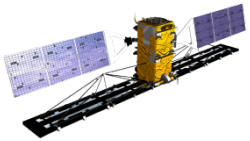


Characterization of Oil Slicks using RADARSAT-2 Quad-Polarized Data

Gordon Staples

MDA

Richmond, BC, Canada

Outline

- Introduction
- RADARSAT-2 quad-polarized mode
- Data and Methodology
- Results
- Summary and Operational Implementation

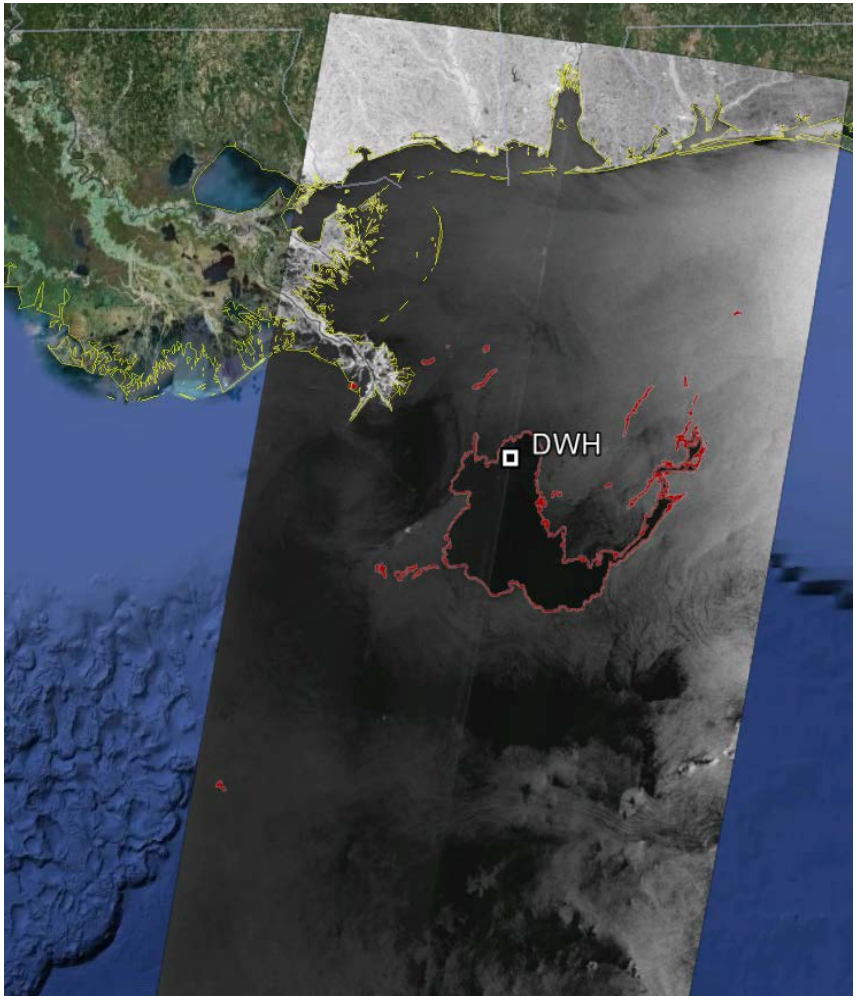
Slick Detection

- There is a good understanding of the underlying physics associated with the detection of ocean-surface slicks using SAR
- The presence of slicks attenuates the Bragg-scale waves resulting in reduced radar backscatter that appear dark in the radar image
- But slick false-positives due to low wind, biogenic films (e.g. algae), river inflow often occur

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

Slick Characteristics

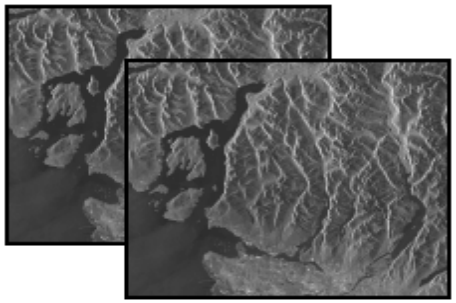
- Spaceborne radar has been used to monitor most of the major oil spills that have occurred using single or dual polarized data
- In general, VV polarization provides better oil-water discrimination that HH polarization
- False-positives notwithstanding, the radar data provides a good representation of the spatial extent of an oil spill, but there is usually limited information about inter-slick variability i.e. sheen vs. emulsion



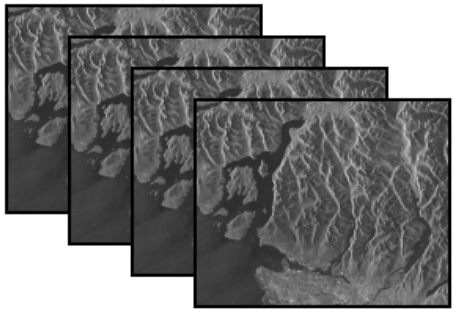
RADARSAT-2 image July 14, 2010

RADARSAT-2 Quad-Polarized Imaging Mode

- Most spaceborne radars Tx/Rx a single channel (amplitude) of data (e.g. HH or VV) or Tx/Rx two channels of data (e.g. HH+HV)
- Note that HH, VV, HV refers to the Tx/Rx orientation of the radar wave
- The concept of quad-polarized is to Tx/Rx four channels (amplitude) of data (HH+HV+VH+VV) in a phase-preserving format
- The quad-pol amplitude and the phase data allow a complete characterization of the target



HH+HV



HH+HV+VH+VV

Oil Slick Characterization using Quad-Polarized Data

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

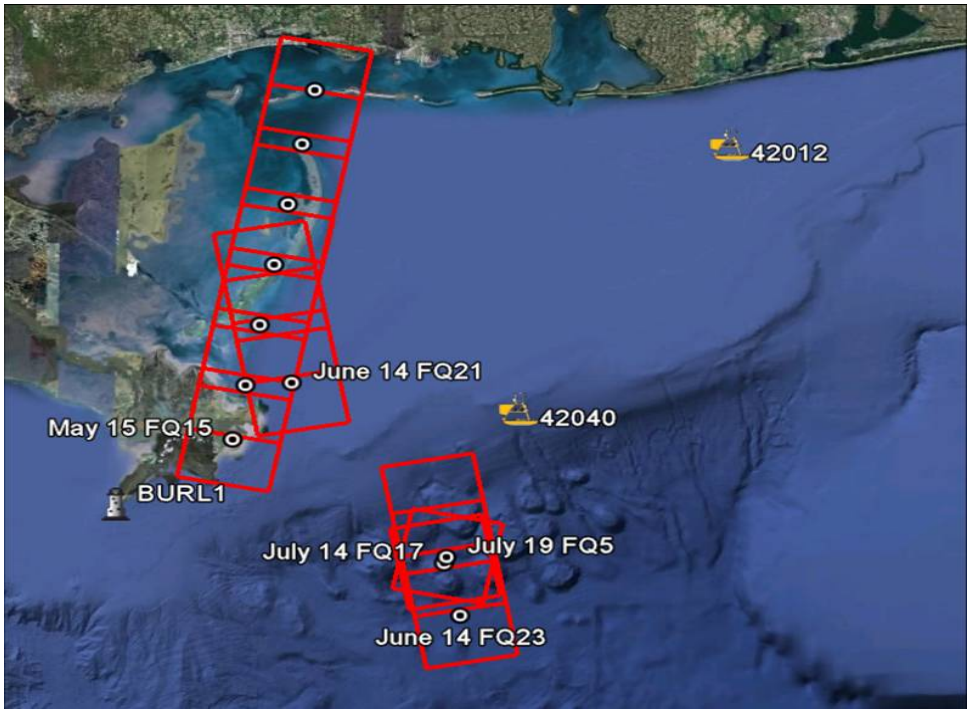
- For a wind-roughened ocean surface, the scattering is dominated by a single dominant scattering mechanisms, namely Bragg scattering (H → 0). In the presence of an oil slick, however, the entropy increases (H → 1) which is due to the number independent scattering mechanisms increasing due to damping of the small-scale Bragg waves.

- In the region between imaging slick-free water and an oil slick, the entropy varied as a function of the properties of the oil (e.g. sheen, emulsion).

Cloude, S.R. and Pottier, E., 1996. A Review of Target Decomposition Theorems in Radar Polarimetry, *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 34, No. 2, pp 498-518.

Acquisition of Quad-Polarized Data

- During the Deep Water Horizon (DWH) spill, RADARSAT ScanSAR Narrow imagery was acquired almost daily and was the default imaging mode.
- To test the idea of using the entropy for slick characterization, RADARSAT-2 quad-polarized data was acquired over the DWH spill-site and along the coast.



Oil Slick Aerial Observations

July 14 Oil Spill Situation Map showing aerial observations.

Overflight Observations → **Flight Path**

1 - Silver Sheen	9 - Convergence Zone	17 - Windrows of Sheen
2 - Transparent Sheen	10 - Gas Leak	18 - Sheen off Wellhead
3 - Orange Pancakes or Streamers	11 - Dull Sheen	19 - Oil on Shoreline
4 - Brown Oil	12 - Red-Orange Emulsion	20 - Oil Pooling
5 - Spill Source Edge	13- Narrow Bands of Sheen	21 - Intermittent Sheen
6 - Tarballs	14 - Light Sheen	22 - Orange Mousse
7 - Surface Suppression	15 - Algae	23 - Brown Mousse
8 - Convergence Line	16 - Rainbow Sheen	24 - Sargassum
		25 - Surface Suppression

Source: Clearwater Overflight from 1000-1450 7/13/10
Mobile Overflight from 0845-1430 7/13/10
Venice Overflight from 0810-1035 7/13/10
Venice Overflight from 1435-1630 7/13/10

http://gomex.erma.noaa.gov

MDA

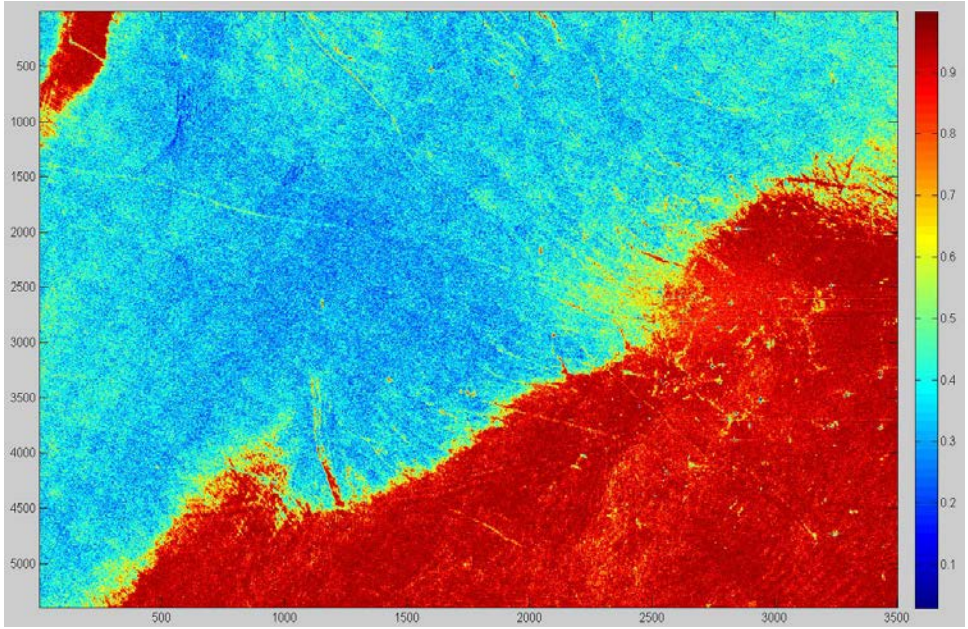
Aerial Observations and Quad-Polarized Data Acquisition

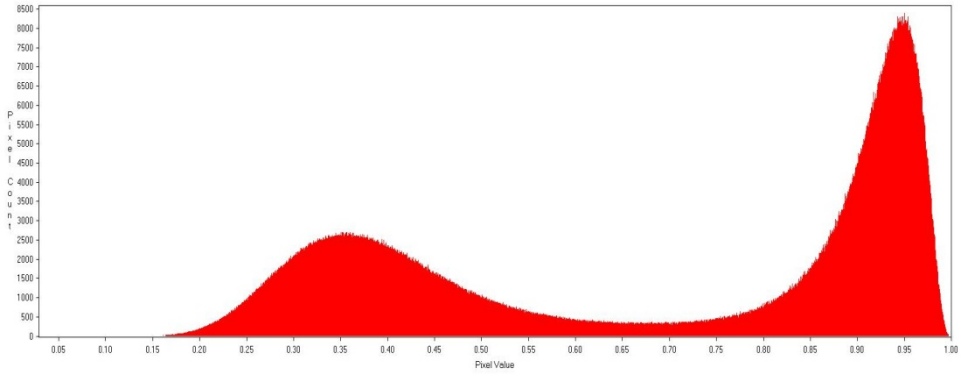
Quad-Pol Date	Quad-Pol Time (UTC)	Overflight Date	Overflight Times (UTC)
May 15	11:55	May 14	14:00 to 23:00
June 14	00:02	June 13	14:00 to 21:00
July 14	23:57	July 14	13:00 to 21:00
July 19	12:00	July 19	13:00 to 20:00

Other than May 15, the time difference between the aerial observations and the acquisition of the quad-polarized image was at most twelve hours.

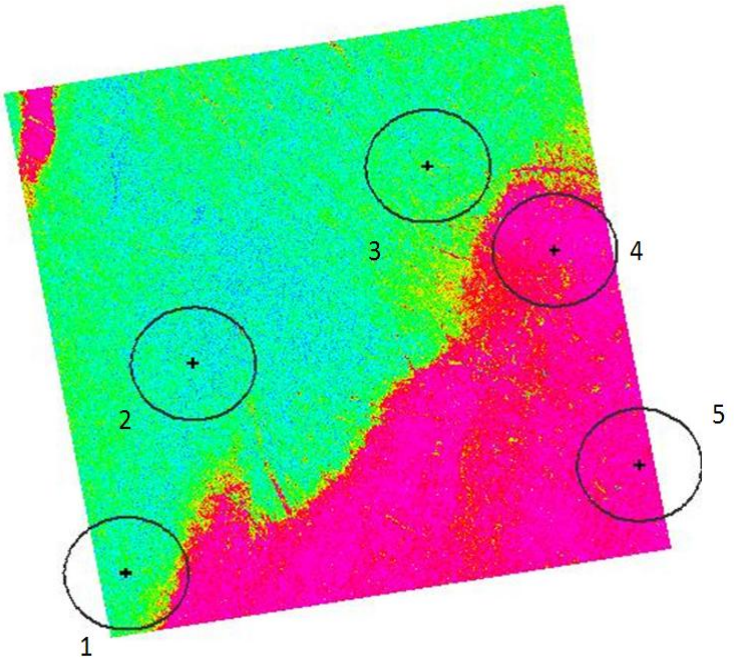
July 14: Oil and Water Entropy

- July 14 entropy (top) and histogram (bottom)
- The histogram has a bimodal distribution, which given the incidence angle (37 º nominal) and the wind speed (~ 3.5 m/s) indicates the presence of oil (high entropy) and regions of no oil or thin oil (low entropy).





Aerial Observations

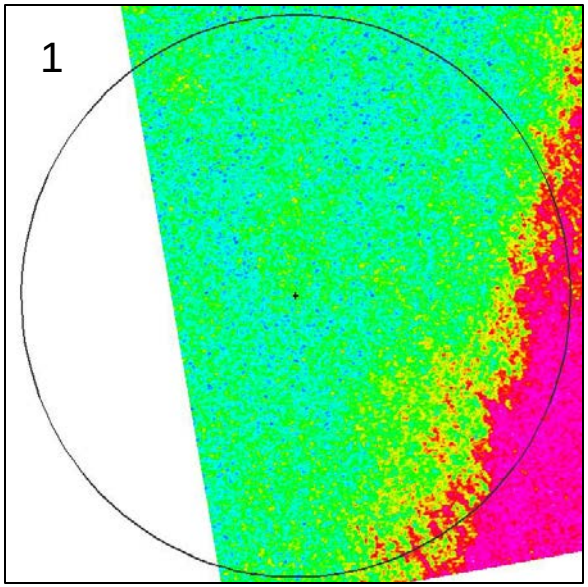


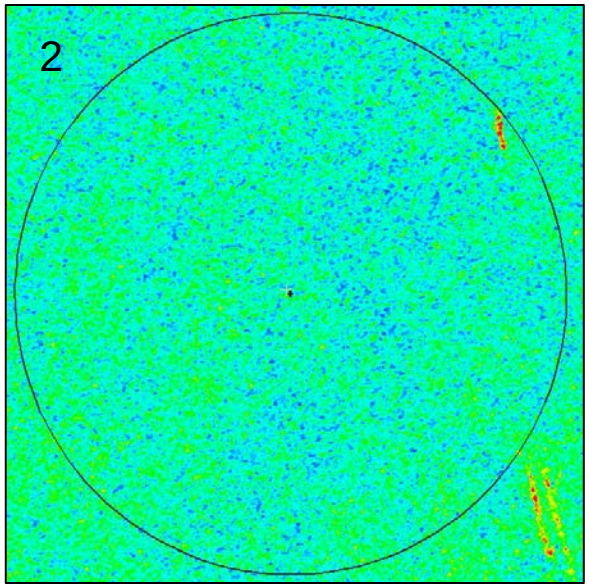
Location	Oil Type Observed
1 and 2	Silver Sheen
3	Silver Sheen, Red-Orange Emulsion
4 and 5	Silver Sheen, Brown Oil, Red-Orange Emulsion

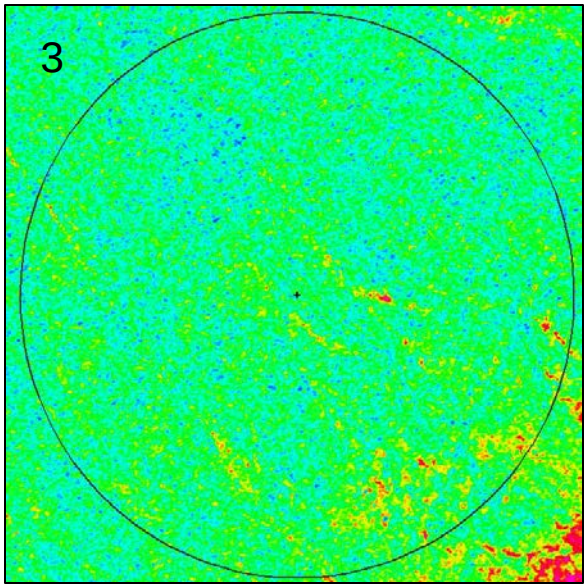
Entropy image overlaid with observations of oil type (left) and the type of oil observed. The circles are a 3 km buffer zone to compensate for the time difference between acquisition of the quad-polarized data and the overflights.

Note that low entropy corresponds to blue, medium to green-yellow, and high to magenta

Locations 1-3

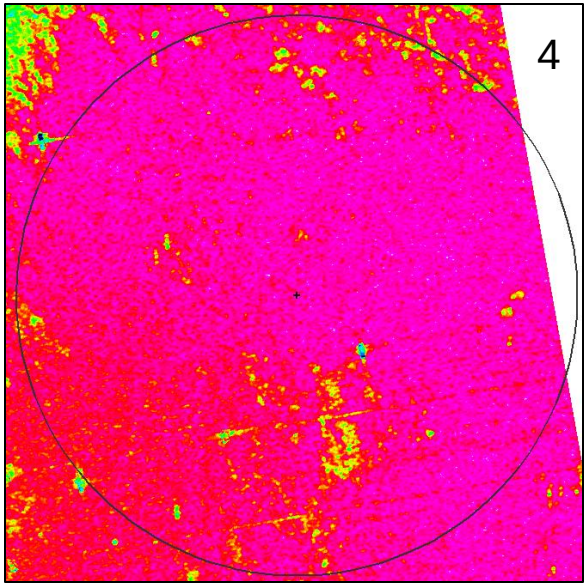


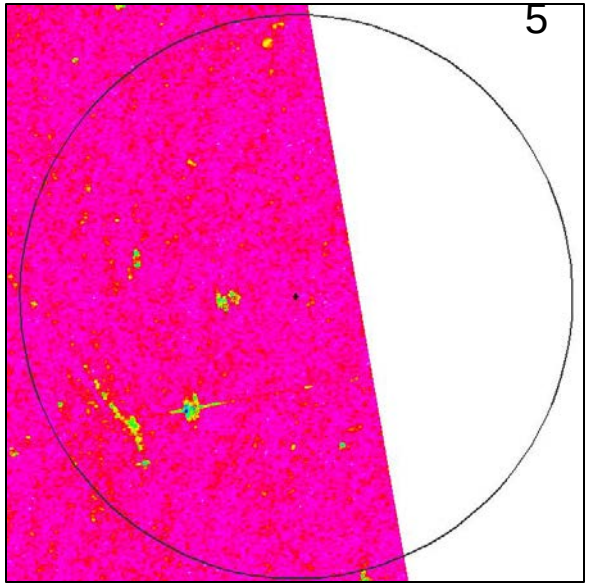




- Locations 1 and 2 had silver sheen (thin oil), so the presence of the sheen increases in the entropy.
- Location 3 had silver sheen and red-orange emulsion.
- In general the emulsion is thicker than the silver sheen so the increased thickness increased ocean-surface damping and hence increase the entropy.

Locations 4-5





- Locations 4 and 5 were in the main part of the oil slick, so an entropy increase was expected. However, the variation of the observed oil type for each location suggests that the variability of the entropy was in response to the variability of oil properties.

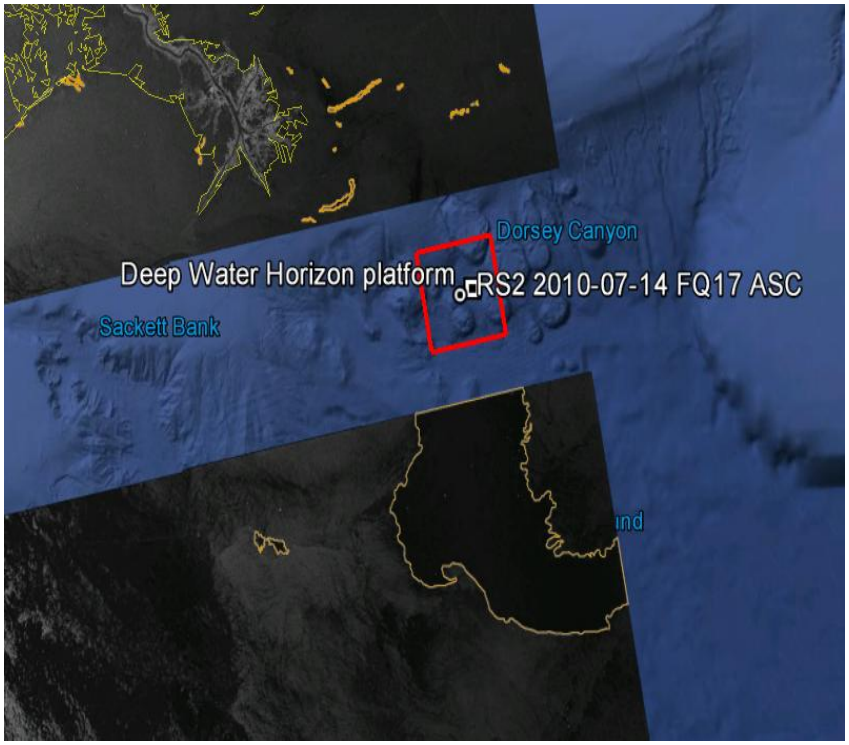
Summary

- The Cloude-Pottier decomposition was used to extract polarimetric information from five RADARSAT-2 quad-polarized images acquired over the DWH oil spill in the Gulf of Mexico.

- Comparison of entropy with aerial observations indicated that the variability of the entropy was consistent with the variability of the oil properties suggesting that the entropy was providing a qualitative measure of the oil characteristics. Specifically, when there was open water and a thin sheen, the entropy was close to 0, but in the presence thicker oil (e.g. emulsion) the entropy had values that were close to 1.

- The aerial observations provided point-source observations of the spill characteristics, so to further validate the approach, it would be beneficial to compare the entropy with oil slick thickness maps derived from other data sources (e.g. airborne) that coincide with the quad-polarized data.

Operational Implementation
Balancing Information and Spatial Coverage



Example of July 14 quad-polarized acquisition that was acquired between ScanSAR Narrow acquisitions

- RADARSAT ScanSAR Narrow provides 300 km swath widths with amplitude-data only.
- RADARSAT-2 quad-pol have up to 50 km swath width with amplitude and phase data.
- By switching bean modes, low priority areas can be imaged with ScanSAR, and high priority areas (e.g. adjacent to sensitive coastal regions) can be imaged with quad-pol.

Acknowledgement

Funding provided by the Canadian Space Agency's Earth Observation Application Development Program (EOADP)

http://www.asc-csa.gc.ca/eng/programs/eoadp/default.asp