP for four RCM SAR modes for oil spill detection. These modes have different spatial resolutions and noise floors. An initial visual interpretation of the results indicates potential of some CP features for the discrimination between oil spills and lookalike.

Index Terms— RCM, compact polarimetric SAR, oil spill.

1. INTRODUCTION

Operational detection and discrimination of oil spills over oceans have received considerable attention recently due to its impact on marine ecosystem from environmental and political points of view. Spaceborne SAR has been used as a major tool for operational oil spill detection programs and has attracted significant research interest. One of the major focuses regarding oil spill monitoring goes to offshore platform, where operational discharges occur regularly. As most of the offshore platforms reside in environmentally sensitive zones and also near coasts, they pose a serious threat to marine and coastal ecosystems in long term. Until now, most of the operational and Near Real Time (NRT) oil spill detection techniques use single-polarization (mainly VV) intensity SAR images where oil spills appear as dark spots [1]. The sea surface roughness responsible for SAR backscatter is primarily produced by capillary and small gravity waves generated by local winds. Damping of these waves by oil slicks reduces the backscatter, resulting in dark areas in SAR images. Although spaceborne SAR has proven to be a valuable tool for oil spill detection and monitoring, major challenges still remain, such as the discrimination between oil and 'lookalike' features. In order to mitigate this situation a major focus of research in this area is the development of automated algorithms based on polarimetric images to distinguish oil spills from lookalikes [2].

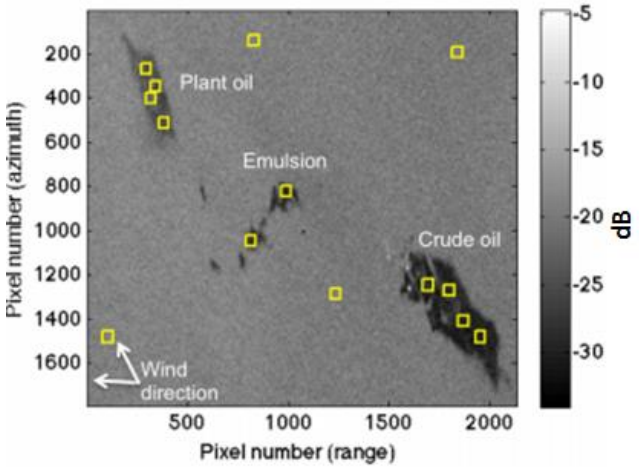

Fig. 1. The test site with the Crude oil, Emulsion, and plant oil that [5].

The RCM is a future Canadian SAR mission, providing C-band SAR data continuity of the RADARSAT-1 and RADARSAT-2 SAR satellite missions. The RCM, to be launched in late 2018, will provide compact polarimetry as a polarization option for all non-quad-polarization imaging modes [3]. A CP SAR system operates with half pulse repetition frequency, reducing the average transmitted power and increasing the swath width [4]. The wider coverage of the CP SAR system reduces the revisit time of the satellite, making this system operationally viable, especially for applications such as maritime pollution. In

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this study, we investigate the potential of CP for four RCM SAR modes with different spatial resolutions and noise floors for oil spill detection and mapping. The considered modes are: 1) Medium Resolution 50m (MR), 2) Medium Resolution 30m (MR30), 3) Medium Resolution 16m (MR16), 4) High Resolution (HR). CP features are simulated for each of the tested RCM modes and investigated for oil spill detection and mapping. Herein we present a visual interpretation of the resulting simulated CP features form the RCM MR50 mode in terms of oil spill detection.

2. DATA AND TEST SITE

The test site for this study is located in the North Sea offshore Norway. A large-scale oil spill exercise at the Frigg field was conducted in June 2011 and previously reported in [5]. Crude oil, emulsion (mixture of oil and water), and plant oil (to be treated as lookalike) were simultaneously captured in a RADARSAT-2 fine quad polarization acquisition with incidence angle ranges between 34.5^{o} and 36.1^{o}. Details about the properties of the spilled oil samples, weather conditions and ancillary information can be found in [5-6]. Fig. 1 shows the types and locations of the oil spills which took place in the experiment [5].

3. DATA PROCESSING

Table I presents the characteristics of each of the aforementioned SAR modes studied. An RCM data simulator, developed at the Canada Center for Mapping and Earth Observation, was used to simulate RCM CP SAR data. The simulator extracts 23 CP SAR features for each mode. Table II presented the extracted CP features by the RCM simulator. Details on the derived CP SAR features and their calculation can be found in [7].

4. RESULTS

A set of 23 CP features were derived for each RCM mode. Fig. 2 shows the resulting features for the case of RCM MR50 mode. An initial visual interpretation of the resulting features indicates potential of some RCM CP SAR features for the discrimination between oil spills and lookalike. An example of these features is the alpha angle, the phase difference between RH and RV, the degree of polarization and the conformity coefficient. A more detailed qualitative and quantitative analysis of the features is to be conducted as a future work for each RCM mode set of features. This analysis is the step before applying a classification algorithm for oil spill mapping using vector of uncorrelated features.

Table I
Tested RCM Modes Characteristics

Beam Mode	Nom. Res. (m)	Swath (km)	Looks (rng x az)	Noise Floor (dB)
MR50	50	350	4x1	-22
MR30	30	125	2x2	-24
MR16	16	30	1x4	-25
HR	5	30	1x1	-19

Table II
Simulated RCM CP Features

CP Parameters	
Short form	**Description**
SV0, SV1, SV2, SV3	Stokes vector elements
SE_Pol, SE_Int	Shannon entropy polarimetric and intensity components
σ^0_{RL}, σ^0_{RR}, σ^0_{RH}, σ^0_{RV}	Sigma naught backscattering – right circular transmit and left circular, right circular, linear horizontal or linear vertical receive polarization
$\sigma^0_{RV}/\sigma^0_{RH}$	Right co-polarized ratio
ρ_{RHRV}	RH RV correlation coefficient
m-δ_S, m-δ_V, m-δ_DB	Surface, volume, and double bounce scattering from m-δ decomposition
m-χ_odd, m-χ_V, m-χ_even	odd, volume, and even bounce scattering from m-χ decomposition
m	Degree of polarization
δ_{RHRV}	RH RV phase difference
u	Conformity coefficient
$\sigma^0_{RR}/\sigma^0_{RL}$	Circular polarization ratio
α_s	Alpha parameter related to the ellipticity of the compact scattered wave

4. CONCLUSIONS

A study on the potential of simulated RCM CP SAR data for oil spill detection and mapping is conducted. The study is based on 23 CP features which are simulated for four tested RCM modes. An initial qualitative evaluation of the MR50 CP features shows potential of some CP features for the discrimination between oil spills and lookalike. Investigation of the oil spill detection in simulated CP features from the other three RCM modes is to be followed.

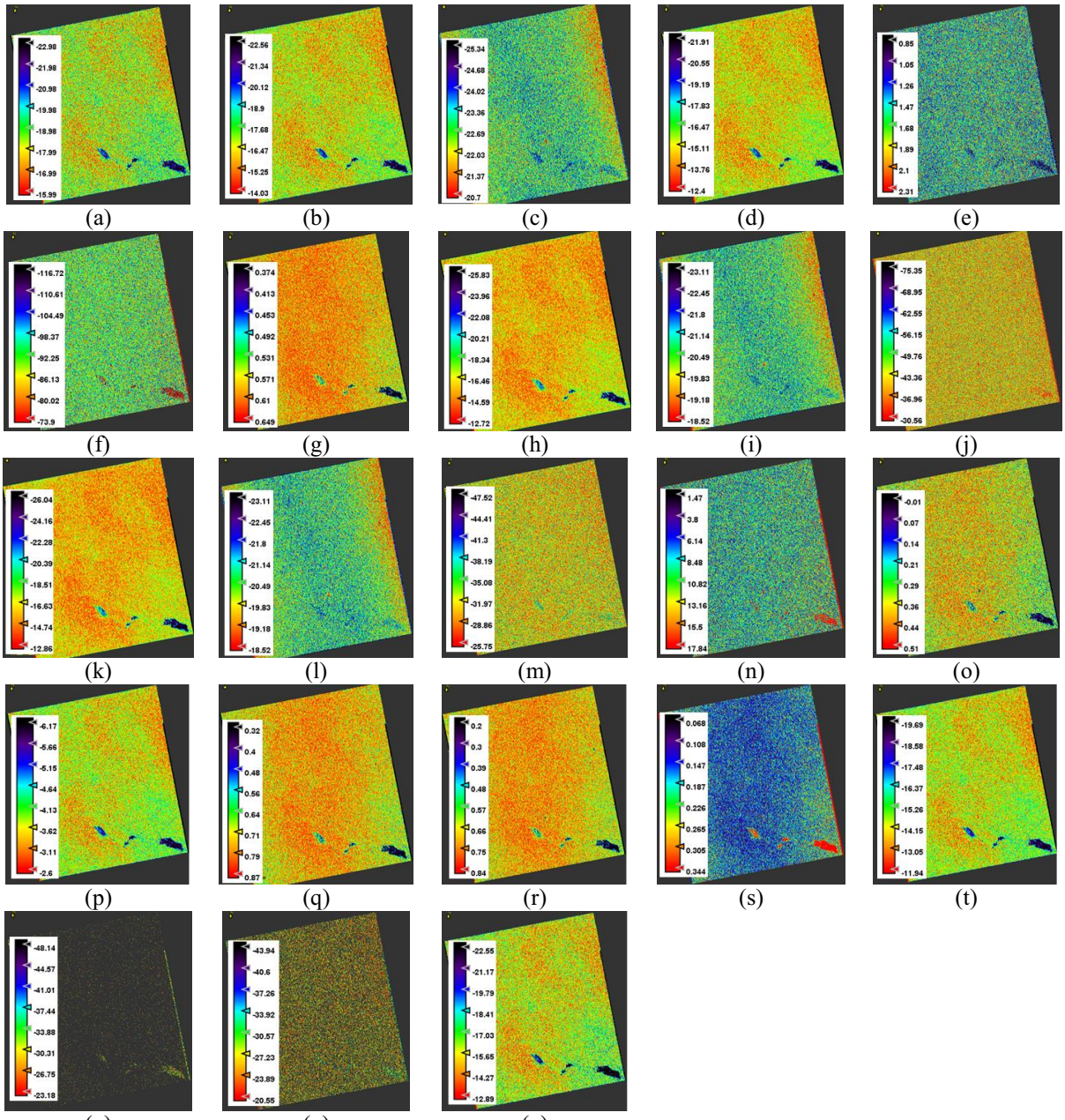

Fig. 2. Derived RCM medium resolution 50m CP features a) σ^0_{RH} (dB), b) σ^0_{RV} (dB), c) σ^0_{RR} (dB), d) σ^0_{RL} (dB), e) $\sigma^0_{RV}/\sigma^0_{RH}$, f) δ_{RHRV} (degrees), g) ρ_{RHRV}, h) m-δ_S (dB), i) m-δ_V j) m-δ_DB (dB), k) m-χ_odd (dB), l) m-χ_V (dB), m) m-χ_even (dB), n) α_s (degrees), o) SE_Pol, p) SE_Int, q) m, r) u, s) $\sigma^0_{RR}/\sigma^0_{RL}$, t) SV0 (dB), u) SV1 (dB), x) SV2 (dB), y) SV3 (dB).

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