RADARSAT Constellation Mission: Image Quality and Calibration Status

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CEOS SAR WORKSHOP 2019

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RCM Initial Calibration - Overview

- RCM launch on June 12, 2019
- Initial Calibration period: July 3-Nov 14 (Constellation Commissioning Complete Review Meeting)
- Main initial calibration activities:
  - Beam Mode Checks
  - Rx Gain and Noise Levels
  - Azimuth Beam Patterns
  - Impulse Response
  - Radiometric Calibration
  - Pointing Calibration
  - Interchannel Timing Offset
  - Polarimetric and Compact-pol
  - Geolocation
  - CCD Interferometric phase
  - Ground Coverage Monitoring
  - Transponder

Main Calibration Targets

- Amazon: most accesses to amazon rainforest calibration sites have been used during commissioning

- Point Targets:
  - 3 primary sites with Corner Reflector pairs:
    - St-Hubert (close to CSA)
    - Alaska Satellite Facility in Fairbanks
    - Kiruna satellite station in Sweden
  - 2 transponders at St-Hubert site

- Ocean for receive-only images

More than 5000 calibration images acquired during commissioning!

Initial Beam Modes Checks - Stripmap

- Montreal area
- Very High Resolution 3m Compact-pol
- 3mx3m, 20 km swath
- 2-bit BAQ
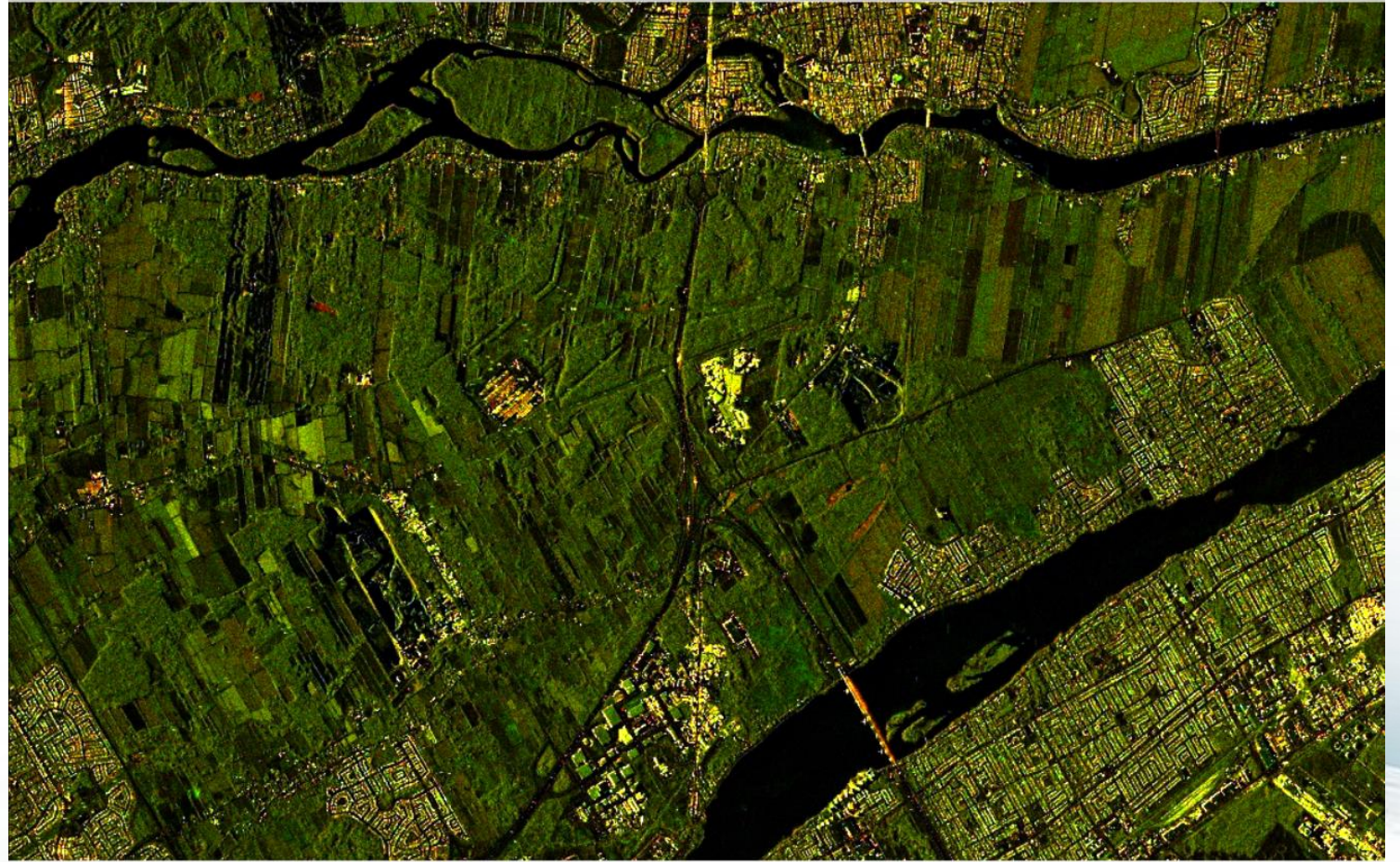
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Initial Beam Modes Checks - ScanSAR

- First RCM image - Baffin Island

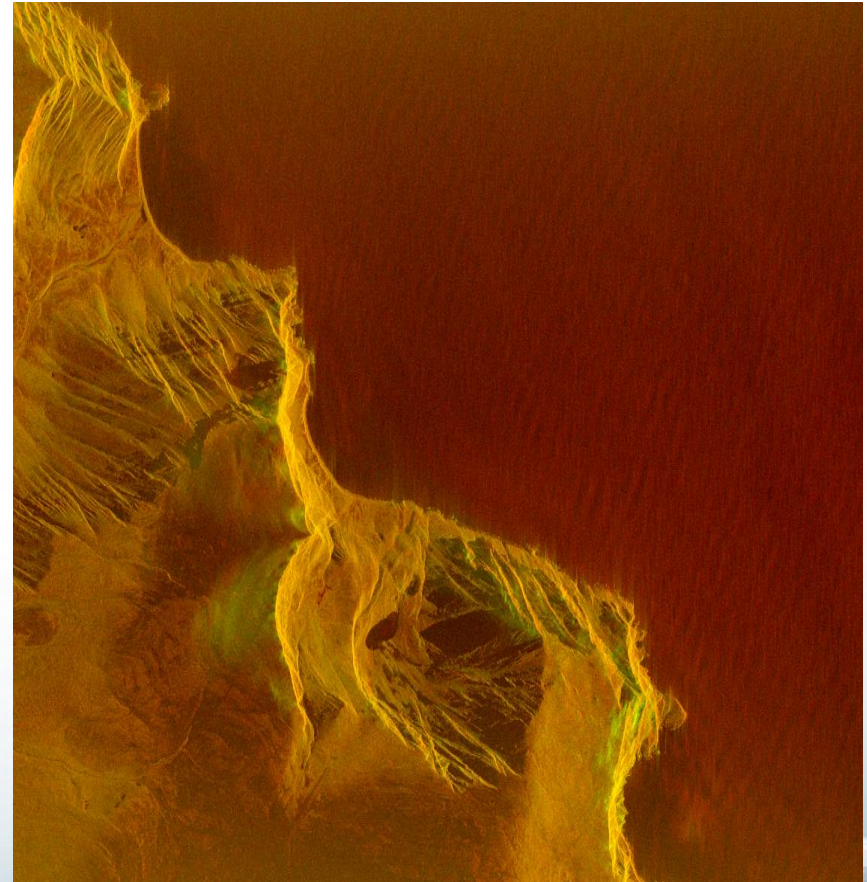- Initially some issues with Stepped Receive delay – now fixed
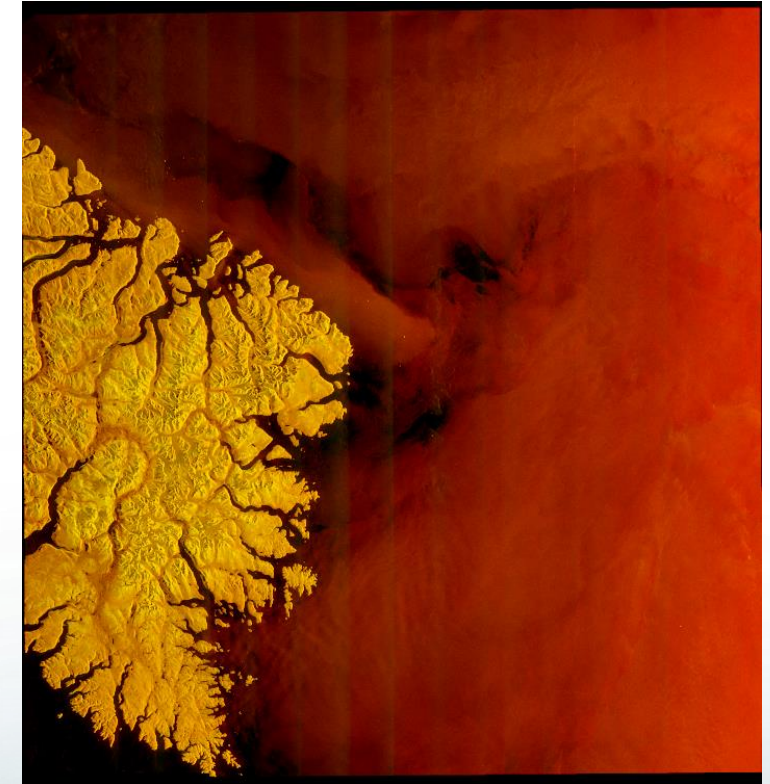
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RCM-1
Low Noise Mode (100m x 100m)
SCLNC HH-HV
Acquisition date: June 29, 2019
First RCM Image!

RCM-1
Low Noise Mode (100m x 100m)
SCLNB HH-HV
Acquisition date: Sept 13, 2019

Initial Beam Modes Checks - Spotlight

- Cape Dyer, Nunavut, Canada
- RCM-2
- Spotlight (1m x 3m)
- FSL17 HH-HV
- Acquisition date: Sept 6, 2019
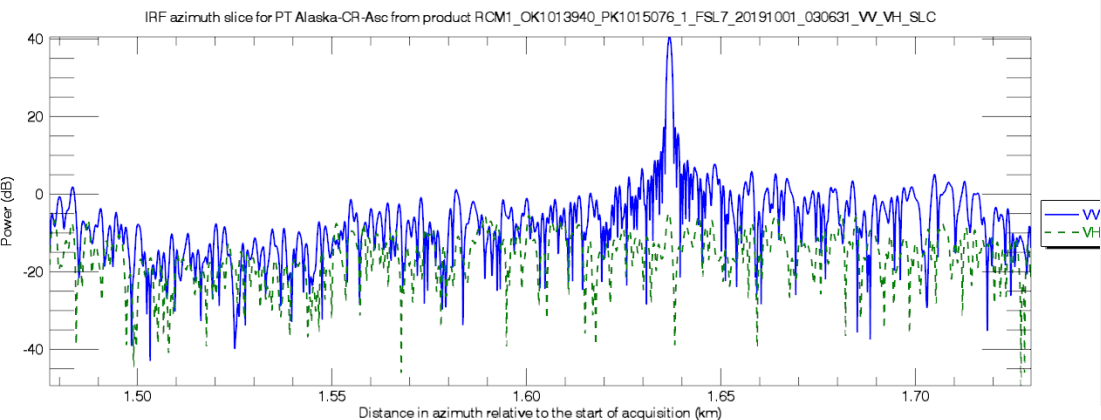- Initial issue with azimuth focusing (3m vs. 1m): was caused by a range timing offset which is now fixed.

RADARSAT

Impulse Response (1/2)

- Alaska CR
- Ascending
- Spotlight FSL7

PT Analysis id: PT_20191112T164413_mlapointe

Point Target analysis results:

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Product: RCM1_OK1013940_PK1015076_1_FSL7_20191001_030631_VV_VH_SLC
BeamString: VH-7

****

Point Target: Alaska-CR-Asc

    Type: Passive
    Height above WGS84 Ellipsoid: 158.636035077 m
    Timing Delay: 0.000000000 sec
    Location: lat   64.885190805   lng -147.705178940
    Location: pixel   1908   line   6491

IRF Measurements channel VV

    Peak power: 40.621056802 dB
    Measured peak location in image without correction for height: pixel   1904.8488   line   6423.5663
    Peak location: lat   64.885455433 deg   lng -147.705546677 deg
    Peak location: pixel   1843.3129   line   6423.5663
    Peak location: Azimuth 1.63681280E+003 m Range 6.58072998E+005 m
    Incidence angle: 25.556410871 deg
    IRW: Azimuth   0.905015272 m (valid) Range   1.603222076 m (valid)   Normalized(35.00 deg incidence)   2.795132323 m
    IRW broadening: Azimuth   0.100% (valid) Range   -1.278% (valid)
    PSLR: Azimuth   23.065506888 dB (valid) Range   20.942743245 dB (valid)
    ISLR: Azimuth   21.722654094 dB (valid) Range   22.039647283 dB (valid)   2-D   18.409806020 dB (valid)
    Integrated power: 44.219743849 dB

[IRF Image] [IRF 3-D plot] [IRF Azimuth slice plot] [IRF Range slice plot] [Analysis Report] [Transfer to permanent database] [OK]

# Impulse Response (2/2)

- Verified that:
  - IRW broadening was within allocation to meet resolution requirement:
    - Azimuth: < 4%
    - Range: < 8%
  - 2D ISLR > 12 dB (requirement)
- Processing with Nominal Chirp showed slightly better performance than using the Replica.

Azimuth IRW Broadening - Nominal Chirp

Range IRW Broadening - Nominal Chirp

2D ISLR (Integrated Side Lobe Raio) Nominal Chirp
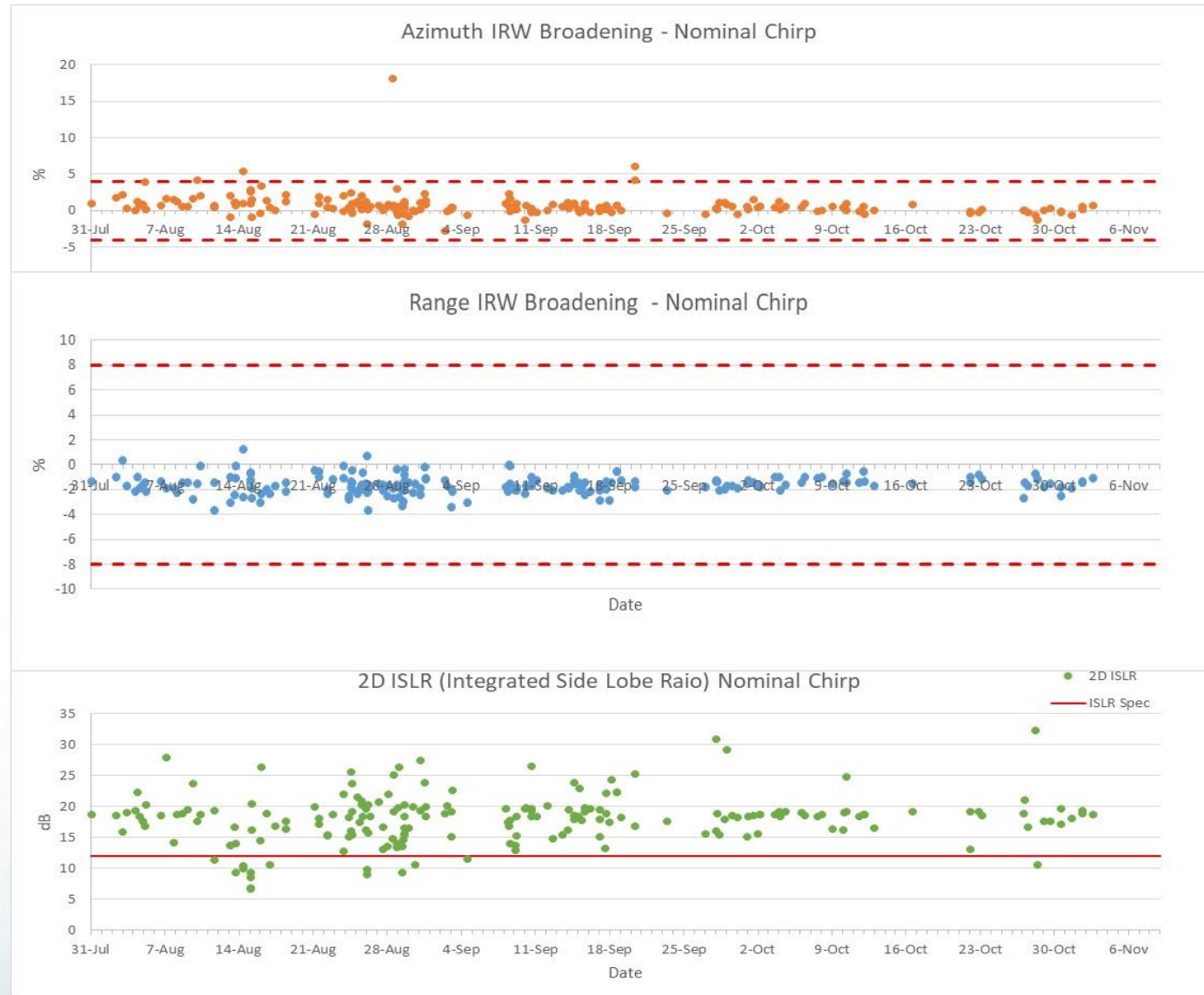
Geolocation Calibration

- Results using Downlink Orbit

- Range:
  - Initially important ground range geolocation error (400-700m)
  - Timing delay offset estimated and adjusted
  - Results are now well within specifications (50m/100m)

- Azimuth:
  - A processor error was initially causing an along-track error close to 40m.
  - Results are now well within specifications (50m/100m)

- On-going work to improve Definitive Orbit data.

Range Geolocation

Azimuth Geolocation
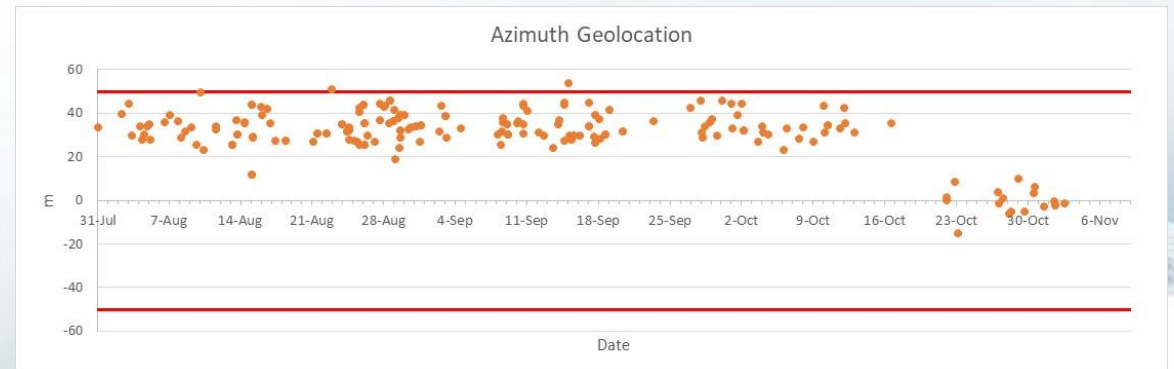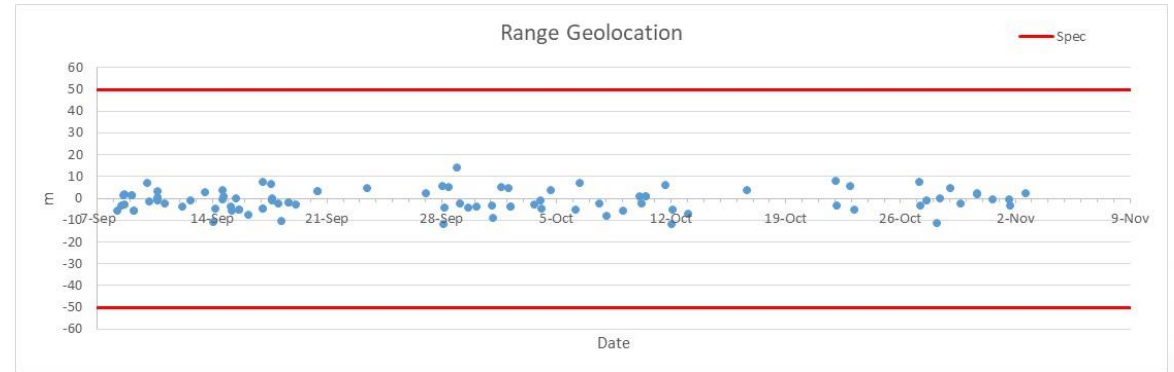
Pointing Calibration Yaw and Pitch

- Compared Yaw/Pitch from Doppler centroid estimates fromSAR data and Yaw/Pitch from spacecraft
- Correction of RCM-1, RCM-2 and RCM-3 yaw and pitch offsets, resulting in better initial estimates of yaw/pitch for processing and Doppler centroid closer to zero.
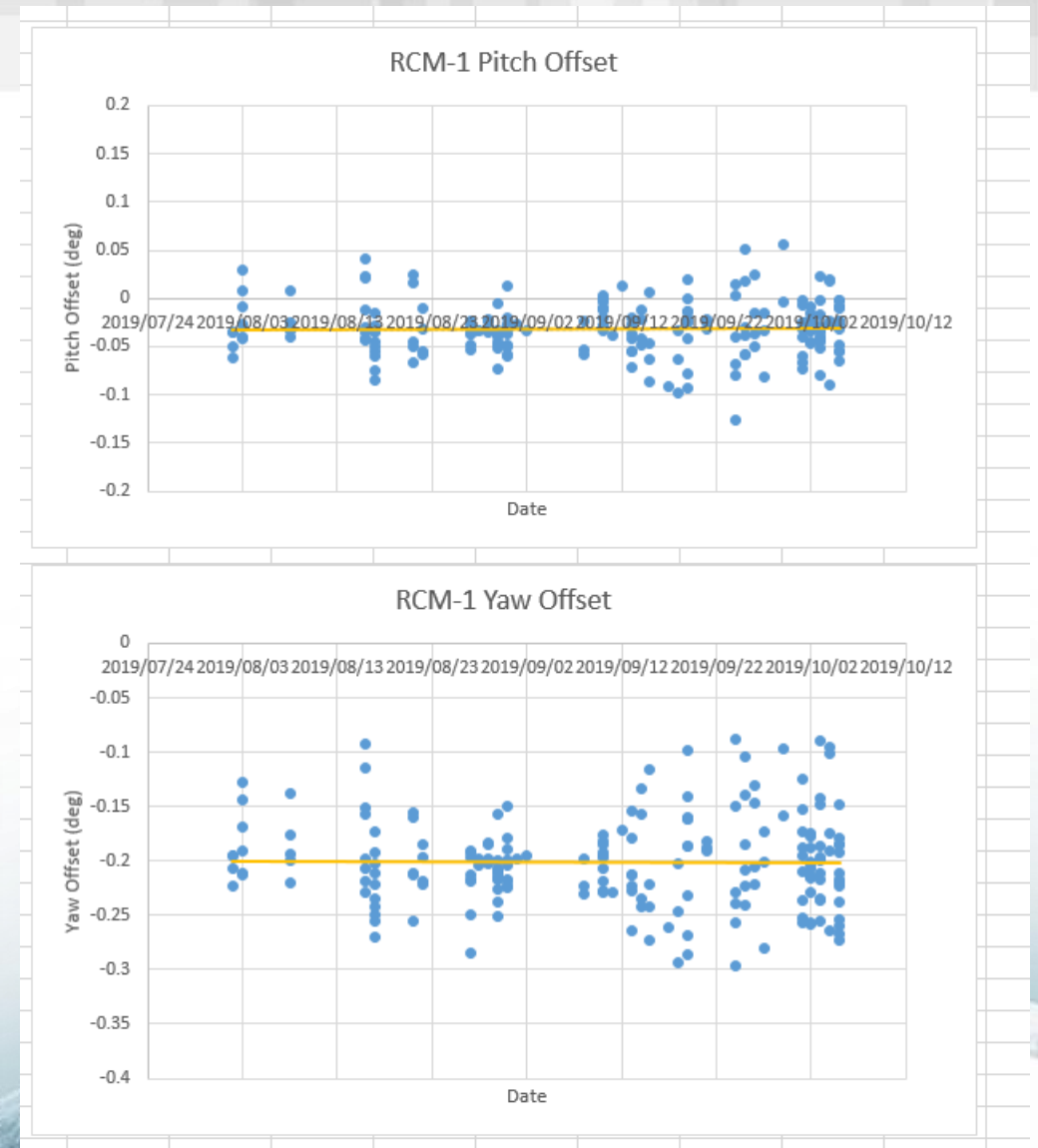
	Pitch Offset		Yaw Offset	
	Average	Std Dev	Average	Std Dev
RCM-1	-0.031°	0.03°	-0.20°	0.04°
RCM-2	-0.196°	0.02°	0.144°	0.03°
RCM-3	0.037°	0.02°	0.109°	0.04°

Pointing Calibration Roll

- Estimated roll offset by comparing the measured elevation patterns (from amazon images) and the reference patterns (from the antenna model)

- Initial correction of RCM-2 roll angle by 0.65 deg

- Recent adjustments of the roll offsets for the 3 satellites in the payload characterization parameters used for processing.
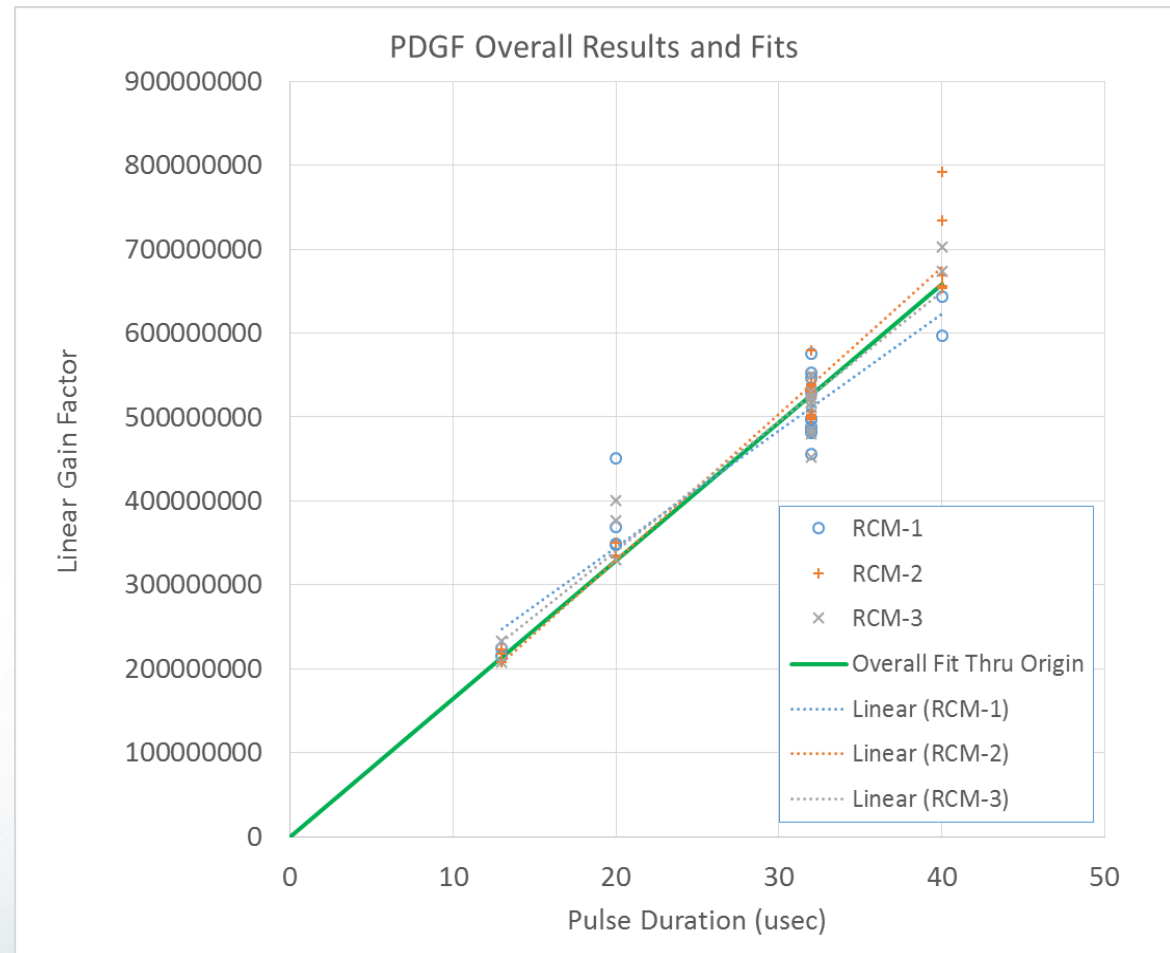
RCM-1 Results:
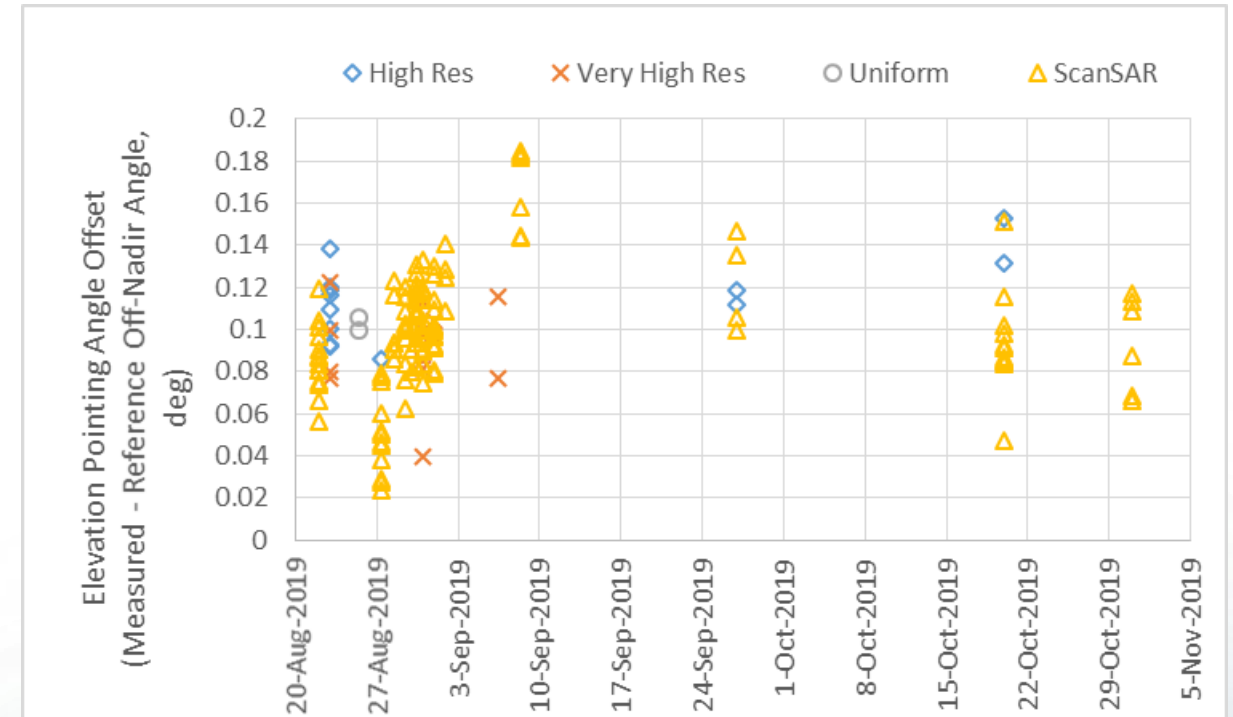
- Mean pointing offset = +0.099 deg (pointing too far out)
- Standard deviation 0.028 deg
- Slight upward trend with incidence angle

Radiometric Calibration

- Pulse Dependent Gain Factor measurements
  - Absolute Calibration using Amazon
  - Using a uniform beam over a variety of pulse durations and bandwidth

PDGF Overall Results and Fits

Radiometric Calibration

- Elevation Patterns Measurements:
  - Measured pattern: Gamma-0 image over Amazon reference expected Gamma-0
  - Comparison with reference pattern (from antenna model)

- Calibration updates were made considering parametric and systemic factors rather than individual beam shapes:
  - Antenna model corrected to account for receive amplitude weighting issue
  - Approximate correction to account for antenna patch modeling issue affecting large scan angles.
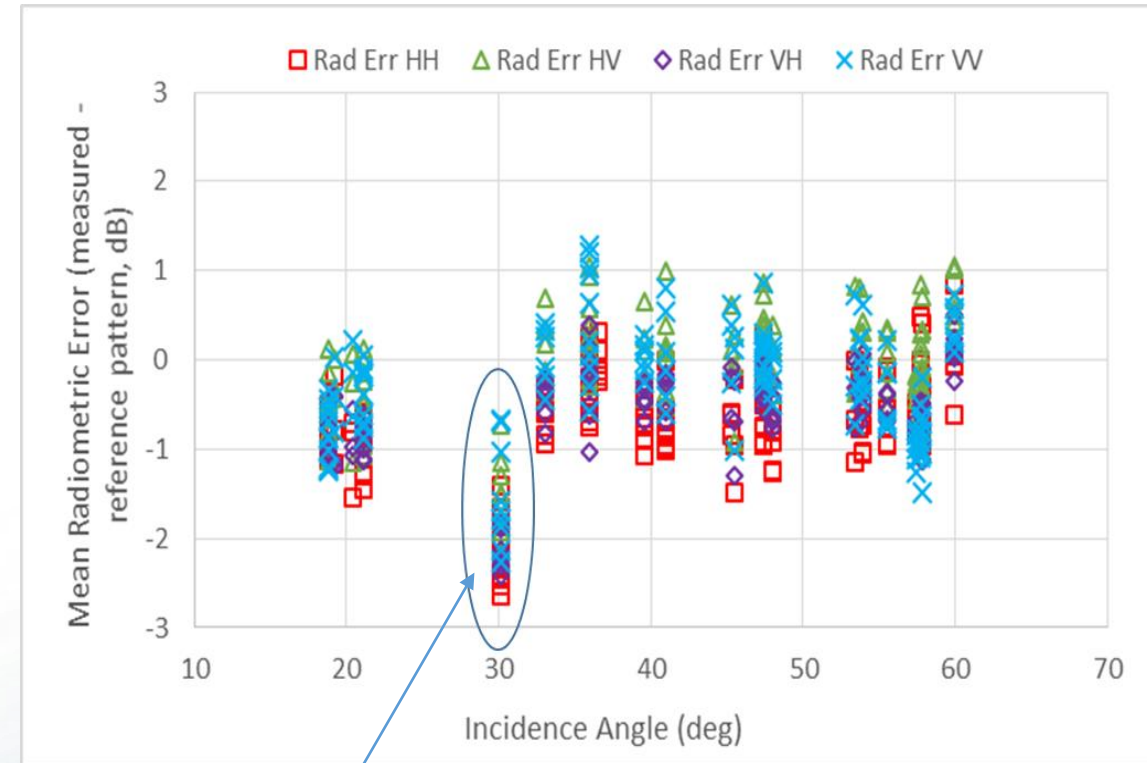
Caused by an issue with receive amplitude coefficients modeling

Polarimetric and Compact-Pol Calibration

- Quad-Pol:
  - Tx and Rx channel imbalances and cross-talk have been measured for selected quad-pol beams images over amazon:
    - Imbalance terms lower than approx. 1 dB
    - Cross-talk lower than -30dB
    - Approximate correction of those terms have been applied
  - Consistent with results over corner reflectors

- Compact-Pol:
  - Tx and Rx imbalances estimated and approximately corrected using special calibration quad-pol modes images over amazon.

IRF azimuth slice for PT SHUB-CR-Desc from product RCM1_OK1018555_PK1019356_2_QP7_20191023_111139_HH_VV_HV_VH_SLC
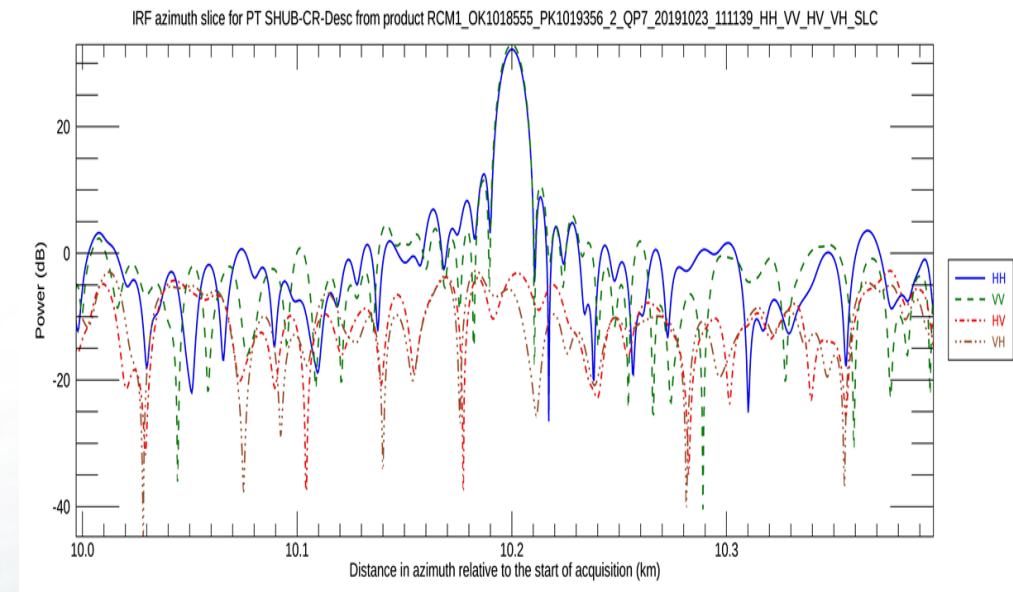
Coherent Change Detection

2D Bandwidth Overlap well within requirement of 75%
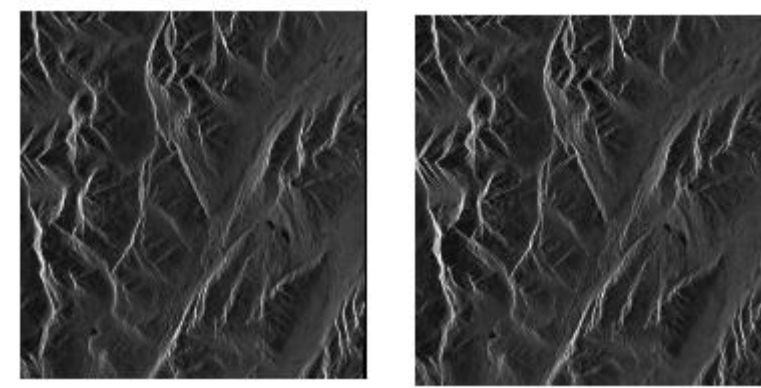
| Sat 1	Date 1st acq	Sat 2	Date 2nd acq	Days between acqs	Beam Mode Mnemonics	AOI	Doppler BW Overlap	Ground Range BW Overlap	2D BW Overlap
RCM-2	2019-10-23	RCM-3	2019-10-27	4	3M27	Inuvik	0.985	0.992	0.977
RCM-2	2019-10-23	RCM-1	2019-10-31	8	3M27	Inuvik	0.985	0.992	0.977
RCM-2	2019-10-23	RCM-2	2019-11-04	12	3M27	Inuvik	0.999	0.999	0.998
RCM-3	2019-10-29	RCM-1	2019-11-02	4	3MCP32	Montreal	0.982	0.998	0.980
RCM-3	2019-10-24	RCM-1	2019-10-28	4	5M1	BC	0.000	0.971	0.018
RCM-3	2019-10-24	RCM-2	2019-11-01	8	5M1	BC	0.972	0.987	0.960
RCM-3	2019-10-24	RCM-3	2019-11-05	12	5M1	BC	0.995	0.984	0.979
RCM-3	2019-10-25	RCM-1	2019-10-29	4	5MCP18	Montreal	0.969	0.999	0.968
RCM-3	2019-10-24	RCM-1	2019-10-28	4	16M11	Montreal	0.978	0.972	0.951
RCM-3	2019-11-02	RCM-1	2019-11-06	4	16M7	Australia	0.998	0.979	0.977
RCM-1	2019-10-23	RCM-3	2019-10-31	8	SC30MD	North Qc	0.968	0.9889	0.957
RCM-2	2019-10-26	RCM-3	2019-10-30	4	SC30MC	North Qc	0.993	0.981	0.974
RCM-1	2019-10-26	RCM-2	2019-10-30	4	SC30MD	Ontario	0.987	0.980	0.967
RCM-1	2019-11-02	RCM-2	2019-11-06	4	SC30MA	Alberta	0.952	0.952	0.906

Low BW overlap caused by a GPS issue

PRODUCT 1
Product ID: RCM3_OK1020669_PK1020756_1_16M7_20191102_090752_VV_SLC
Product Type: SLC
Acquisition Date: 2019-11-02T09:07:52.850000Z
Beams: H-7

PRODUCT 2
Product ID: RCM1_OK1020669_PK1021779_1_16M7_20191106_090730_VV_SLC
Product Type: SLC
Acquisition Date: 2019-11-06T09:07:30.030000Z
Beams: H-7

SECONDARY PRODUCT SEARCH PARAMETERS

Minimum Geographic % Overlap: 10
Must contain first image's centroid: Yes

REFERENCE POINT SELECTION

Reference Point Description: Intersection Center
Reference Point [Latitude, Longitude]:
[-27.886, 140.646]
Reference Height: 77.214

2D BANDWIDTH OVERLAP RESULTS

2D Bandwidth Overlap: 0.977277
Ground Range Bandwidth Overlap: 0.979422
Doppler Bandwidth Overlap: 0.997810

ADDITIONAL INFORMATION
Range Bandwidth: 2.20000E+007, 2.20000E+007 [Hz]
Azimuth Bandwidth: 1.57000E+003, 1.57000E+003 [Hz]
Radar Center Frequency: 5.40500, 5.40500 [GHz]
Slant Range: 6.92435E+005, 6.92432E+005 [m]
Satellite Orbit Radius: 6.97435E+006, 6.97437E+006 [m]
Elevation Angle: 28.3677, 28.3651 [Degrees]
Inclination Angle: 31.3266, 31.3237 [Degrees]
Ground Range Low Frequency: 2.80443, 2.80419 [GHz]
Ground Range High Frequency: 2.81586, 2.81563 [GHz]
Along-Track Effective Doppler Shift: 1.33579, 1.33579 [Hz]
Doppler Center Frequency: -83.6993, -88.4735 [Hz]

Ground Coverage Monitoring

RCM-1 coverage % evolution during commissioning
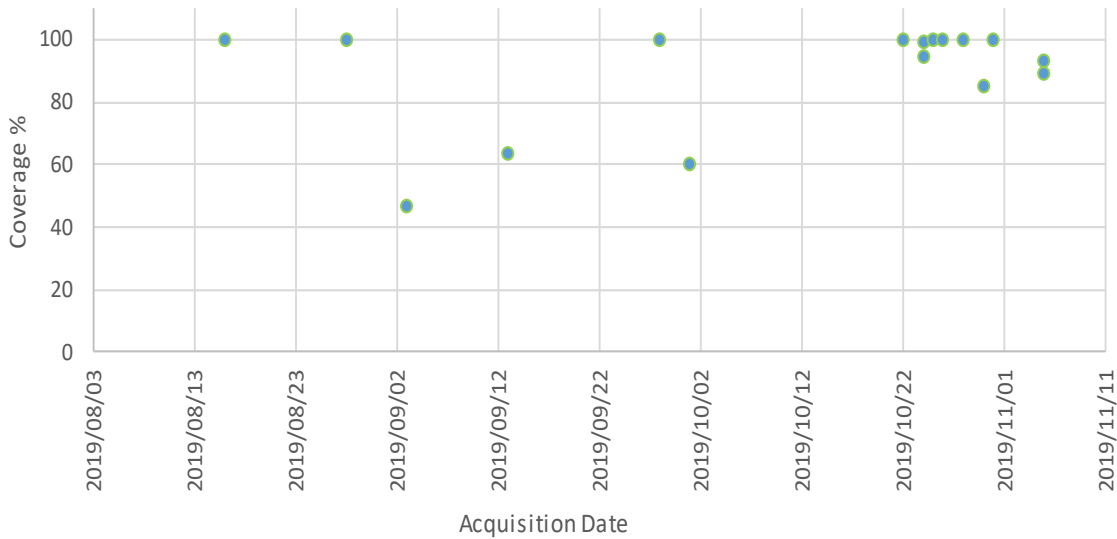
Product Information
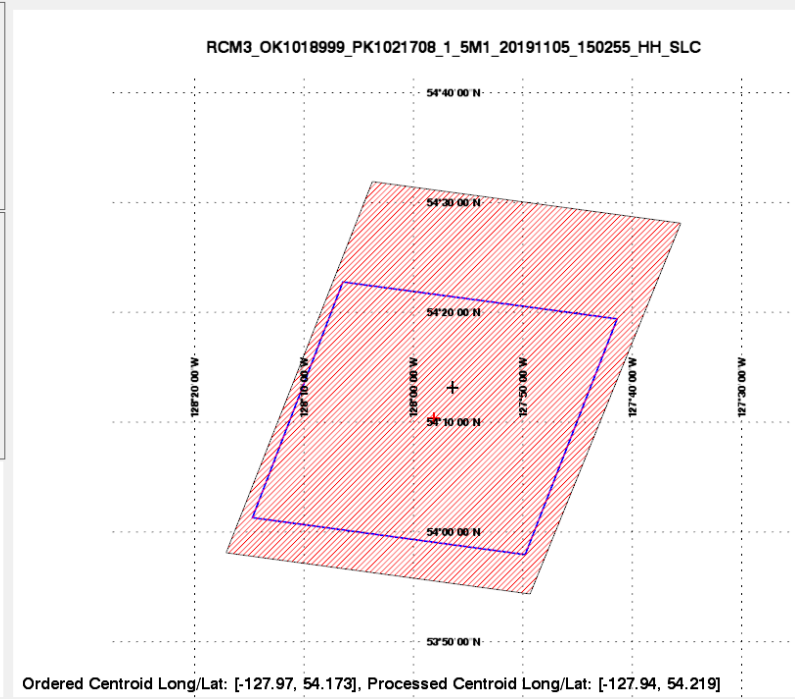
Downlink Segment ID: 8302_11199
Satellite Name: RCM-3
Beam ID: 201
Beam Name: Stripmap 5m Resolution 30km Swath 1
Polarization: HH
Pass Direction: Descending
Acquisition Date: 2019-11-05T15:02:55.767Z
Duration: 9.2561
Terrain Height: 1.1716E+003

Display Coverage Analysis Results

☐ Center Distance: 5.4961E+003 [m]
☐ Center Azimuth: 31.791 [deg]
☐ Percent Overlap: 100.00 [%]
☐ Near Edge Offset: 2.0051E+003 [m]
☐ Far Edge Offset: 1.0055E+003 [m]
☐ Start Edge Offset: 1.7161E+004 [m]
☐ Stop Edge Offset: 6.3606E+003 [m]
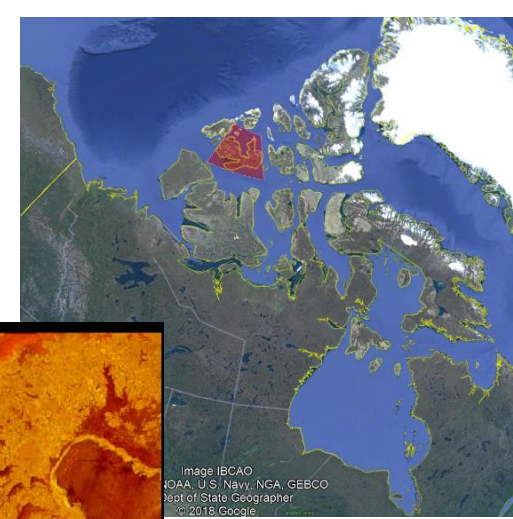☐ Inclination Diff: 0.66660 [deg]

LEGEND

☐ **Acquisition Footprint**

▨ **Processed Footprint**

▨ **Other Scenes**

RCM3_OK1018999_PK1021708_1_5M1_20191105_150255_HH_SLC

Ordered Centroid Long/Lat: [-127.97, 54.173], Processed Centroid Long/Lat: [-127.94, 54.219]

RCM Image Quality Status Summary

- Impulse response:
  - Resolution as expected
  - Sidelobes as expected

- Geolocation:
  - Adjustments of timing delay offset + processor fix: geolocation accuracy now within specs
  - On-going assessment of Definitive orbit

- Yaw-Pitch-Roll pointing corrections have been made.

- Preliminary Radiometric calibration:
  - Pulse Dependent Gain Factor measured
  - Many elevation patterns measured
  - Some corrective measures implemented to fix observed discrepancies

- Preliminary correction for channel imbalance and cross-talk just completed for quad-pol and compact-pol

- Routine calibration will continue throughout the mission!

Thank you!