



Canadian Government Cal/Val Activities: 13 Years of RADARSAT-1 SAR Calibration Operations and One Year of RADARSAT-2 SAR Image Quality Monitoring

S. Cote, S. Srivastava
Canadian Space Agency

S. Muir
Calian Technologies Ltd

R. Hawkins
Canada Centre for Remote Sensing





Outline



Canadian Space Agency
Agence spatiale canadienne

Introduction

Distributed Target sites and results

Point Target sites and results

NESZ, Isolation

Summary



The RADARSAT Program



Canadian Space Agency
Agence spatiale canadienne



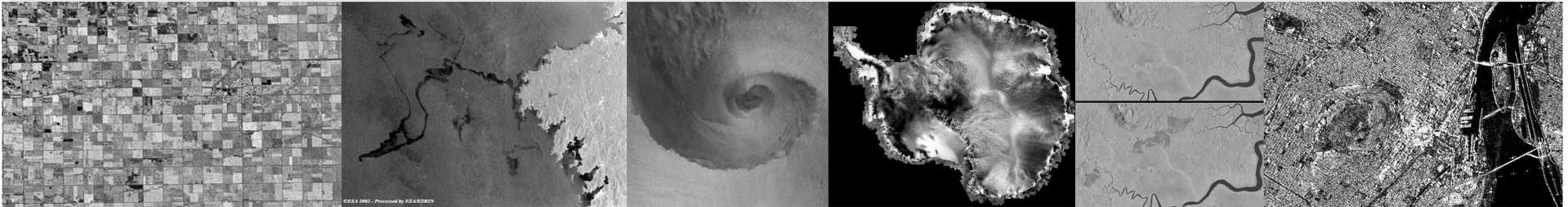
Builds on the history of Canadian realisations in remote sensing and space technologies.

Developed to monitor environmental change and support resource sustainability.

Provides Canada and the world with an operational EO system for routine delivery of C-band SAR data:

Ice monitoring
forestry
agriculture
geology

surveillance of sea polluters
International Charter for Space and Major Disasters
mapping missions (Antarctic in 1997 and 2000)
etc.

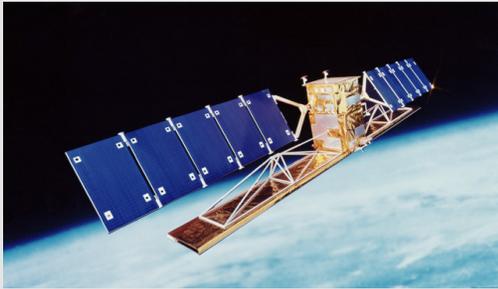




The RADARSAT Program



Canadian Space Agency
Agence spatiale canadienne



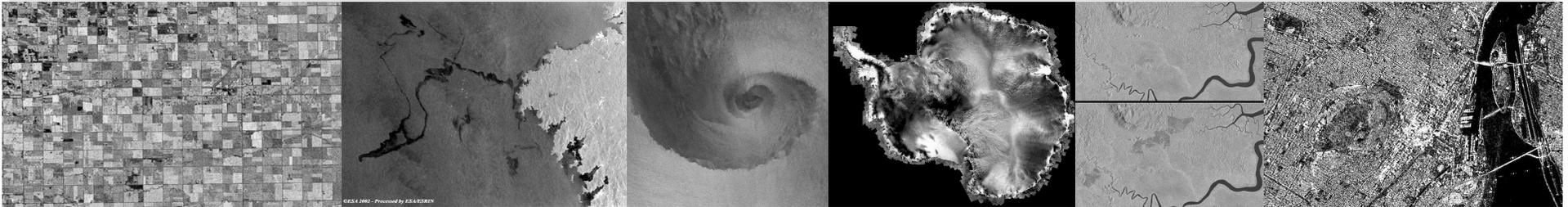
RADARSAT-1

- Launched 11-1995
- Operational 04-1996
- C-band, HH, right looking
- 33 acquisition modes
- 323 000 images (commercial + GoC clients)
- Owned & operated by GoC



RADARSAT-2

- Launched 12-2007
- Operational 04-2008
- C-band, polarimetric, right & left looking
- ~1000 acquisition modes
- 24 000 images to date for GoC clients
- Owned & operated by MDA





The RADARSAT Program



Canadian Space Agency
Agence spatiale canadienne

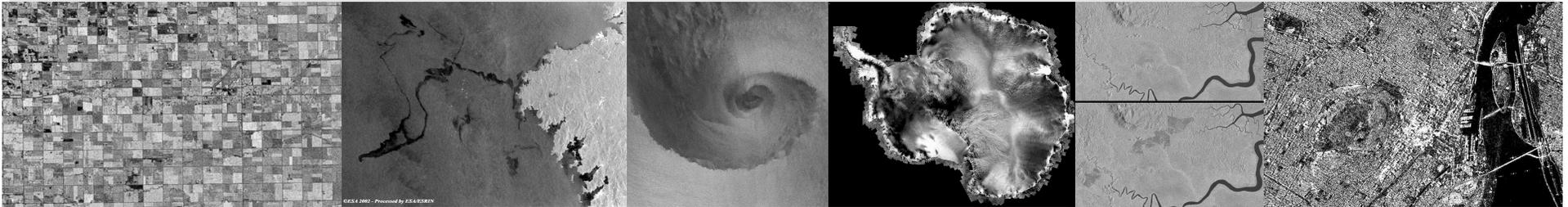


RADARSAT-1

As end of November 2009

Years since launch:	14
Total Orbits completed:	73 000
Total minutes of data:	620 000
Average system performance:	better than 95 %
On-Board Recorder status:	OBR1 operations were terminated in February 2009. Both OBRs are OFF.

Data received and processed at 40 ground stations





RADARSAT Calibration Activities at the CSA



Canadian Space Agency
Agence spatiale canadienne



RADARSAT-1



RADARSAT-2

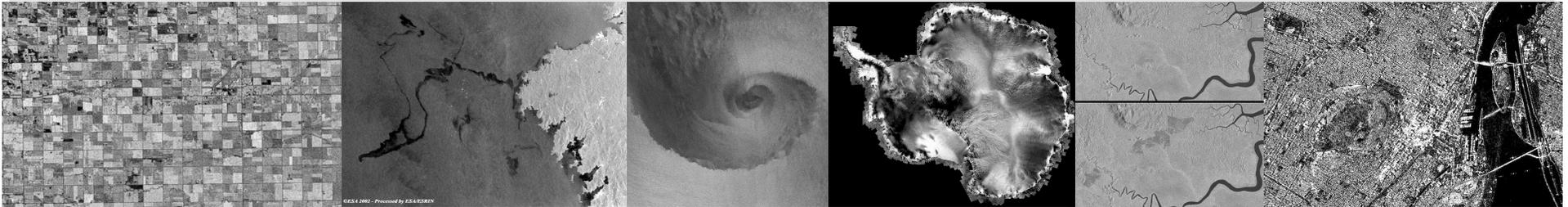
Calibration operations

CSA exercises an Image Quality Assurance mandate for the GoC (Crown is the major sponsor of the project)

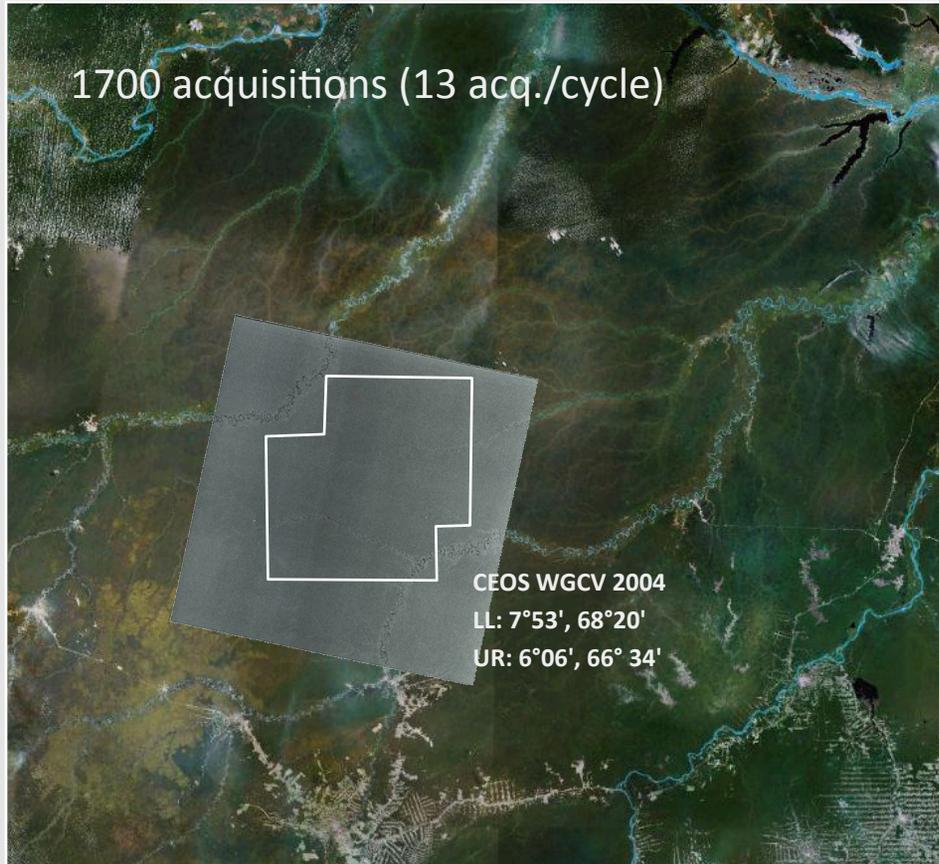
Analysis of imagery from:

- Distributed target sites: antenna beam pattern monitoring
- Point target sites: end-to-end impulse response characterization

⇒ Recalibrations

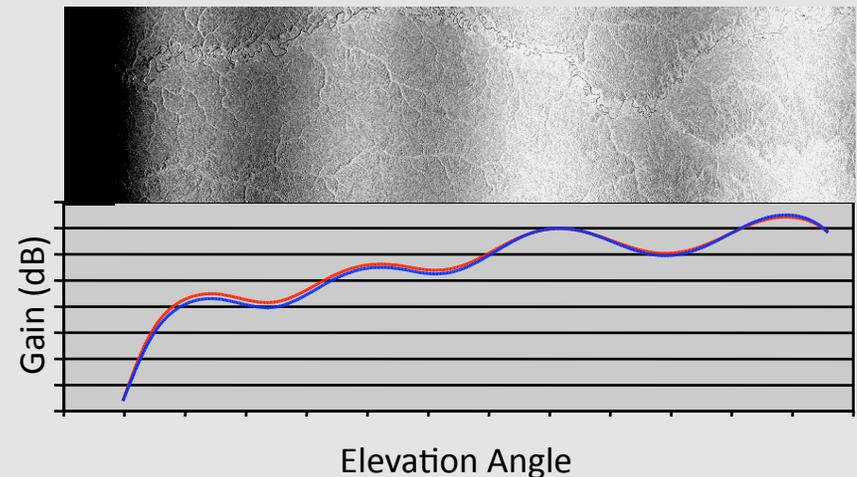


Amazon



Derivation of Relative radiometric accuracy:

Routine extraction of antenna elevation beam patterns from averaging of uncorrected imagery

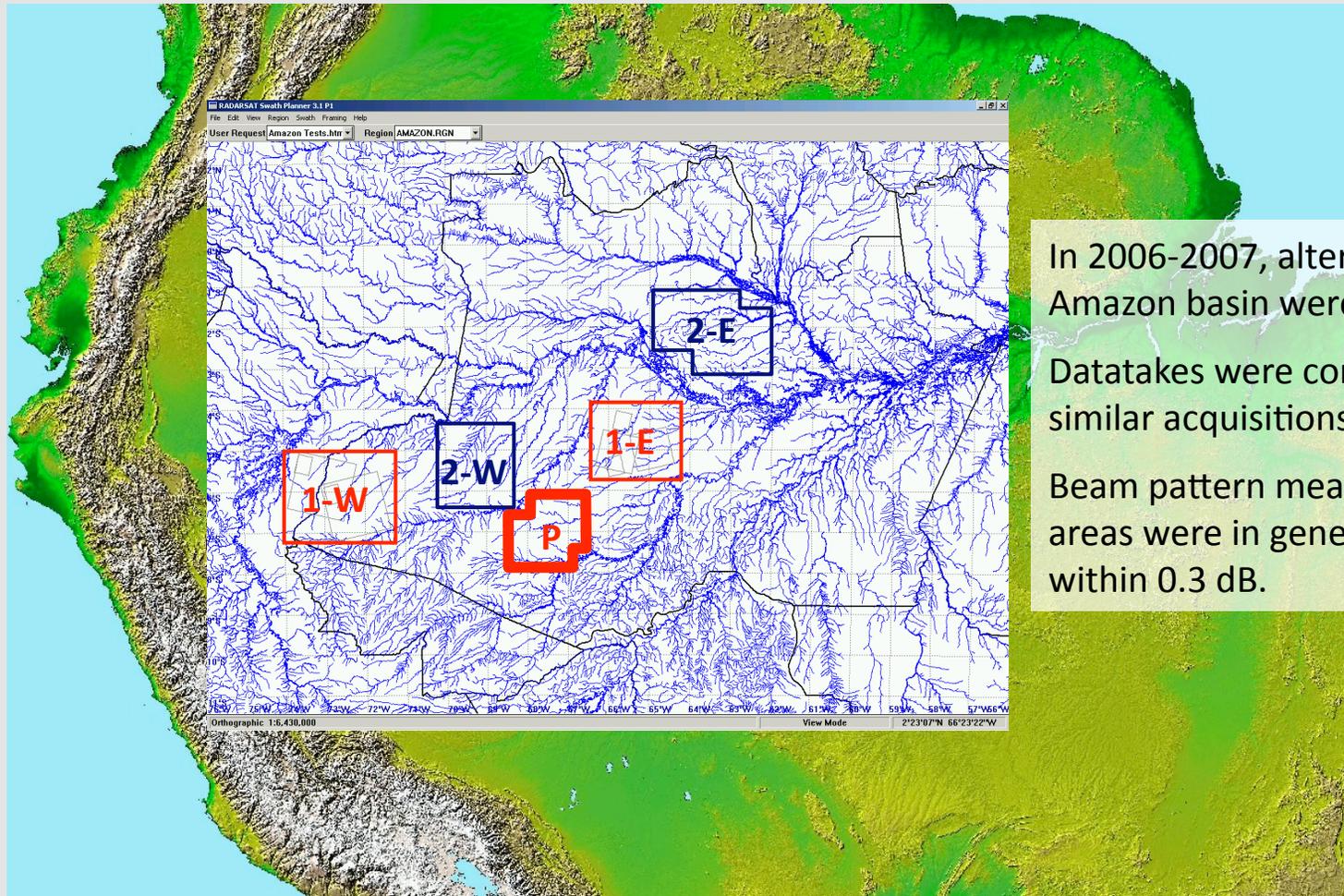


Latest recalibrations were performed in March 2009 on beams F3, S1, S4, EL1, EH3, EH6.

Since initial in-orbit calibration (October 1997):

- Four beams still retain their initial calibrated patterns.

Alternate areas of the Amazon



In 2006-2007, alternate areas of the Amazon basin were tested with R1. Datatakes were compared against similar acquisitions at the prime area. Beam pattern measurements from all areas were in general agreement to within 0.3 dB.



Relative Radiometric Accuracy

R-1 and R-2 requirements:

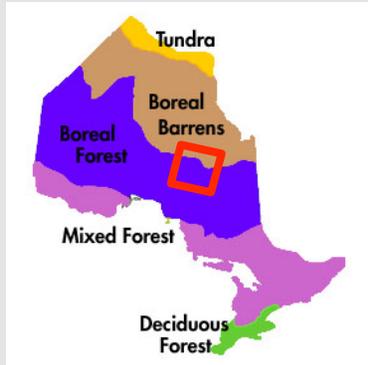
- < 1 dB within a 100 km square scene
- < 1.5 dB within one orbit
- < 2 dB over 3 days

Achieved:

Beam	Image Size (km)	Relative Radiometric Accuracy (dB)	
		R1 (11 y) HH	R2 (1 y) right-looking, all pol.
Wide	150	0.59	0.75
Standard	100	0.48	0.53
Fine	50	0.34	0.38
Fine QP	25	-	0.43
Multi-look Fine	50	-	0.37
Ultra-fine	20	-	0.37
ScanSAR	400	1.60 typ.	< 1 dB typ.

Canadian Boreal Forest

OBR degradation over the years led to a search of alternate sites within reach of Canadian receiving facilities.

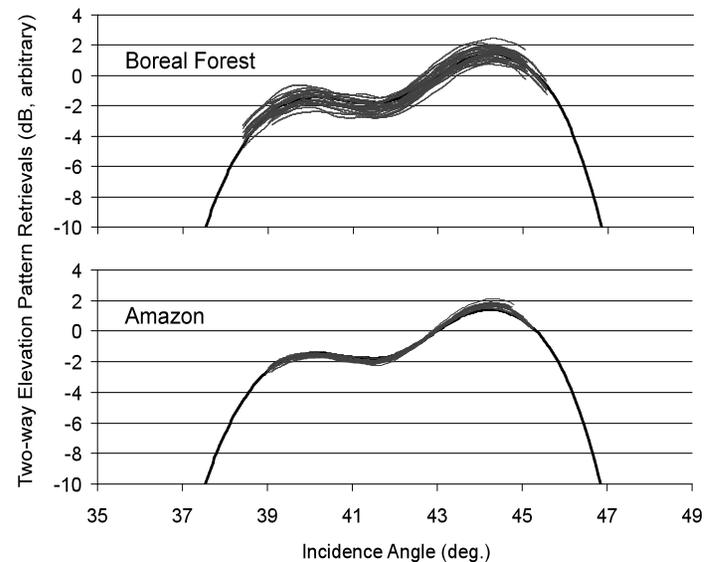
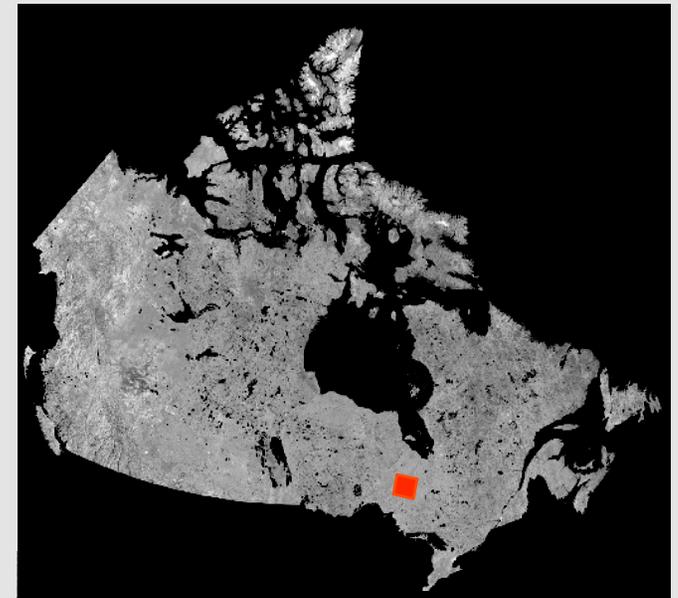


The best potential site for beam pattern measurements was found in the Northwestern Ontario Landmass

Stable seasonal periods were identified and reflectivity profiles $\gamma(\theta)$ were characterized for these periods.

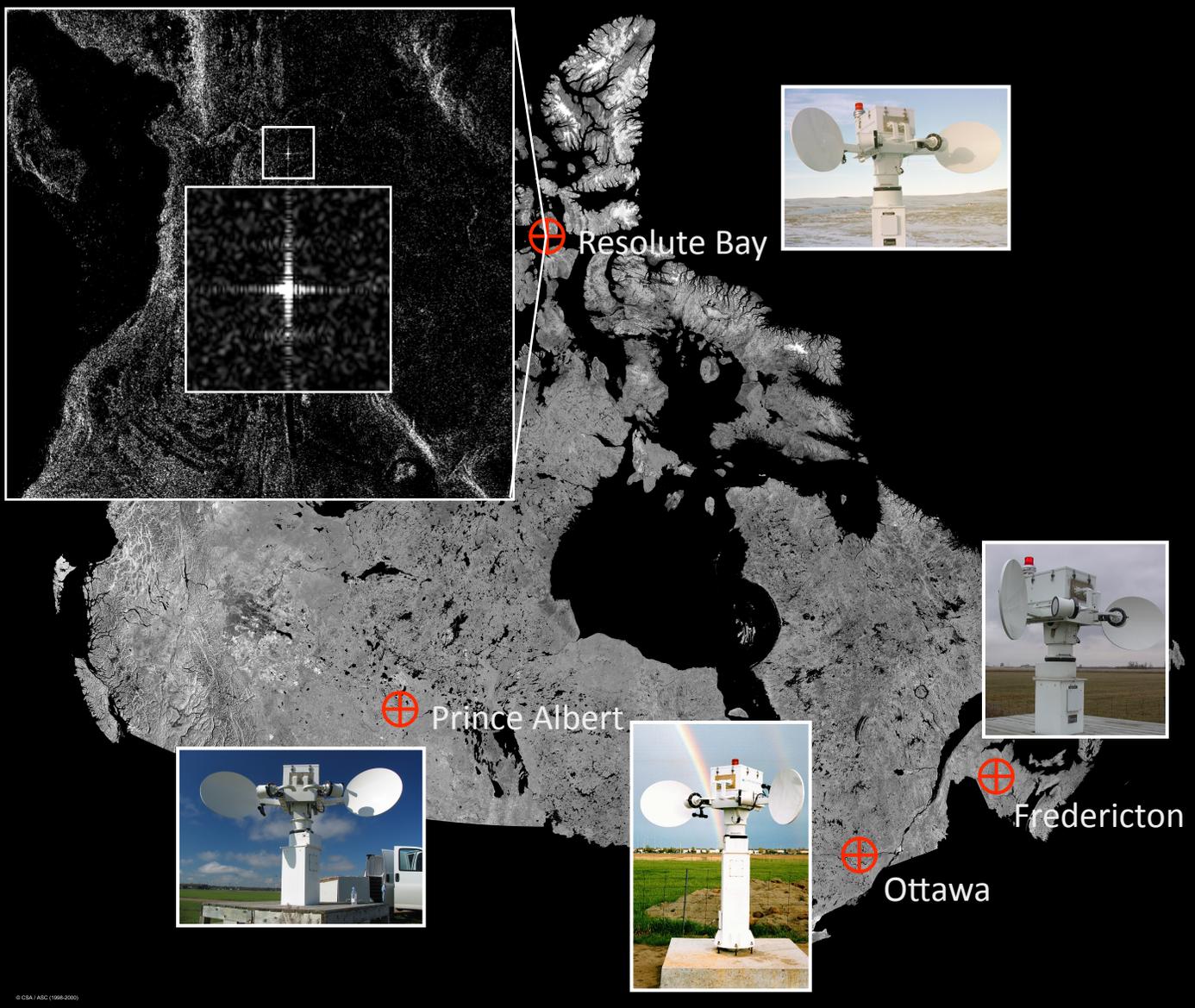
The area was used experimentally for elevation beam pattern estimates since 2005,

The area is used operationally since summer 2008, when OBR operations became restricted.

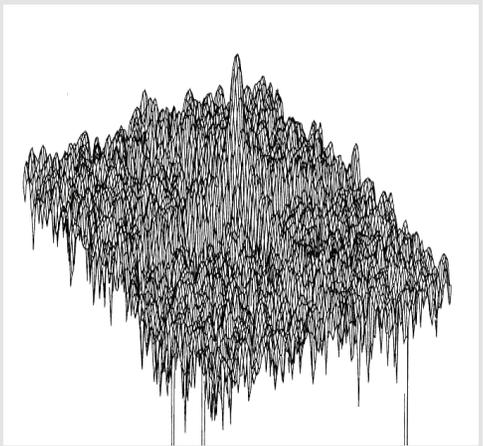




RADARSAT-1 Point Target Sites



Impulse response measurements



- 3 dB Width
- PSLR
- ISLR
- Location Accuracy
- Radiated Power Level
- Radiated Flux
- Azimuth Pattern
- Chirp Pulse Envelope

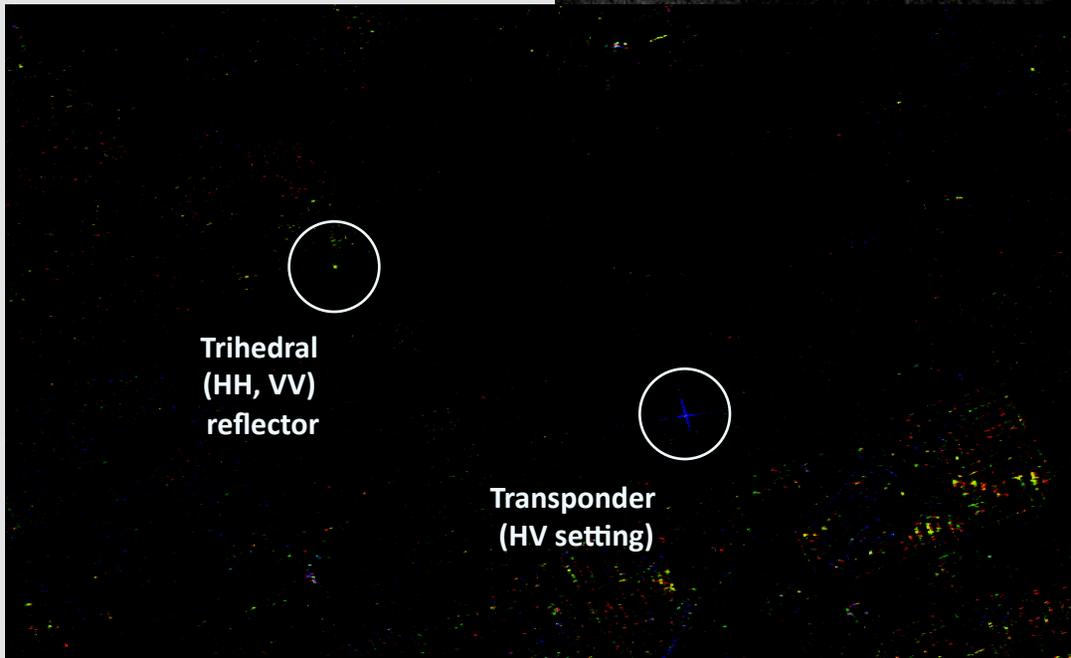


RADARSAT-2 Point Target Site



Canadian Space Agency
Agence spatiale canadienne

Ottawa Point Targets





R-1 / R-2 Point Target Results



Impulse Response Measurements (Image Quality)

Achieved:

		R1 (11 y)	R2 (1 y)
2D ISLR (dB)	SDNR allocation: > 9.2 dB	15.0	15.7
PSLR (dB)	Requirement: > 18 dB	20.6	21.1

Beam	IRW: Range @ 35° X Azimuth (m)		
	R1	R2	Design goal
Wide	24 x 25	24 x 25	28 x 28
Standard	(17, 24) x 25	(16, 24) x 24	(19, 28) x 28
Fine	9 x 8	9 x 8	11 x 9
Fine QP	-	9 x 8	11 x 9
Multi-look Fine	-	9 x 8	11 x 9
Ultra-fine	-	3 x 3	3 x 3
Low Incidence	17 x 25	16 x 25	19 x 28
High Incidence	25 x 25	24 x 25	28 x 28



Absolute Location Accuracy

R1: requirement is < 1500 m, with a 'desirable' design goal at < 750 m. Accuracy of along-track location of spacecraft was the limiting factor.

R2 requirements:

- 'downlinked' orbit data: < 300 m
- 'definitive' (post-processed) orbit data: < 100 m

Achieved:
('downlinked')

Beam	Absolute Location Accuracy (m)	
	R1 ('predicted')	R2 ('downlinked')
Wide	57	23
Standard	60	24
Fine	58	13
Fine QP	-	26
Multi-look Fine	-	13
Ultra-fine	-	15
Low Incidence	83	55
High Incidence	55	9
All single beams	63	23

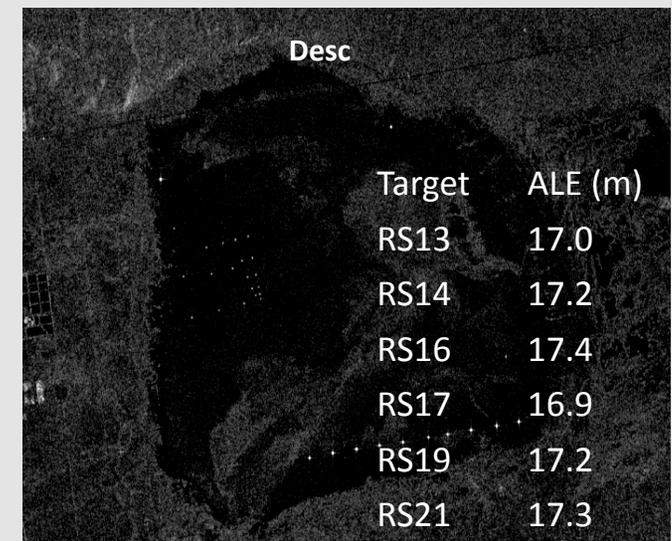
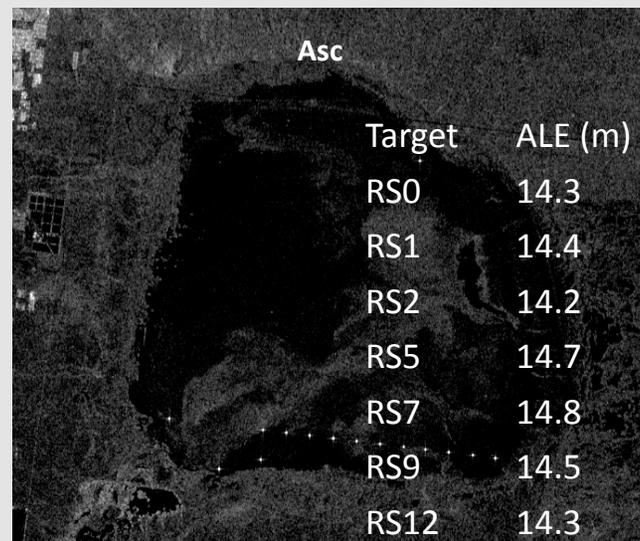
Geometric Distortion

R1 and R2 requirements: < 40 m

Achieved: R1: average since 2000: 37 m

based on Ottawa scenes: active calibrator and Gatineau receiving facility antenna.

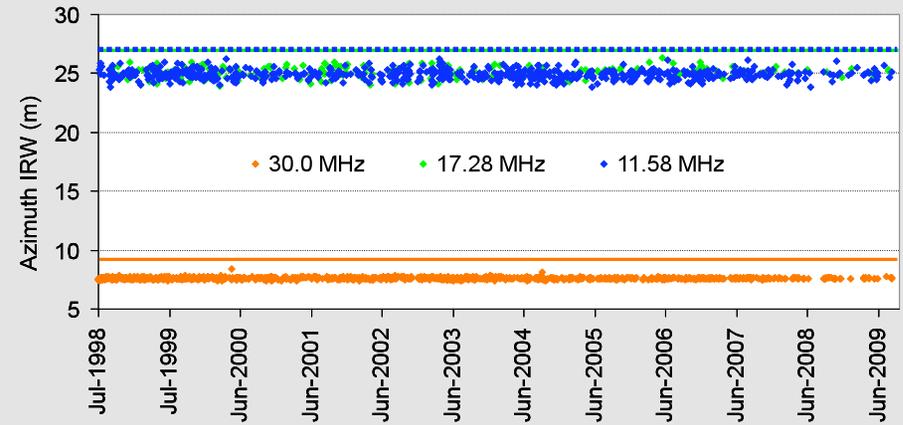
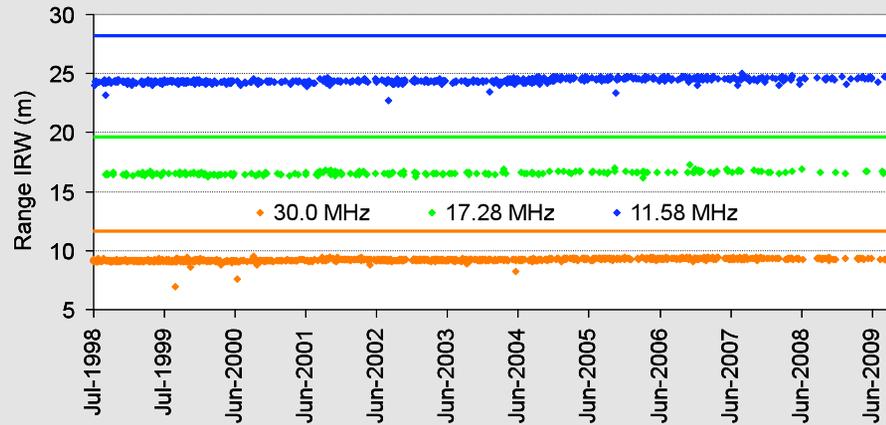
Trihedral array in Rosamond, Ca (NASA Dryden Flight Research Center) with R-2 beam EH6.



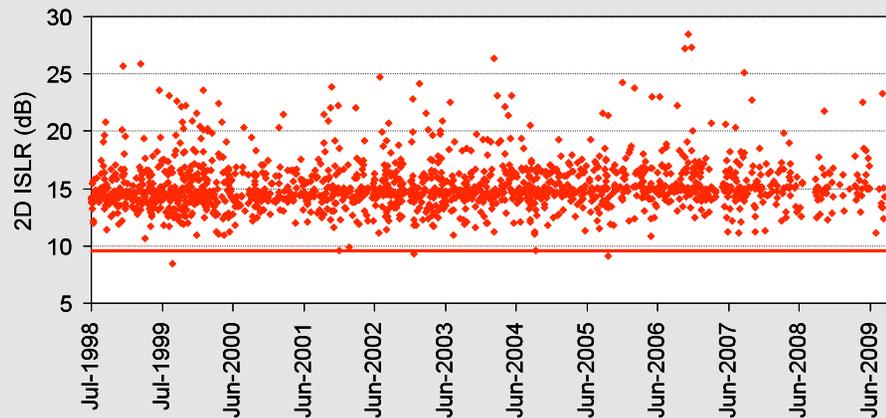


R-1 Point Target Result History

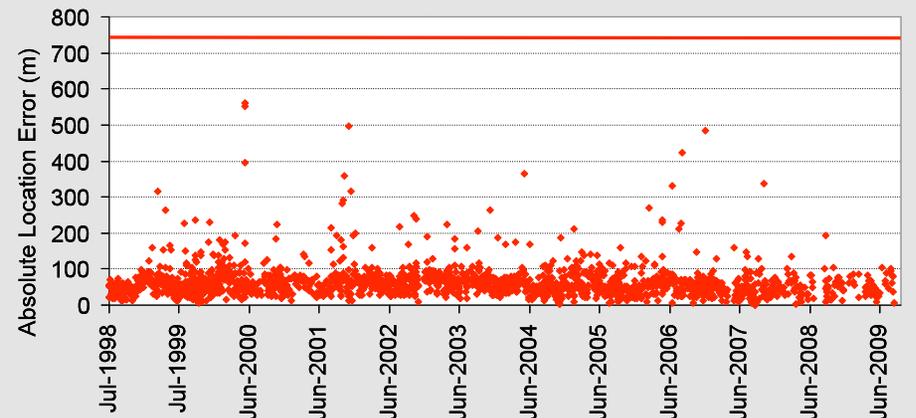
Range and Azimuth 3 dB Impulse Response Width (3 chirp bandwidths)



2D Integrated Side Lobe Ratio



Absolute Location Accuracy





NESZ

R1: requirement: < -18.5 dB, design goal at < -21 dB

R2: general requirement at < -21 dB, worst-case (EOL) estimates for each beam.

Achieved:

R1: measured early in the mission:

< -23 dB for the 30 MHz BW, and;

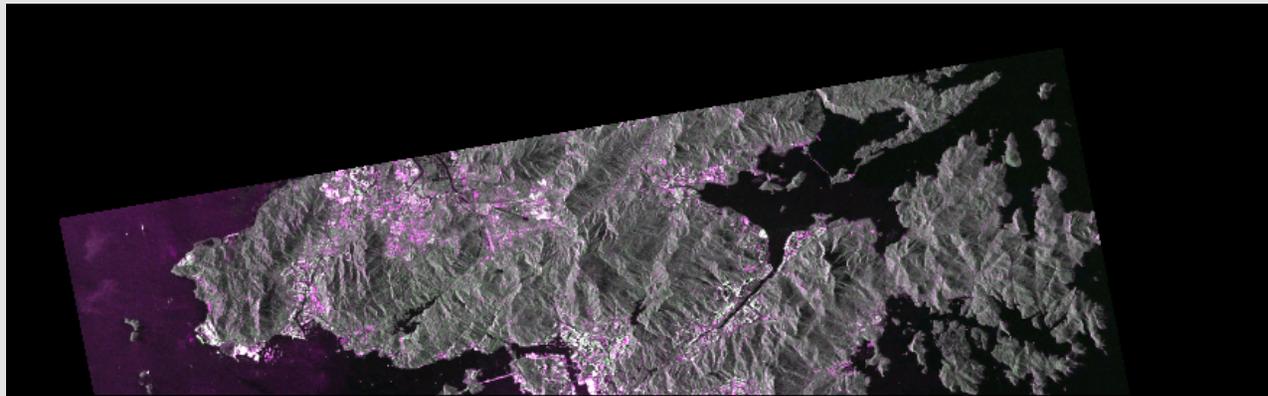
< -25 dB for the 11.6 MHz BW.

R2: estimates from low backscatter scenes so far indicate NESZ to be lower than their corresponding worst case (EOL) estimates.

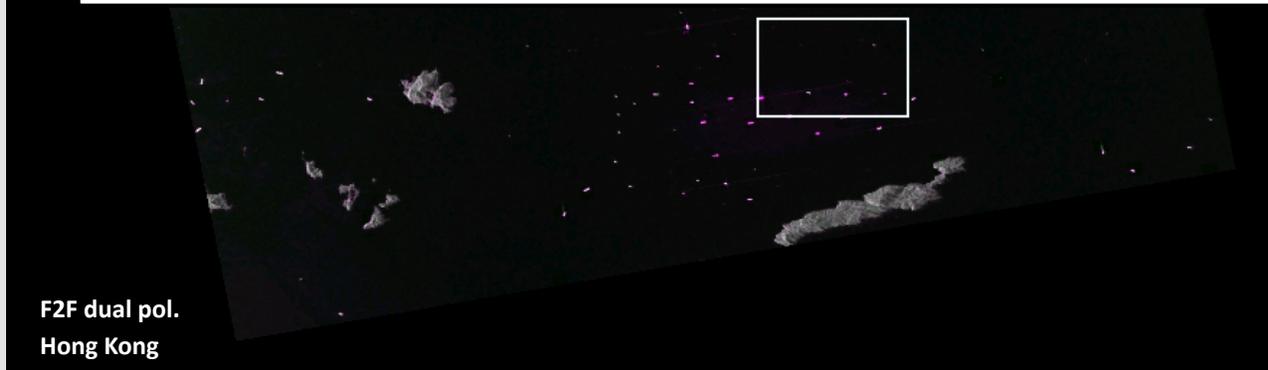
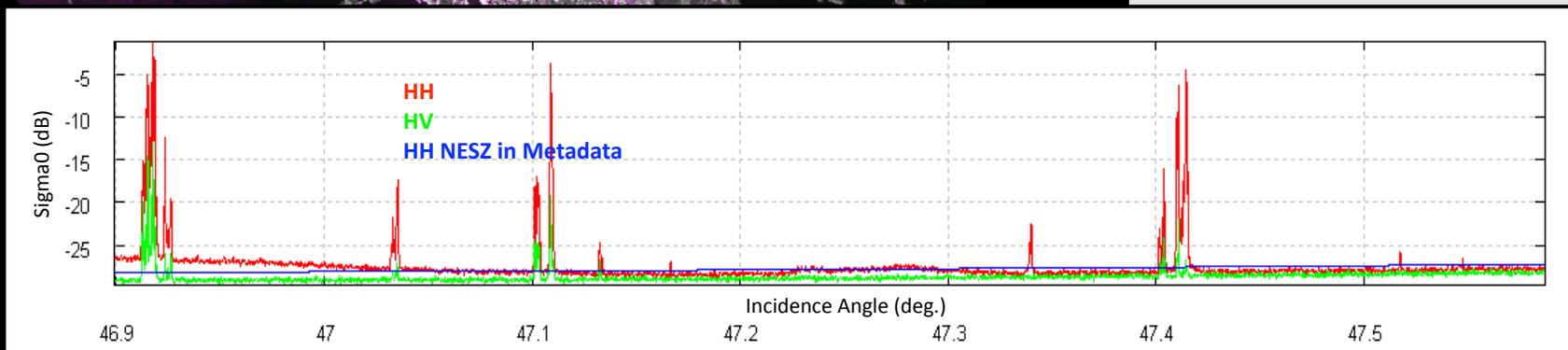
Channel Isolation in Quad Pol. products

R-2 polarisation crosstalk measurements continued from quad pol data (HH, VV, HV, VH) at the transponder/trihedral site.

< -39 dB for calibrated products (R. Touzi, PolInSAR 2009)



NESZ estimates are compared against the NESZ profile provided in the product's metadata.



The NESZ profiles of the metadata are commensurate with Sigma-0 estimates from low backscatter scenes.



The CSA has operated the RADARSAT-1 Calibration Plan since 1997:

- IQ parameters have remained stable, better than their related SAR impulse response design goals.
- Using the Amazon area, relative radiometric accuracy for single beams has been maintained to within 1 dB for more than 12 years, through recalibrations.
- The Amazon being out of range of certified receiving stations, the Canadian boreal forest is used as a distributed target area since termination of OBR operations.

In its mandate to monitor the RADARSAT-2 SAR image quality, the CSA reports:

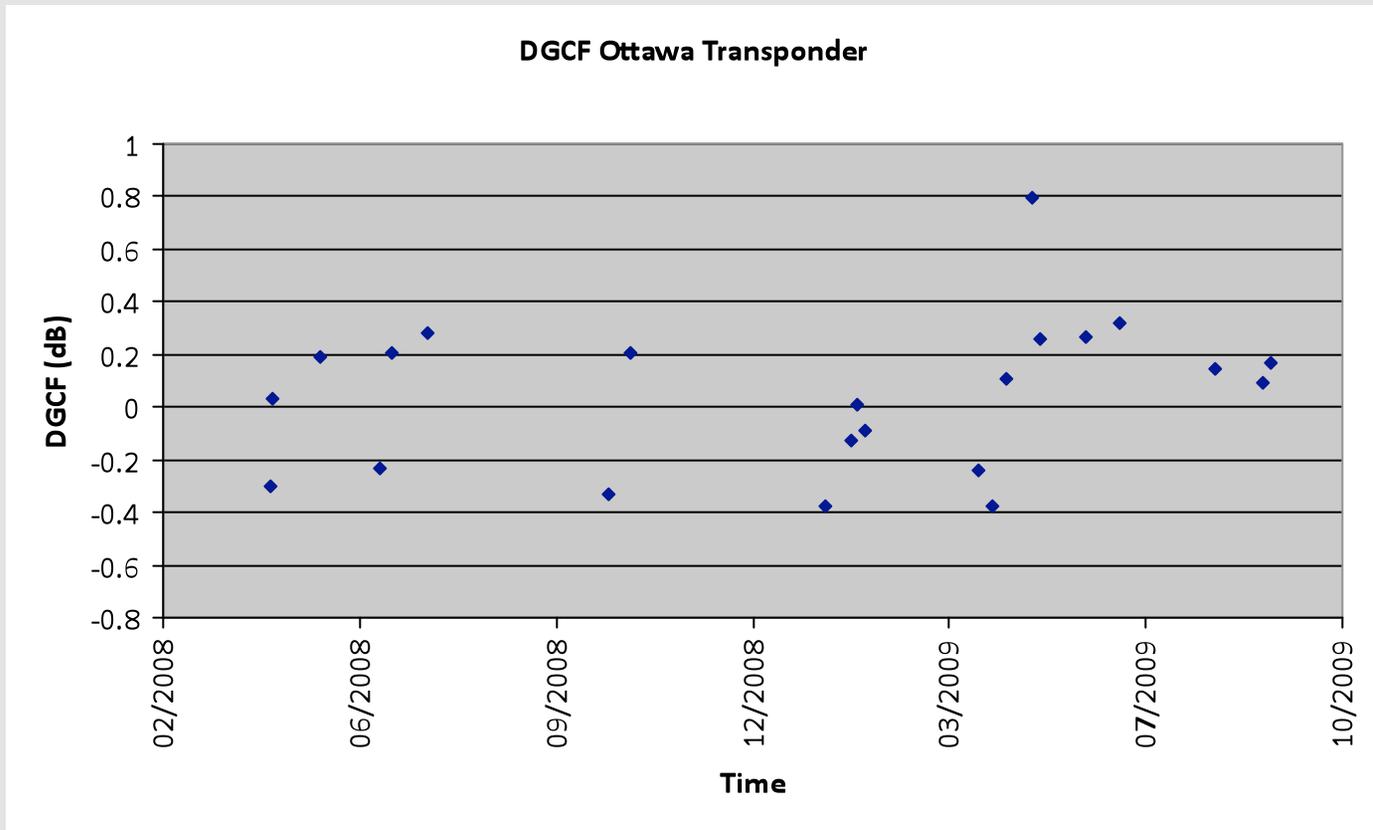
- That the performance of the RADARSAT-2 SAR instrument is compliant with, and more often superior to, the requirements and design goals set out in the R2 Mission Requirement document (radiometric accuracy, impulse response parameters, location error, distortion, NESZ and isolation).
- That GoC clients are very satisfied with overall image quality – most issues are related to the high dynamic range, making ambiguities and similar effects visible on high contrast scenes despite compliant levels.



DGCF – Ottawa Transponder



Canadian Space Agency
Agence spatiale canadienne



$\mu = 0.008$

$\sigma = 0.578$