RADARSAT-2 Imaging Modes and Applications

presented by Gordon Staples
Interactions During the Event

• Please ask lots of questions
  – We’ll answer both during the event and at the end

• To ask a question, type it in the “Q&A” tab
  – Webinar control panel (top right)
  – Chat panel in the same location for general event questions

• Watch for poll questions throughout the event
Today’s Panelists

Gordon Staples
Senior Analyst/Manager, Maritime Services

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Product Manager
MDA Geospatial Services
Agenda

• Introduction
• RADARSAT-2 Imaging Mode Review
• Application Overview and Recommendations
  – Terrestrial
  – Maritime
Introduction

• RADARSAT-2 imaging modes were selected to meet a range of requirements
  – Operational applications and research
• At launch, the imaging modes provided a balance between spatial coverage, resolution, and noise floor
• Enhancements have been made to the pre-launch modes
  – Wide-swath modes provide increased spatial coverage without loss of resolution
  – High resolution Spotlight mode;
  – Noise-subtracted ScanSAR developed to aid visual interpretation of cross-pol
Introduction

Webinar objectives:
• Outline the enhancements to RADARSAT-2 modes
• Provide recommendations for land and maritime applications
  – Beam modes, polarization, and incidence angles
All RADARSAT-2 beam modes available in right-looking (shown) or left-looking (not shown).
RADARSAT-2 Single Beam Modes

- Standard
- Fine Resolution
- Multi-Look Fine
- Ultra-Fine Resolution
- Fine Quad. Pol.
- Standard Quad. Pol.
- Extended Low

- Extended High
- Wide Swath
- Wide Fine Resolution
- Wide Multi-Look Fine
- Wide Ultra-Fine Resolution
- Wide Fine Quad. Pol.
- Wide Standard Quad. Pol.

Beams:
- E1
- S1
- W1
- F23
- FO
- MF23
- U'
- SQ'
- EL1

- E2
- S2
- W2
- F22
- FO
- MF22
- U'
- SQ'

- E3
- S3
- W3
- F21
- FO
- MF21
- U'

- E4
- S4
- F1
- MF1
- MF1W

- E5
- S5
- F2
- MF2
- MF2W

- E6
- S6
- F3
- MF3
- MF3W

- E7
- S7
- F4
- MF4
- MF4W

- E8
- S8
- F5
- MF5
- MF5W

- E9
- S9
- F6
- MF6
- MF6W
ScanSAR

- 2, 3 or 4 single beams covering adjoining swaths are used in combination
- Data are collected from a wider swath than is possible with a single beam
- A noise-subtracted ScanSAR mode is available
  - Reduces the appearance of image artifacts
Spotlight

- The radar operates with the highest sampling rate
- Ground swath coverage limited to keep data rate within recorder limits
- Images are of fixed size in the along-track direction
Achieving Wide Swath Modes – NESZ

• Radar imaging-mode performance is constrained by three main parameters
  – Resolution
  – Swath width
  – Noise Equivalent Sigma Zero (NESZ)

• NESZ is a measure of the sensitivity of a given SAR
  – Indicates the minimum signal that a SAR can measure

• For example
  – ↑ resolution = ↓ swath width for constant NESZ
  – ↑ swath width = ↑ NESZ for constant resolution
Achieving Wide Swath Modes – BAQ

• Variability of the radar return is small as a function of time
  – To reduce data volumes, a compression is used
  – Block Adaptive Quantization (BAQ)

• RADARSAT-2 generally uses 3-bit BAQ
  – Some of the wide swath modes use 2-bit BAQ
  – Achieves wide swaths, while maintaining constant resolution

• Impact of 2-bit BAQ
  – Generally not noticeable
  – When there is large change in the radar return with time 2-bit BAQ does not provide enough dynamic range to capture the difference
    • Results in increased noise (e.g. ship-water interface)
Examples of Wide Swath Modes – Extra-Fine

**Improvement**

- 1-look product with nominal 5 m resolution
  - Swath widths of ~ 108 to 160 km
- 4-look product with nominal resolution 10 m rg. x 8 m az.
  - Reduced speckle
  - Improved image quality with respect to 1-look
- 28-look product with nominal resolution of 22 m
  - Reduced speckle with respect to 4-looks

**Image Quality Impact**

- BAQ reduced to 2-bit
- Increases the noise level in darker areas that are close to bright features

**Application Impact**

- Large data volume can exceed 4 GB limit of TIFF
  - Requires the BIGTIFF format
Extra-Fine Examples

1-look
~ 5 m resolution

4-looks
~ 10 resolution

28-looks
~ 25 m resolution
Examples of Wide Swath Modes – Wide Ultra-Fine

Improvement
– Swath increase to 38-54 km (depends on beam) from 20 km

Image Quality Impact
– Noise floor rises towards the edges of the swath
– BAQ reduced to 2-bit from 3-bit
  • Increases the noise level in darker areas that are close to bright features

Application Impact
– For interferometric applications, 2-bit BAQ may increase the phase noise in SLC products
– Increased noise in areas with strong return adjacent to low return areas
  • e.g. water-land, ship-water, aircraft-runway
The impact of the increased noise floor at the beam edges is most pronounced in the HV image due to inherently low HV backscatter from smooth surfaces.
Applications, Imaging Modes, and Recommendations

• Terrestrial
  – Mapping
  – DEM
  – InSAR
  – Flooding
  – Crop Monitoring
  – Forestry

• Maritime
  – Ice Mapping
  – Oil Slick Detection
  – Ship Detection
## Selected Mapping Recommendations

<table>
<thead>
<tr>
<th>Acquisition Modes</th>
<th>Polarization</th>
<th>Incidence Angle</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Detection and Recognition of Infrastructure (e.g. road, rail)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wide, Ultra-Fine*, or Spotlight depending on feature size</td>
<td>Single</td>
<td>25° - 40°</td>
<td>• Ascending and descending may be required, depending on terrain</td>
</tr>
<tr>
<td><strong>Topographic Mapping (e.g. wood, grassland, land cover)</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Fine*, Multi-Look Fine*, Extra-Fine, Ultra-Fine*, or Spotlight depending on feature size and spatial coverage</td>
<td>Dual-Pol (VV+VH)</td>
<td>25° - 40°</td>
<td>• Scale 1:25 000 to 1:50 000 for Ultra-Fine or Wide Ultra-Fine</td>
</tr>
<tr>
<td></td>
<td>Quad Pol</td>
<td></td>
<td>• Ascending and descending may be required, depending on terrain</td>
</tr>
<tr>
<td><strong>Mapping of Urban Areas</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Multi-Look Fine*, Extra-Fine, Ultra-Fine*, or Spotlight depending on feature size and spatial coverage</td>
<td>Single (HH)</td>
<td>20° - 40°</td>
<td>• Visual interpretation or semi-automated classification.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Incidence angle selection depends on type of buildings and surrounding.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Recommend ascending and descending to avoid shadows</td>
</tr>
</tbody>
</table>

* Wide swath version of this mode is also suitable.
Industrial Mapping

RADARSAT-2 SpotLight

Source: Google Earth
Image Credit ©DigitalGlobe
# DEM Recommendations

<table>
<thead>
<tr>
<th>Acquisition Modes</th>
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<th>Incidence Angle</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radargrammetry</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Fine*, Multi-Look Fine*, Ultra-Fine* depending on vertical resolution</td>
<td>Single Pol (HH)</td>
<td>30° with angular separation of ~ 15°</td>
<td>• Two stereo pairs, each pair viewing from different sides of the terrain</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• For best results, minimize temporal offset</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Lower resolution beam modes cover a larger area</td>
</tr>
</tbody>
</table>

* Wide swath version of this mode is also suitable.
Digital Elevation Models (DEM)

• 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

Colina, Chile. RADARSAT-2 Multi-Look Fine DSM
# InSAR Recommendations

<table>
<thead>
<tr>
<th>Acquisition Modes</th>
<th>Polarization</th>
<th>Incidence Angle</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Displacement or Subsidence of Infrastructure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fine*, Standard, Multi-Look</td>
<td></td>
<td></td>
<td>• Differential interferometry in area with high phase coherence</td>
</tr>
<tr>
<td>Fine*, Ultra-Fine*, Extra-Fine,</td>
<td>Single Pol (HH)</td>
<td>30° - 50°</td>
<td>• InSAR with or without artificial corner reflectors, depending on the considered AOI</td>
</tr>
<tr>
<td>Spotlight</td>
<td></td>
<td></td>
<td>• Long term observation with large number of images, especially in moderately coherent areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Result: time series of movement</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Measurements in the mm to cm per year range</td>
</tr>
</tbody>
</table>

* Wide swath version of this mode is also suitable.
Subsidence Monitoring Using InSAR

Vancouver airport subsidence using Ultra-Fine data
# Flooding Recommendations

<table>
<thead>
<tr>
<th>Acquisition Modes</th>
<th>Polarization</th>
<th>Incidence Angle</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flooding</td>
<td></td>
<td></td>
<td>• Choice of polarization is based on backscattering analysis.</td>
</tr>
<tr>
<td>Wide, Standard, Wide Fine or Extra-Fine for large AOIs</td>
<td>Dual Pol (HH+HV)</td>
<td>&gt; 30°</td>
<td>• On low to moderate wind conditions HH polarization allow better discrimination between the flood (calm water) and the surrounding land</td>
</tr>
<tr>
<td>Multi-Look Fine, Ultra-Fine for small AOIs</td>
<td></td>
<td></td>
<td>• Rough surfaces may cause misinterpretation of water as vegetation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Water under vegetation cover not found (e.g. mangroves, other flooded vegetation)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Compare against archived scene to derive flood vectors</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Overlay flood vectors over archived optical image to provide context</td>
</tr>
</tbody>
</table>
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 23:16 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 23:16 UTC, Wide 1 W1 beam, HH)
Crop Monitoring Recommendations

<table>
<thead>
<tr>
<th>Acquisition Modes</th>
<th>Polarization</th>
<th>Incidence Angle</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine Quad-Pol*, Fine*</td>
<td>Dual Pol (VV+VH)</td>
<td>&gt; 30°</td>
<td>• Crop discrimination can be improved by multi-temporal analysis within growing season</td>
</tr>
<tr>
<td></td>
<td>Quad Pol</td>
<td></td>
<td>• Repeated monitoring is of great benefit for detection and classification</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Multi-polarization analysis enhances discrimination capability</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Single pol HH suitable for rice crop monitoring</td>
</tr>
</tbody>
</table>

* Wide swath version of this mode is also suitable.
Time series of RADARSAT-2 Fine Quad-Pol data showing rice cropping from fallow fields in May-June through heading July-October.
# Forestry Recommendations

<table>
<thead>
<tr>
<th>Acquisition Modes</th>
<th>Polarization</th>
<th>Incidence Angle</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Forest Type Mapping</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fine*, Fine Quad Pol*</td>
<td>Dual Pol</td>
<td>&gt; 35°</td>
<td>• VV is first choice</td>
</tr>
<tr>
<td></td>
<td>Quad Pol</td>
<td></td>
<td>• Forest type classification is challenging with radar</td>
</tr>
<tr>
<td><strong>Clear Cut Mapping</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultra-Fine*, Extra-Fine, Multi-Look Fine*, Fine*</td>
<td>Single Pol</td>
<td>&gt; 35°</td>
<td>• Temporal averaging provides the best results</td>
</tr>
<tr>
<td></td>
<td>Dual Pol</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Wide swath version of this mode is also suitable.
July 2013 (3-image Temporal Filter)
July 2014 (2-image Temporal Filter)
Changes to Forest Canopy Cover

Partial cuts

Clear cuts
# Ice Mapping Recommendations

<table>
<thead>
<tr>
<th>Acquisition Modes</th>
<th>Polarization</th>
<th>Incidence Angle</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary ice information e.g. Ice edge location, Ice concentration</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| ScanSAR Wide, ScanSAR Narrow or Wide Fine | Dual Pol (HH+HV) | > 30° | • SCW and SCN are the most common  
• In some cases, for tactical monitoring of a limited area Wide Fine may be useful  
• High-res modes applicable for area-specific information |
| **Secondary Ice Information e.g. Leads, Ridges** | | | |
| ScanSAR Wide, ScanSAR Narrow, Wide Fine or Wide Fine Quad-Pol for the assessment of detailed information | Dual Pol (HH+HV)  
Quad Pol | > 30° | • SCW and SCN are the most common  
• In some cases, for tactical monitoring of a limited area Wide Fine may be useful  
• High-res modes applicable for area-specific information |
| **Iceberg Monitoring** | | | |
| Wide Fine, Extra-Fine | Dual Pol (HH+HV)  
Single (HH) | > 35° | • Research is ongoing for improved ship/iceberg discrimination |
Noise Subtraction

ScanSAR Wide data ($\sigma_0$) over the Beaufort Sea
(a) HV without Noise Subtraction (b) Noise Subtracted HV
## Oil Slick Detection Recommendations

<table>
<thead>
<tr>
<th>Acquisition Modes</th>
<th>Polarization</th>
<th>Incidence Angle</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>ScanSAR Wide, ScanSAR Narrow, Extra-Fine and Wide Fine</td>
<td>Dual Pol (VV+VH)</td>
<td>20° - 40°</td>
<td>• Oil covered areas have less roughness than open water and can be distinguished from clear water</td>
</tr>
<tr>
<td>Wide Fine Quad-Pol</td>
<td>Quad Pol</td>
<td></td>
<td>• HH is a suitable alternative to VV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Analysis can include delineation of dispersion and direction of movement for containment</td>
</tr>
</tbody>
</table>
Oil Slick Discrimination

Oil slick discrimination using RADARSAT-2 quad-polarized data.
Plant oil is on the left, emulsion in the middle, and crude oil on the right.
## Ship Detection Recommendations

<table>
<thead>
<tr>
<th>Acquisition Modes</th>
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<th>Incidence Angle</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Detection of Vessels in Open Waters</strong></td>
<td></td>
<td></td>
<td>• Higher resolution beam modes recommended for vessels smaller than 25 m</td>
</tr>
<tr>
<td>ScanSAR Narrow, Wide, Extra-Fine</td>
<td>Dual Pol (HH+HV)</td>
<td>&gt; 35°</td>
<td>• HH recommended for large (&gt; 35°) incidence</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• HV recommended for small (&lt; 35°) incidence</td>
</tr>
<tr>
<td><strong>Detection of Vessels Anchored in a Protected Area</strong></td>
<td></td>
<td></td>
<td>• HH preferred, since less backscatter due to water surface roughness</td>
</tr>
<tr>
<td>Spotlight, Ultra-Fine, Wide Ultra-Fine</td>
<td>Single Pol (HH or VV)</td>
<td>&gt; 40°</td>
<td>• Large incidence angles are in favor of vessel recognition, thus visibility of vessels’ silhouette</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Size, material and orientation of object towards the radar are important.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Both ascending and descending may be useful</td>
</tr>
</tbody>
</table>
Ship Detection/Classification – Open Ocean

ScanSAR Wide (100 m)
ScanSAR Narrow (50 m)
Wide (30 m)
Extra-Fine (5 m)

AIS Information

Confidence: -
MMSI: 356812000
IMO: 9479905
Call Sign: 3FXU3
Flag: Panama
Type: Cargo
Length: 288 meters
Width: 45 meters
Beam Mode: XF0W3
Pol. Mode: HH
Lat/Long: 34°27′60″ N / 139°45′06″ E
Time: 2014-08-24 08:44:01 UTC
Age: 1 day ago
Speed: 5.1 knots
Heading: 64.0°
COG: 77.0°
ROT: 0.0°
Status: Not Active
Cargo: 0
Action: 0
Destination: JP KAWO W3
ETA: 2014-08-24T21:00:00Z

260 m Vessels
Ship Detection - Ports

SpotLight, August 2014
Conclusion

• Since the launch of RADARSAT-2, new modes and features have been implemented
  – Wide swath modes
  – SpotLight
  – Noise-subtraction ScanSAR

• The multitude of RADARSAT-2 modes can be configured to meet operational requirements
  – High resolution (< 5 m), single-pol for region-specific applications, e.g. Spotlight for detection
  – Medium resolution (10 – 30 m), dual/quad-pol for large-area monitoring, e.g. Fine Quad for classification
  – Low resolution (> 50 m), dual-pol for wide-areas, e.g. ScanSAR Narrow for maritime surveillance

• Client service staff are available to help with image mode selection
Thanks for submitting your questions!
Thank you for attending our webinar!
Register for future events and find past recordings at
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