RADARSAT-2 Modes and Applications

Gordon Staples
MDA Geospatial Services

February 6, 2017
Introduction

- RADARSAT-2 was developed to meet operational needs via a versatile space segment and a responsive ground segment.

- Multiple beam modes provide a balance between wide-area imaging at reduced resolution or area-specific, high-resolution imaging.

- RADARSAT-2 data have been used world-wide to support near-real time applications such as flood mapping and oil spill monitoring.

- The objectives of this presentation are to:
  - Outline RADARSAT-2 beam modes
  - Discuss RADARSAT-2 capability for key land and maritime applications
  - Provide an overview of matching user requirements to RADARSAT-2 capability
Radar Remote Sensing
Benefits

- Radar provides its own source of illumination, so one of the key benefits of radar is all-weather, day-night imaging.

- Cloud cover can be a significant issue for applications that are time-dependent:
  - Emergencies: flooding, oil spills, humanitarian relief → data acquisition on a regular basis;
  - Time-sensitive: agriculture, shoreline mapping, map updating → data acquisition at a specific time (e.g. crop growth stage, high/low tide) or data before a specified date (e.g. map updating);
  - Surveillance: maritime surveillance (e.g. ships, bilge dumping, security (port monitoring), land-based illegal activities (e.g. logging, drug operations) → data acquisition on an on-going basis.
RADARSAT-2 Imaging Modes

All RADARSAT-2 beam modes available in right-looking (shown) or left-looking (not shown)
RADARSAT-2 Beam Mode Coverage

- **ScanSAR Wide**
  - 500 km x 500 km
  - 100 m res

- **ScanSAR Narrow**
  - 300 km x 300 km
  - 50 m res

- **Wide**
  - 140 km x 140 km
  - 30 m res

- **Standard**
  - 100 km x 100 km
  - 25 m res

- **Fine/ML**
  - 50 km x 50 km
  - 10 m res

- **ExtraFine**
  - 125 km x 125 km
  - 5 m res

- **Quad Fine**
  - 25 km x 25 km
  - 10 m

- **SpotLight**
  - 10 km x 20 km
  - .8m x 2.2 m res

(Nominal values)
Land Applications

- Forestry
- Rice Crop Monitoring
- Illicit Crop Detection
- Mapping
  - DEM
  - Change Detection
- Disaster Management
Forestry

- Cutblock detection
  - forest harvesting
- Forest regrowth mapping
- Disturbance detection
  - Partial harvesting
- Fire scar mapping

Example of forest change report using an MDA-developed forest-change algorithm
Cutblock Example

Before harvest

After harvest
South Sumatra Forest Fires Map, 2015

Legend
- Green: Forest South Sumatra
- Red: Burn Area
- Blue: District Boundary
- Line: IUPHHK-HT/RE/HA/HD di Sumatera

(Sumber: Citra Sateki Landsat8 path/row 123-126/80-63 November 2015, dilakukan dan dibuat oleh Tim GIS, Hutan Kita Institute/Hasil- Sumatera)
Example of RADARSAT-2 imagery that was acquired to detect and map fire scars. The colours correspond to different images acquired between June and November 2015.

The areas of changes (right) correlate with fire locations (top).

Green (June 22-Aug 9), Yellow (Aug 9 – Sept 26), Red (Sept 26 – Oct 20), and Black (Oct 20 – Nov 13).
Rice Crop Monitoring

- Rice crop parameters of interest include:
  - Rice crop area
  - Planted versus non-planted rice paddies
  - Yield
  - Heath

- Rice yield and health are in the R&D phase. Optical is required to obtain early assessment of crop health.

- If the crop type is known, then monitoring crop growth can be done with single polarized data (HH polarized data for rice crops)

- If crop classification is required, then dual polarized (VV+VH) or quad polarized data are required. Radar+optical will improve classification performance.
Radar data can be used to classify rice crops based on how the radar backscatter changes from planting (low backscatter), through growth (high backscatter), and harvest (reduced backscatter). Example based on RADARSAT-2 quad-polarized data.
Illicit Crop Detection

- Detection of illicit crops is essentially crop classification, but it is more challenging than legal crops because:
  - Classification requires training data which requires access to illicit crops
  - Illicit crops are commonly intercropped

- SAR + optical can be integrated

Coca plants interspersed with plantain cultivation
Mapping

- DEM
- Change Detection
- Feature Extraction/Map Updating
DEM Image Acquisition

Acquire two images at different incidence angles and exploit parallax to produce height. For rugged terrain, ascending and descending may be required.
Digital Elevation Models Accuracy

- RADARSAT-2 Ultra Fine DEM
  - 6 m post spacing
  - Typical vertical accuracy (LE90) of 8 m or better: 0% to 40% slope, median over large area, with GCPs
  - Typical horizontal accuracy (CE90) of 6 m or better

- RADARSAT-2 Multi-Look Fine DEM
  - 10 m post spacing
  - Typical vertical accuracy (LE90 10 m) or better: 0% to 40% slope, median over large area, measured against SRTM-3
  - Typical horizontal accuracy (CE90) of 6 m or better
Subsidence Monitoring Using InSAR

Subsidence measurements using Ultra-Fine data
Subsidence Time Series

Subsidence of ~ 2 cm in one year
Acquire Baseline Image

Urban Change Example
Baseline + Changes
Disaster Management

- Flood mapping
- Land slide detection
RADARSAT-2 Modes for Disasters

Maritime: oil spills

Terrestrial: floods, storm damage, land slides
RADARSAT-2 Ground Segment

- **Programming**
  - 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
Rapid Beam Mode-Switching to Track Hurricane Matthew

Oct 7/16 ~ 7 AM local time

Oct 7/16 ~ 7 PM local time
FLOOD WATCH PRODUCT - RADARSAT-2

Derived from new collection (2011-10-02 23:16 UTC, Wide 1 W1 beam, HH)
relative to archive collection (2011-08-15 23:18 UTC, Wide 1 W1 beam, HH)
FLOOD WATCH PRODUCT - RADARSAT-2

Derived from new collection (2011-10-02 23:16 UTC, Wide 1 W1 beam, HH)
relative to archive collection (2011-08-15 23:18 UTC, Wide 1 W1 beam, HH)
FLOOD WATCH PRODUCT - RADARSAT-2

Derived from new collection (2011-10-02 23:16 UTC, Wide 1 W1 beam, HH)
relative to archive collection (2011-08-15 23:18 UTC, Wide 1 W1 beam, HH)
SAR Detection of Landslide event
Image 1 of 3
SAR Detection of Landslide event
Image 2 of 3
SAR Detection of Landslide event
Image 3 of 3: Change detection
Maritime Applications

- Ship Detection
- Oil Slick Detection
- Coastal Zone Management
# Ship Detection

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Performance Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ship Characteristics</strong></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>Detection improves with increasing ship length</td>
</tr>
<tr>
<td>Material</td>
<td>Detection improves with metal vs wood vs fiberglass</td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td></td>
</tr>
<tr>
<td>Wind speed</td>
<td>Detection degrades with increasing wind speed</td>
</tr>
<tr>
<td><strong>Radar</strong></td>
<td></td>
</tr>
<tr>
<td>Resolution</td>
<td>Higher resolution improves detection and introduces the possibility of ship classification</td>
</tr>
<tr>
<td>Polarization</td>
<td>Detection optimized using cross-pol (HV) in the near range and co-pol (HH) in the far range. HV improves detection for high wind speeds.</td>
</tr>
<tr>
<td>Incidence angle</td>
<td>Detection improves with increasing incidence angle</td>
</tr>
</tbody>
</table>
Wide Swath Mode: ScanSAR Narrow

RADARSAT-2 ScanSAR Narrow
300 km x 300 km scene size
50 m nominal resolution

Typical ship in English Bay anchorage
L=191 m; Breadth=32 m; Depth = 22 m

50 m resolution (HH)
Narrow Swath: UltraFine

RADARSAT-2 UltraFine mode
20 km x 20 km scene size
3 m nominal resolution

Full resolution scenes showing a ship the harbour (left) and harbour infrastructure (top)
Slick Detection

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

- Semi-automatic approaches give effective results

- Skilled analysts improve information:
  - Mitigate false positives
  - Apply contextual information (platforms, ships, etc.)
  - Assign confidence / classification levels

RADARSAT-2 image showing oil from offshore drilling platform. The oil appears as a dark tone, and the offshore platforms appear as bright white targets.
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 Seep Detection
Coastal Zone Management

- Coastline mapping
- Intertidal zone mapping
- Coastal changes
- Feature mapping
- Shallow water bathymetry

Thousand Islands, Indonesia
Comparison of VV and HV polarization showing ocean-surface waves. In the offshore area, the wave crests are visible in the VV image, but not the VH. At the shoreline, the waves break and are visible in both the VV and VH images.
Coastal Structures Change Detection

GoogleEarth™
RADARSAT-2 Imagery for Intertidal Mapping

Fraser River estuary imagery acquired at high tide (top) on April 7, 2016, and low tide (bottom) on May 28, 2016.
Delineation of the Intertidal Zone

Water

Intertidal

Land
Evaluation of SAR Requirements

- Assessment of information needs:
  - What is the need, e.g. rice crops, flooding, forest change, maritime sovereignty?
  - How large is the area, e.g. 10s of sq km - 1000s of sq km?
  - How often is the information needed, e.g. daily-weekly-monthly?

- Information needs and radar parameters:
  - Beam mode → resolution and spatial coverage
  - Polarization
  - Incidence angle

- Radar data to information products:
  - Interpretable
  - Interoperable
  - Timely
Selection of Radar Parameters
Rice Paddy Monitoring

- Re-visit
  - Re-visit 3 – 4 times during the cropping cycle can be achieved using the same incidence angle and beam mode
  - Increased re-visit with variable incidence angle, but this will impact crop information.

- Spatial Coverage and Resolution
  - Depends on field size and spatial coverage needed
  - High resolution → individual fields
  - Low resolutions → multiple fields

- Polarization
  - HH polarization for paddy monitoring

- Recommended RADARSAT-2 mode:
  - ExtraFine (XF): 5 m res, 125 km swath width
Selection of Radar Parameters
Marine Surveillance

- Re-Visit
  - Re-visit every 2-3 days will usually meet sovereignty, fisheries, and pollution requirements
  - Variable incidence angles can be used without significant impact to the ship/pollution information

- Spatial Coverage/Resolution
  - High resolution – detection/classification for well-defined areas
  - Low resolution – detection for wide-area coverage

- Polarization
  - Single polarization for ship detection mode
  - Dual-polarized for marine surveillance mode

- Recommended RADARSAT-2 Modes:
  - Ship detection (DVWF): 20 m vessel detection, 450 km swath width
  - Ocean surveillance (OSVN): 35 m vessels + oil slicks, 500 km swath width
Mode selection depends on user needs:
- Spatial coverage
- Resolution
- Polarization
- Re-visit

Maritime Surveillance
- Detect/monitor
- Wide area coverage
- Single/dual pol

Terrestrial/Maritime Surveillance
- Detect/monitor and (classify terrestrial)
- Medium resolution, adaptable coverage
- Dual/Quad pol

Terrestrial/Maritime Surveillance
- Detect/monitor and (classify ships)
- High resolution, adaptable coverage
- Single pol
Way Forward

- Assessment of information needs:
  - What is the need?
  - How large is the area?
  - How often is the information needed?

- Information needs and radar parameters:
  - Beam mode → resolution and spatial coverage
  - Polarization
  - Incidence angle

- Radar data to information products:
  - Interpretable
  - Interoperable
  - Timely
RESTRICTION ON USE, PUBLICATION OR DISCLOSURE OF PROPRIETARY INFORMATION AND IMAGES

This document contains information and images that are proprietary to MacDonald, Dettwiler and Associates Ltd. ("MDA"), to its subsidiaries, and/or to third parties to which MDA may have legal obligations to protect such information or images from unauthorized disclosure, use or duplication. Any disclosure, use or duplication of this document or of any of the information or images contained herein is expressly prohibited. The statements contained herein are based on good faith assumptions and provided for general information purposes only. These statements do not constitute an offer, promise, warranty or guarantee of performance. The products depicted are subject to change, and are not necessarily production representative. Actual results may vary depending on certain events or conditions. This document should not be used or relied upon for any purpose other than that intended by MDA.

COPYRIGHT © 2017 MacDonald, Dettwiler and Associates Ltd., subject to General Acknowledgements for the third parties whose images have been used in permissible forms. All rights reserved.

RADARSAT-2 Data and Products © MacDonald, Dettwiler and Associates Ltd (2012-2014). All Rights Reserved. RADARSAT is an official mark of the Canadian Space Agency.