RADARSAT-2 Products to Support Near-Real Time Oil Spill Response

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Outline

- Slick detection with radar
- Data acquisition and delivery
- Discrimination of sheen and oil emulsion
- RADARSAT Constellation Mission

Slick Detection with SAR

- Good understanding of slick detection which depends on:
  - Radar parameters
  - Environmental conditions
  - Oil characteristics

- Slick detection algorithms are used, but an analyst is usually required to:
  - Mitigate false positives
  - Apply contextual information (platforms, ships, etc.)
  - Assign confidence / classification levels

RADARSAT-2 image showing and oil slick and offshore platforms. The oil appears as a dark tone and the offshore platforms appear as bright white targets.

Oil Spill Continuum and the Role of SAR

Spill Category	Example	Duration	SAR Data Applicability
Routine	• Bilge dumping • Offshore platform spill	10s of hours	• Strong role for SAR • Requires an on-going monitoring program
Short-Term	• Small spills in marina, lake, etc. • 10s of barrels	< 24hr	• Time frame generally too short for SAR
Moderate	• Refugio Beach, CA • 100s to 1000s of barrels	Days to weeks	• Depends if spatial extent and duration are commensurate with SAR acquisition times → many kms and > 2 - 3 days
Spill of National Significance	Deep Water Horizon	Weeks to months	• Strong role for SAR

Information form Radar

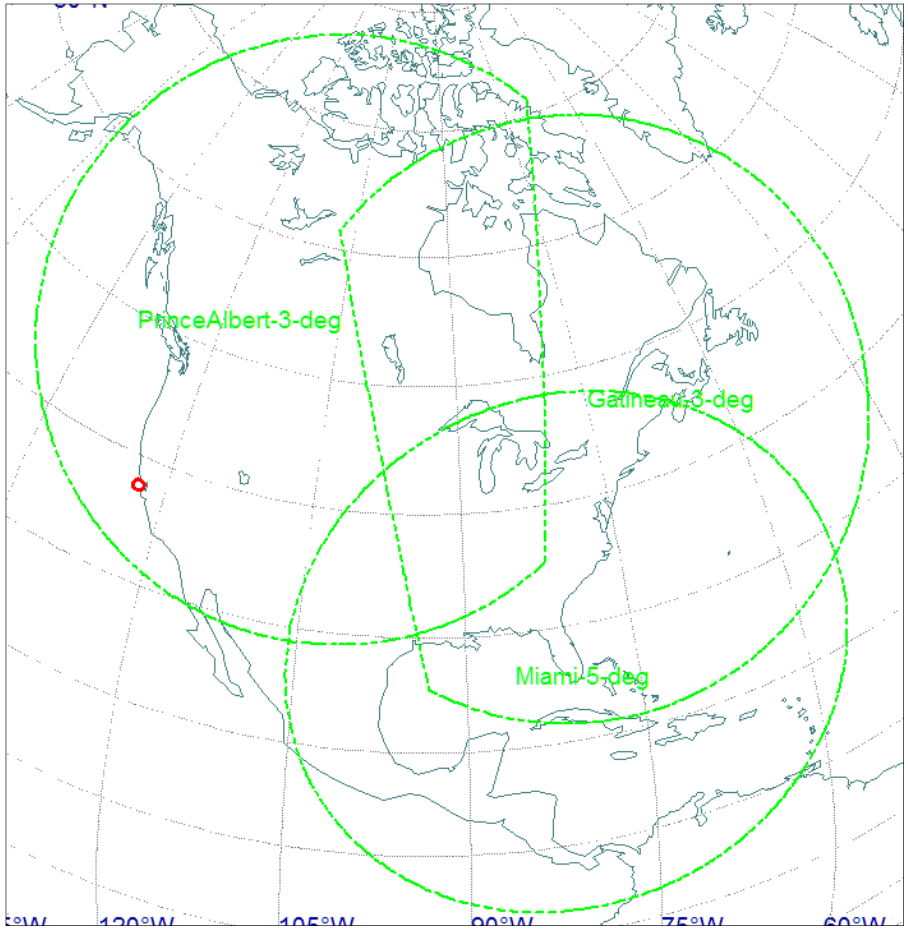
- Size of the spill (surface area)
- Wind speed and direction (directly derived from the satellite imagery)
- Locations of vessels and other local/regional infrastructure to aid in response management
- Oil slick characteristics
  - Sheen vs. emulsion

Putting the Real in Near-Real Time Delivery

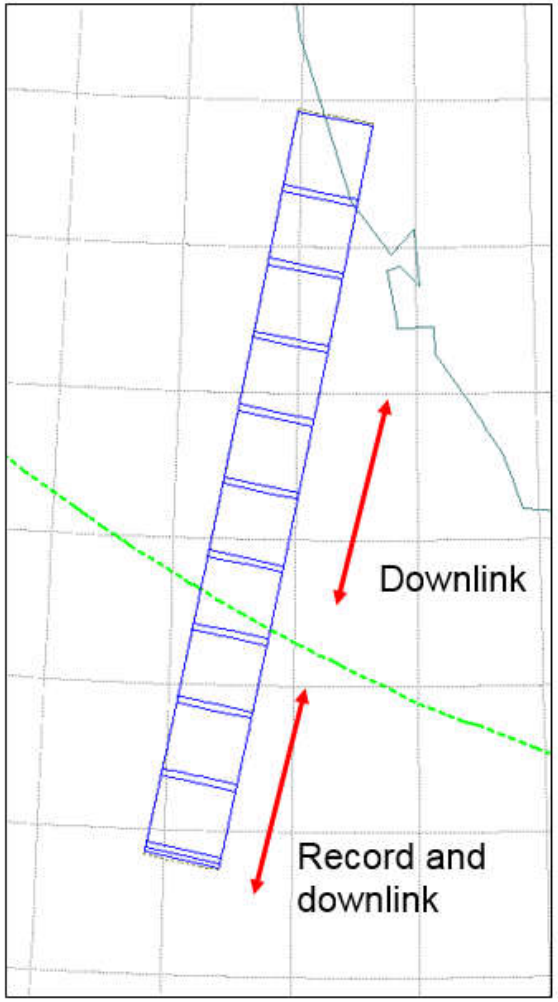
- Programing
  - The satellite can be programmed in as little as twelve hours, with four-hour programming possible for emergencies as defined by RADARSAT-2 Mission Management

- Data Downlink
  - Within a ground station mask: data acquisition/downlink are simultaneous
  - Record and downlink: depends on ground station location with-respect-to acquisition AOI, but typically no more than ~ 4-6 hours

- Data Processing, Information Extraction, and Delivery
  - Processing: < 10 minutes
  - Information extraction: depends on scene complexity, but usually < 2 hours
  - Electronic delivery: depends on communication bandwidth and information-product volume



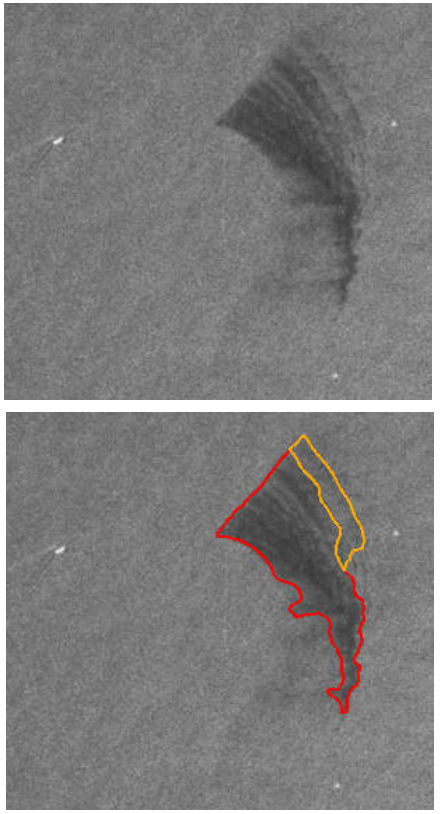
North American ground station mask



Take That Amazon Prime!

- As part of an oil-spill response study off the coast of Louisiana, RADARSAT-2 Fine quad-polarized data was acquired on at 07:00 Central Time and downlinked to the Gatineau, Quebec ground station for processing.

- A digitized oil-extent map and compressed RADARSAT-2 image (~ 2 MB) of the oil slick were delivered via satellite link to the vessels 42 minutes after acquisition.



RADARSAT-2 sub image showing the oil slick (top) and the delineation of the slick (bottom). Red indicates high confidence and amber medium confidence.

Discrimination of Shen and Emulsion

- Previous studies by MDA on a persistent oil slick located at MC20 off the coast of Louisiana have shown the capability of RADARSAT-2 quad polarized data for discrimination of sheen and emulsified oil. Although these results were encouraging, validation was based on observations that were not simultaneous with the RADARSAT-2 data acquisition.

- RADARSAT-2 data was acquired on April 25, 2017 in concert with research cruises at MC20, NASA UAVSAR data, WorldView and ASTER imagery, and in situ measurements.

Outline of the Taylor oil slick (off the coast of Louisiana) from 2014 – 2017 derived from RADARSAT-2 imagery. April 25/17 slick is coloured green.

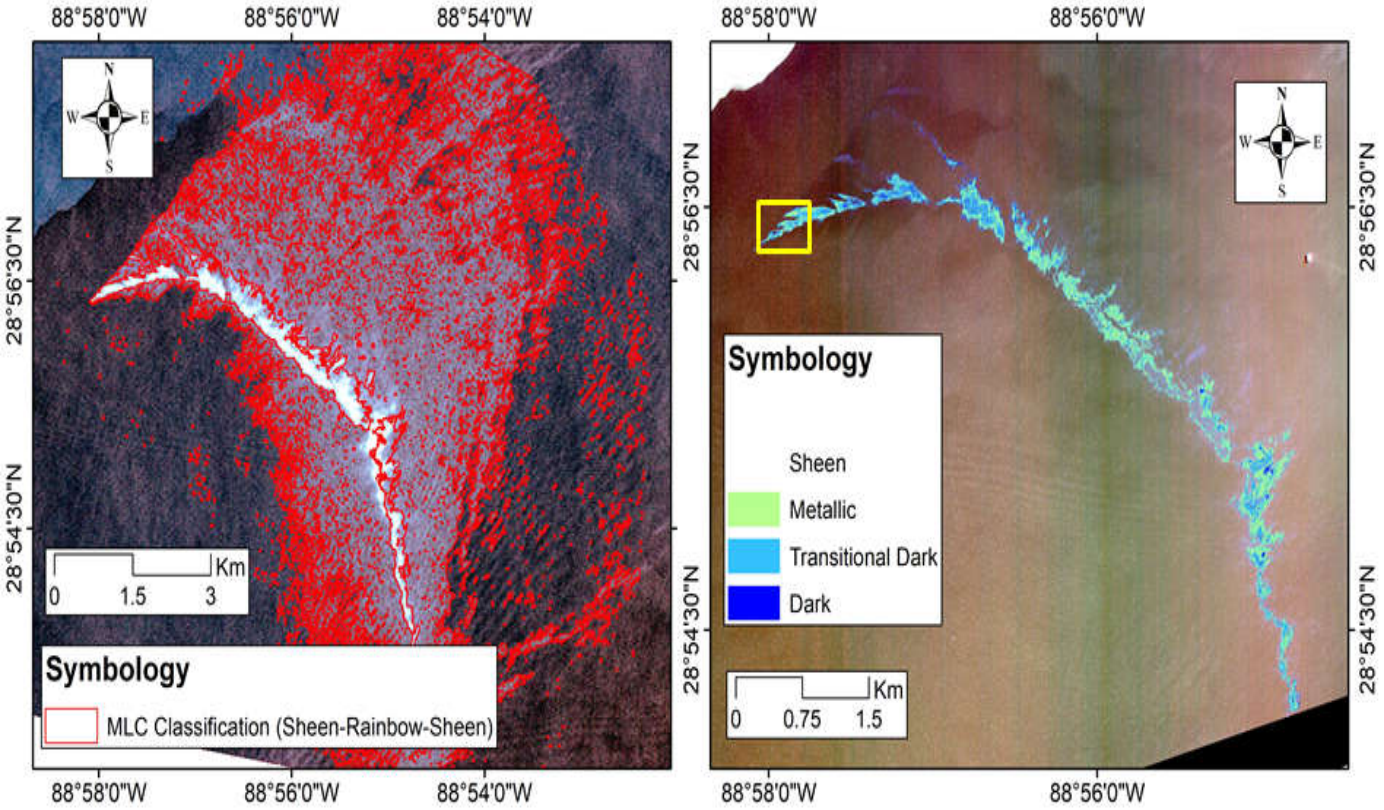
Polarimetric Analysis
Entropy

- The Cloude-Pottier entropy (H) ($0 \leq H \leq 1$) provides a measure of the amount of mixing between radar scattering mechanisms.

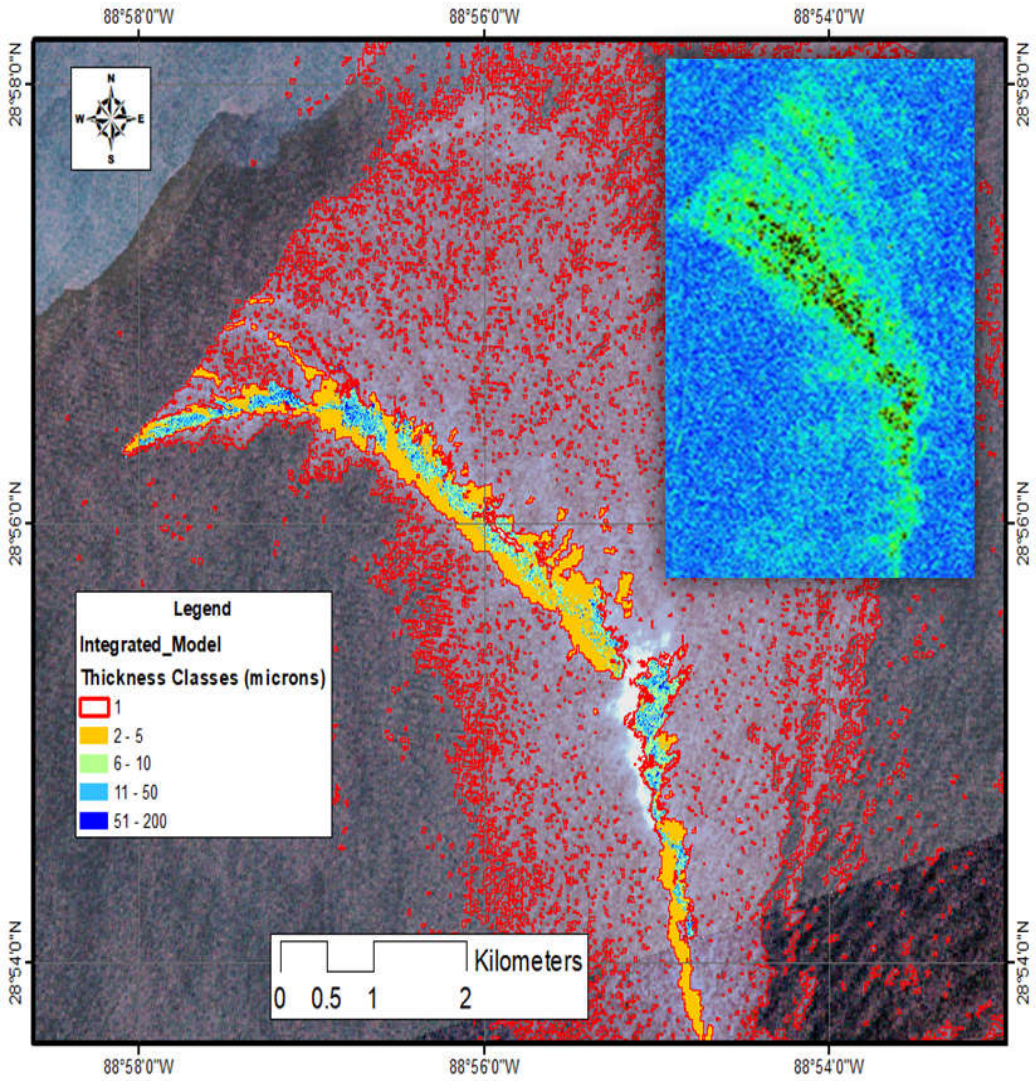
- Entropy:
  - H → 0 for oil-free water
  - H → 1 when oil is present

- Previous work has suggested the following[1]:
  - H for oil-free water < sheen < emulsion

1. Staples and Brunke, Slick Discrimination using RADARSAT-2 Quad Polarized and Single Polarized Data, (2015), *Proceedings IGARSS'15, July 2015, Milano, IT.*



Maximum Likelihood Classification (MLC) of ASTER (left) and WorldView (right) images collected on April 25, 2017. ASTER was classified as one class: Sheen-Rainbow-Sheens, and WorldView-2 was classified as 3 classes: Metallic, Transitional Dark, and Dark. In situ samples of the oil were taken in the area outlined by the yellow box at the time of the WorldView and were used for classification.



- By combining the classes obtained by ASTER (sheen) and WorldView-2 (Metallic, Transitional Dark, and Dark), an integrated output was generated.
- The inset shows the RADARSAT-2 entropy image: blue (slick free); light green (sheen – thin oil), and black areas (emulsion – thicker oil),
- The areas of high entropy (black) agree with the areas of thicker oil in the integrated output.

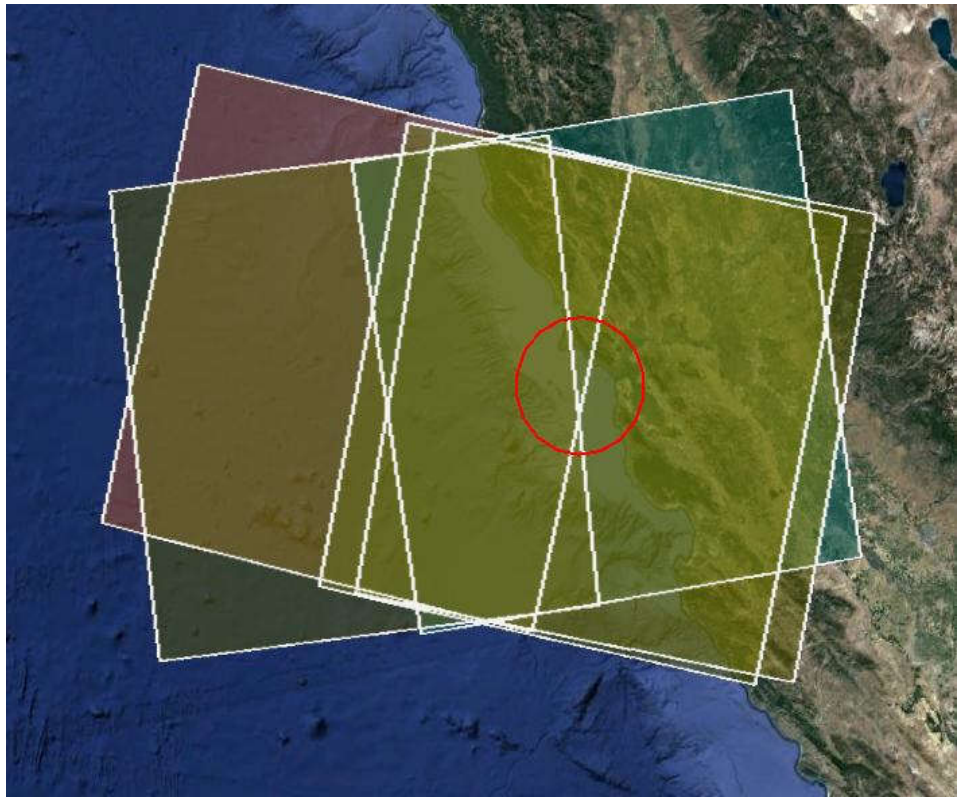
RADARSAT Constellation Mission

- The RADARSAT Constellation Mission (RCM) is the next generation of Canadian SAR satellites that has a strong focus on maritime surveillance

- A constellation of three RADARSAT-2 like SAR satellites scheduled for a mid 2019 launch → three at once, so all or nothing!

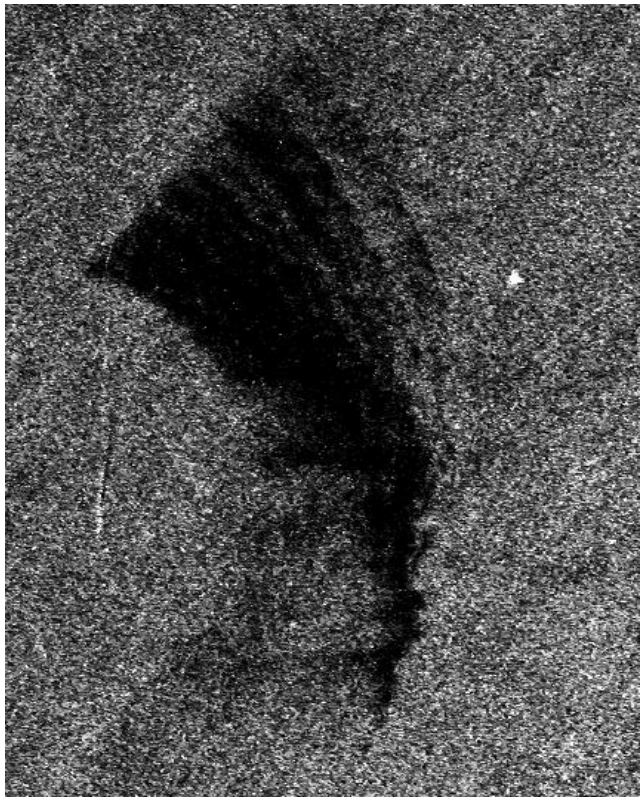
- Benefits for oil spill detection and monitoring:
  - Compact polarimetry modes that provide increased polarimetric information with-respect-to dual polarized modes, but without a reduction in swath width;
  - Daily imaging at the equator and more frequent imaging with increasing latitude, so better than every 2-3 days for RADARSAT-2 at mid-latitudes.

Example of RADARSAT Constellation Mission Coverage



- March 1 02:18 UTC
- March 1 14:26 UTC
- March 2 14:10 UTC
- March 3 02:06 UTC
- March 3 14:12 UTC

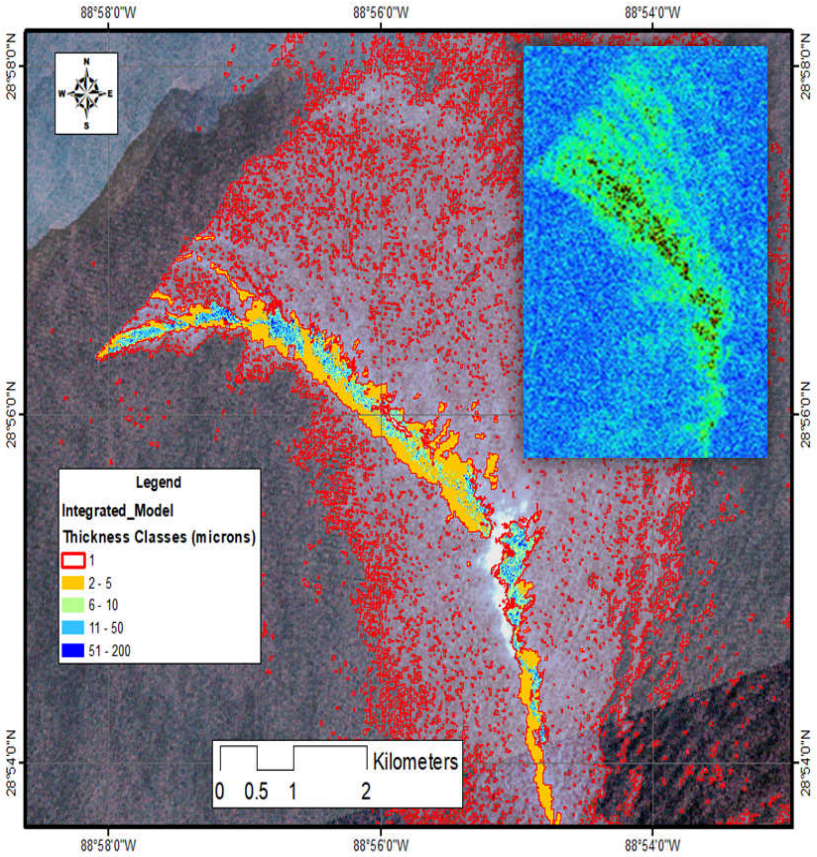
SC50 mode: 50 m resolution, 350 km x 350 km scene size

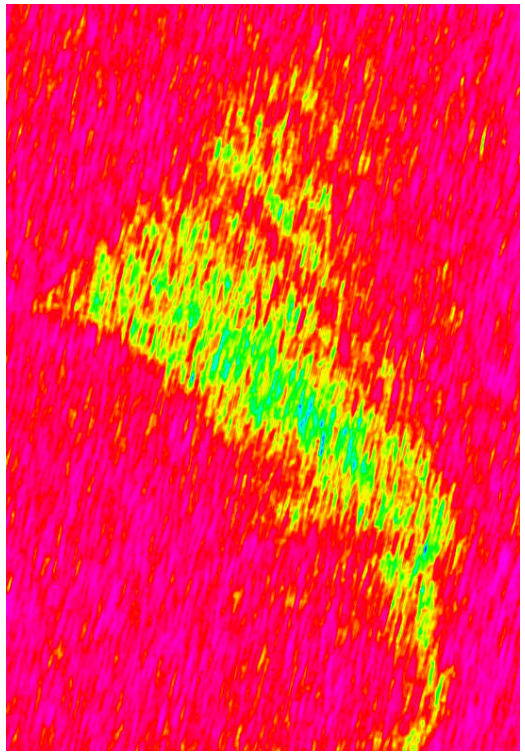


RADARSAT-2 HH

SC50 RH

- RADARSAT-2 HH image from April 25/17 quad polarized image (10 m resolution, 25 km x 25 km scene size) and simulation of the 50 m resolution, 350 km x 350 km scene size RCM SC50 mode.
- Image size ~ 10 km x 10 km





- SC50 simulation showing entropy. The light-green areas qualitatively correlate with the black areas in the RADARSAT-2 entropy image

Summary

- The capabilities and limitations of spaceborne radar to detect oil slicks are well understood
- MDA has invested significant effort not only in the space segment but also in the ground segment to ensure near-real time delivery of information from RADARSAT-2 to support oil spill response:
  - From data acquisition to delivery of information within hours is routine
- The discrimination of seen and oil emulsion (or actionable versus non-actionable oil) using RADARSAT-2 quad polarized data appears to be a viable application
- RADARSAT Constellation Mission:
  - Initial results suggest that for sheen – emulsion discrimination, the RCM compact polarimetry modes will provide similar information (but not quite as good) as the RADARSAT-2 quad polarized modes
  - Further validation work is planned after the RCM launch

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