Report on CEOS WGCV SAR Subgroup Activities

Presented at

CEOS WGCV 30th Plenary
Ilhabela, SP, Brazil
May 26 – 29, 2009

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CEOS WGCV SAR Subgroup

- Action Plan:
  - Annual Workshop/Meeting
  - Set up, characterize standard CAL/VAL sites – inter-sensor comparison
  - Calibration specification, requirements and techniques for Polarimetry, Interferrometry, POLInSAR
  - Support **GEO Tasks**
- Recent Annual Workshop/Meeting
  - 2008 – Hosted by DLR in Oberpfaffenhofen, Germany
  - 2007 – 7th Advanced SAR Workshop, hosted jointly by CSA and CEOS WGCV SAR Subgroup in Vancouver, Canada
  - 2006 – Hosted by University of Edinburgh in Edinburgh, UK
  - 2005 – Hosted jointly by DSTO and University of Adelaide in Adelaide, Australia
  - 2004 - Hosted by ESA in Ulm, Germany
  - 2003 – 5th Advanced SAR Workshop, hosted jointly by CSA and CEOS WGCV SAR Subgroup in Saint-Hubert, Canada

16th CEOS SAR CAL/VAL Workshop/Meeting (2008)

- Hosted by German Aerospace Center (DLR)
- Held on November 27 - 28, 2008 in Oberpfaffenhofen, Germany
- Attended by more than 60 people from different countries
- Had nine oral sessions and one poster session (RADARSAT-2, COSMO-SKYMED, TerraSAR-X, TerraSAR-X/TanDEM-X, Processing, Performance Update on Running Missions, Calibration Techniques & Targets, Sentinel-1 & KOMPSAT-5, Propagation)
- 44 Presentations were made
- Workshop concluded with a presentation of session summaries and discussions and recommendations made to WGCV
- Workshop Proceedings produced and distributed on CD to attendees by DLR
- For details visit http://www.dlr.de/HR/ceos2008

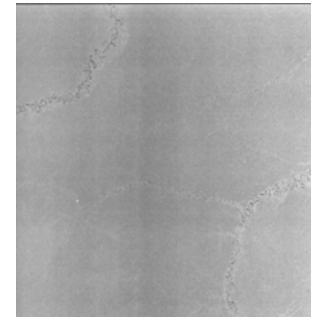
Next CEOS SAR CAL/VAL Workshop/Meeting

- Will be hosted by JPL
- A 2-day Workshop to be held in Pasadena, CA on November 17-18, 2009
- First Announcement to follow in a few weeks

Natural Calibration Sites

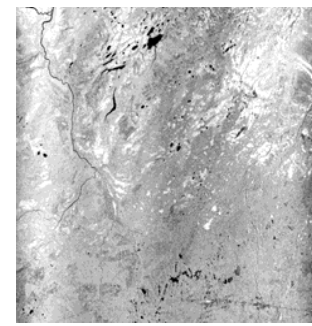
➢ International Amazon Rainforest Site

- A CEOS radiometric calibration reference site (WGCV 2004)
- Data routinely collected and analyzed for calibration monitoring of SAR satellites, including RADARSATs
- Radiometry of the site remains stable



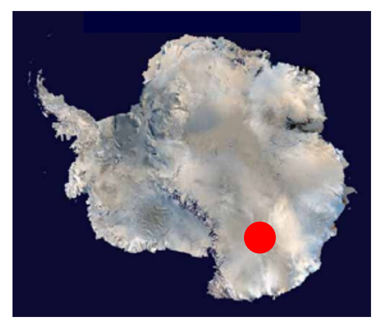
➢ Canadian Boreal Forest Site

- Radiometric characterization completed at C-band using RADARSAT-1 data
- Site seasonally dependent
- Can be used as a reference site, but with reduced radiometric accuracy



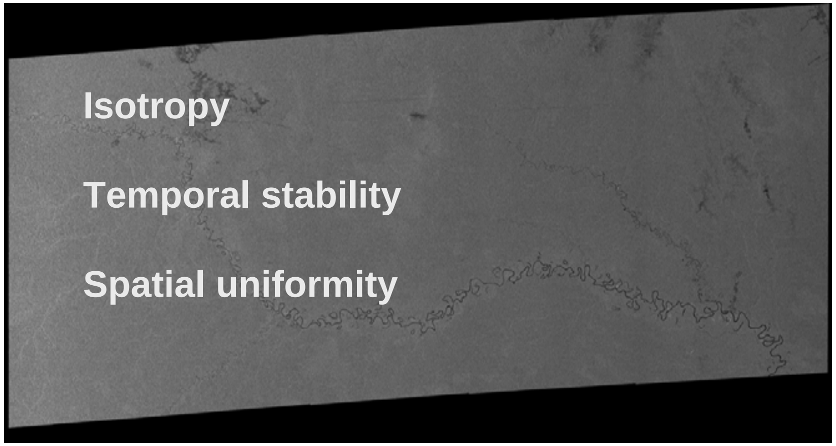
➢ Antarctica – Dome-C Site

- Radiometric characterization ongoing at C-band using RADARSAT-2 data



Radiometric Calibration: Amazon Rainforest

Rainforest Properties

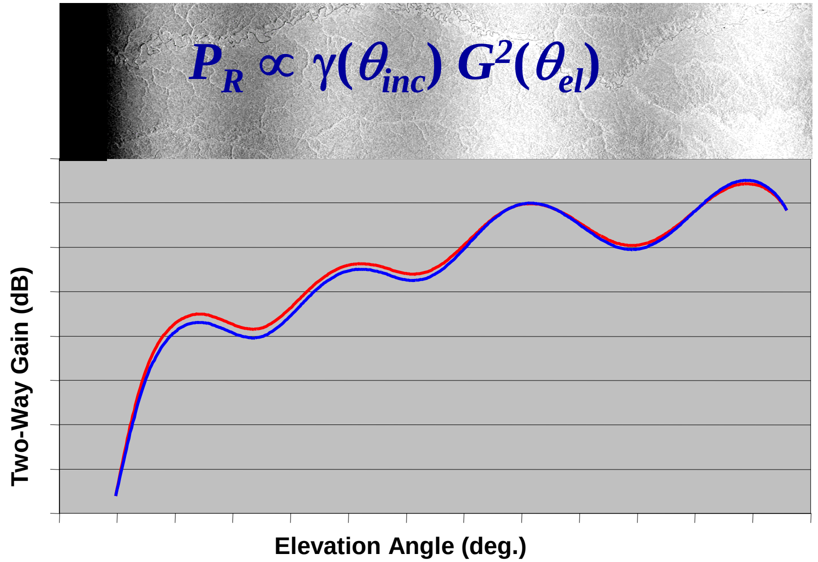


Radiometrically well characterized

Recognized distributed target reference:

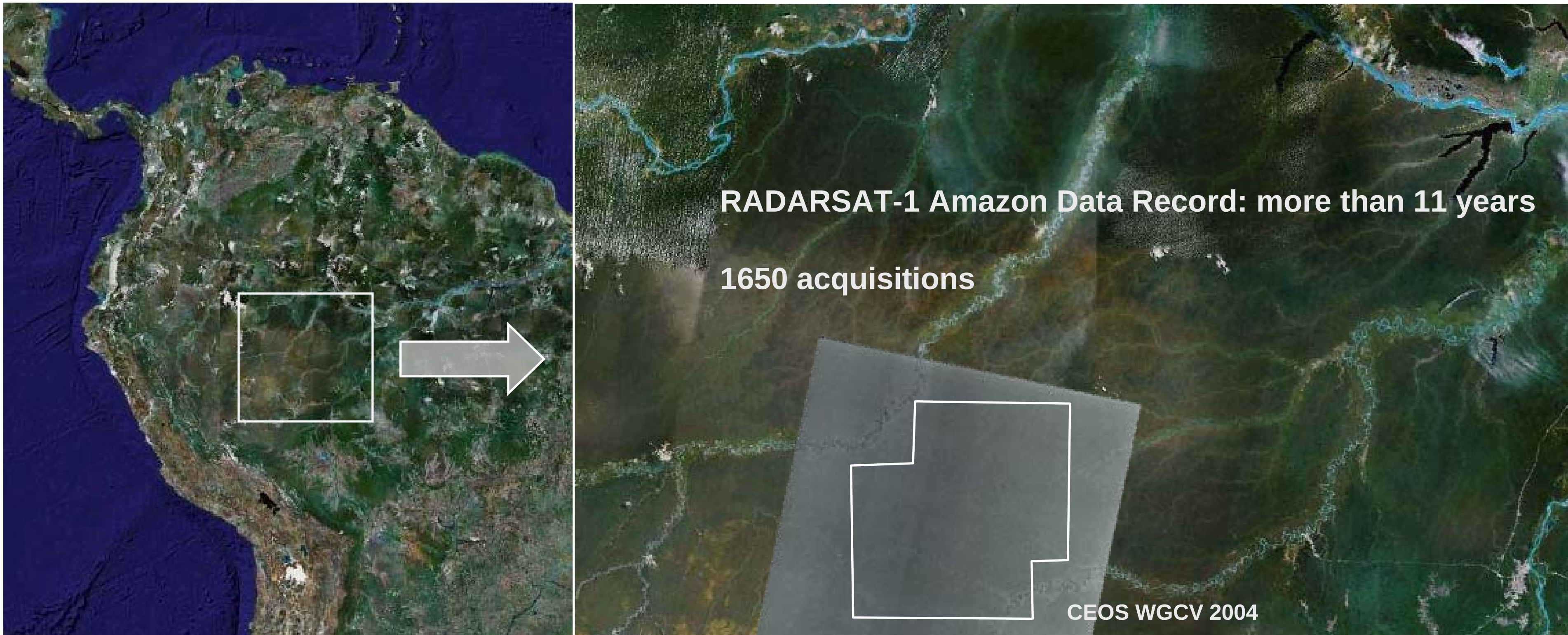
- 1978 Seasat (L)
- 1985 SIR-B (L)
- 1991 ERS-1 (C)
- 1992 ERS-2 Scatterometer (C)
- 1994 SIR-C (X)
- 1992 JERS-1 (L)
- 1996 RADARSAT-1 (C)
- 2002 ENVISAT (C)
- 2006 ALOS PALSAR (L)
- 2007 TerraSAR-X (X)
- 2008 RADARSAT-2 (C)

Use of Amazon imagery (uncorrected)



- ➢ **Extraction of in-flight elevation beam pattern from Amazon Rainforest images (antenna pattern correction off)**
- ➢ **Range averaging → Elevation beam pattern**
- ➢ **Comparison against calibrated pattern (reference stored in processing)**
- ➢ **Calculate pk-pk deviation: 1 dB tolerance**

Radiometric Calibration: Amazon Rainforest

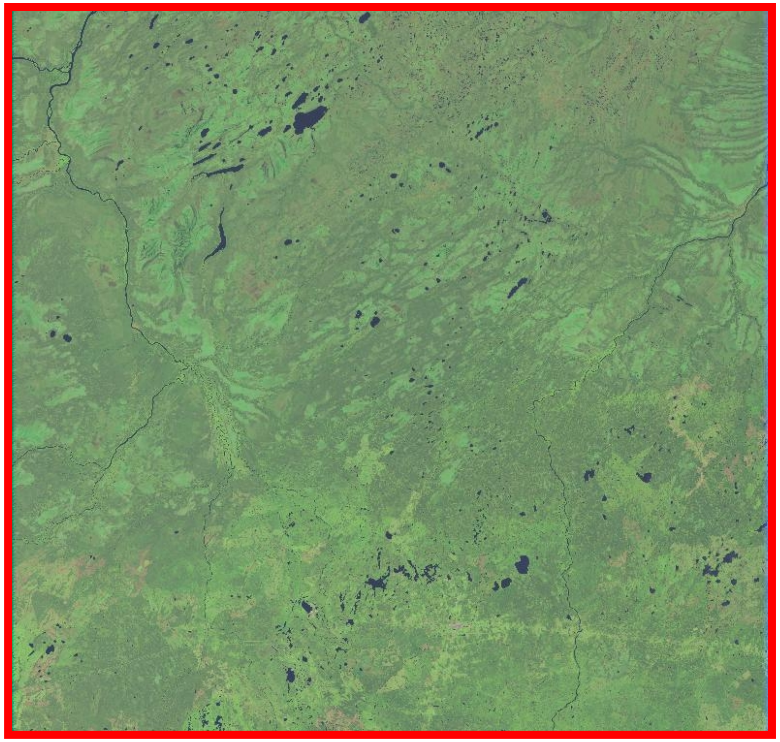


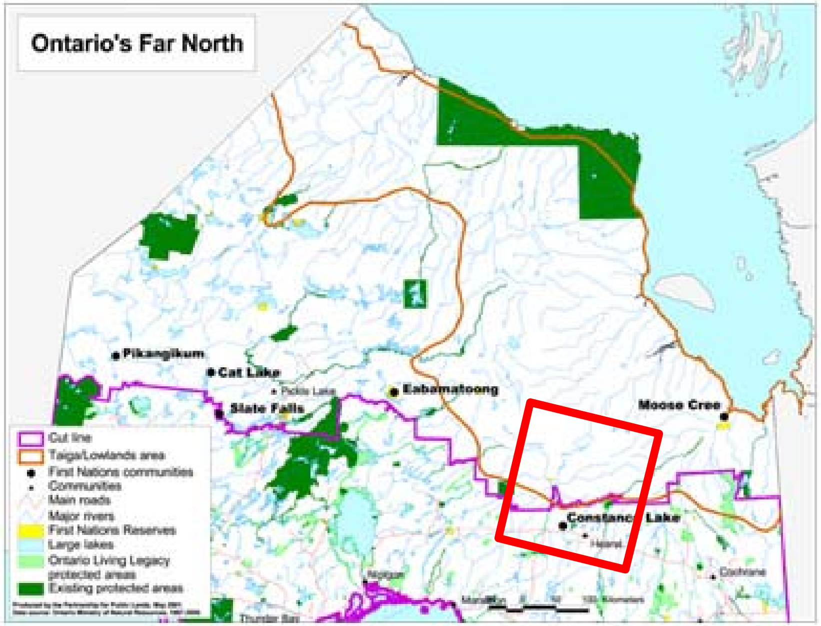
- **In July 2008, latest performance assessment of the remaining On-Board Recorder (OBR) led to a new policy for preserving the life of the OBR, restricting its usage**
- **In February 2009, further reliability analysis led to terminate the use of the OBR**
- **Since February 2009, the Boreal Forest site is now the prime area for the radiometric calibration monitoring of RADARSAT-1, as it is within reach of Canadian receiving facilities**
- **Boreal forest site has now been characterized and exploited for 5 years**

Canadian Boreal Forest - Hearst Site

- **Northwestern Ontario landmass (Hudson Bay basin)**
- **Boreal Forest-Barrens transition**

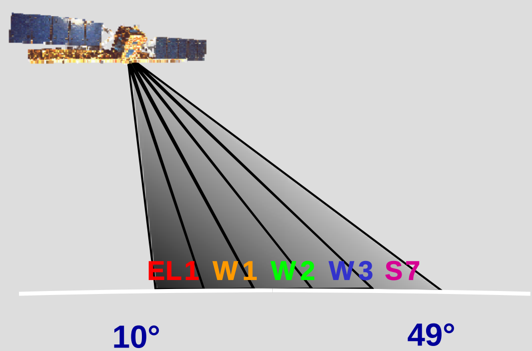
  boreal spruce, balsam fir, jack pine, poplar, birch, tamarack, cedar
- **Seasonal Variations**

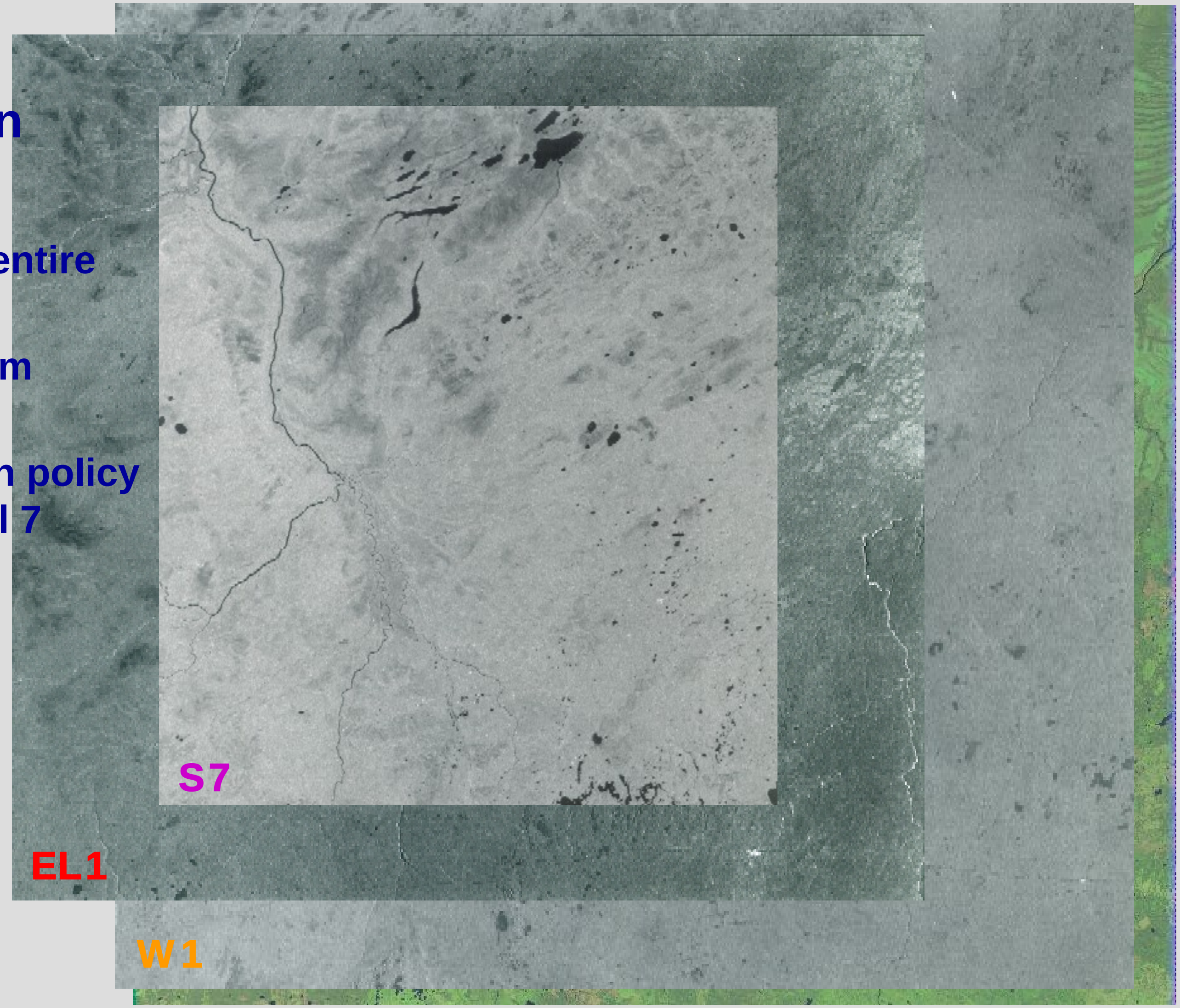


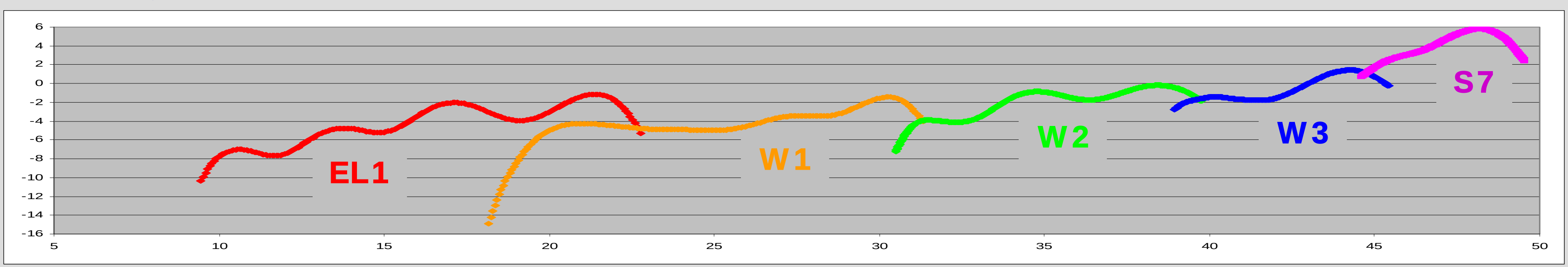


RADARSAT-1 Measurement Campaign

- Started January 2003
- Using beams covering the entire R1 incidence range
- 2 to 4 products of each beam every 24-day cycle
- In summer 2008, acquisition policy was expanded to include all 7 Standard beams (S1-S7)
- 1000 acquisitions to date

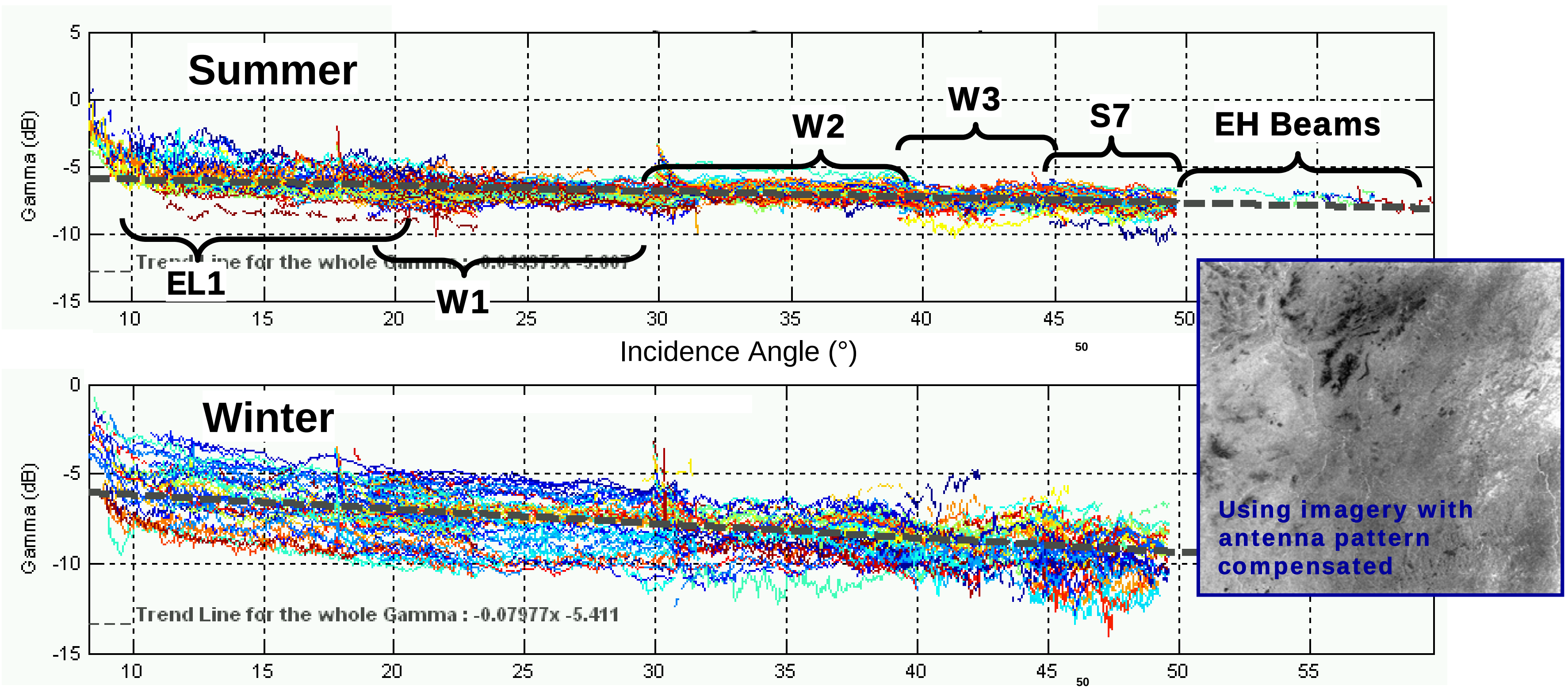






Boreal Forest: Seasonal Reflectivity

Gamma measurements from Boreal Forest imagery, as of May 2009



No change in reflectivity levels since last report (Sept 2009)

- **Gamma centered around the well-known Rainforest value (-6.5 dB)**
- **Linear dependence conforms to clutter models**
- **Large spread of reflectivity levels in winter, but first degree dependence (slope) remains**

Elevation Beam Pattern Estimation Tests

Between June 2004 and January 2009, beam patterns (G) were monitored using seasonal reflectivity estimates ($<\gamma>$) of the site, derived for summer and winter periods

$$G^2(\theta_{el}) \propto P_R / <\gamma>(\theta_{inc})$$

Procedure (as with Amazon imagery):

1. **Extract beam pattern by removing seasonal reflectivity estimate $<\gamma>$ of the area**
2. **Compare with current calibrated pattern and measure deviation: peak-peak of pattern difference (dB)**

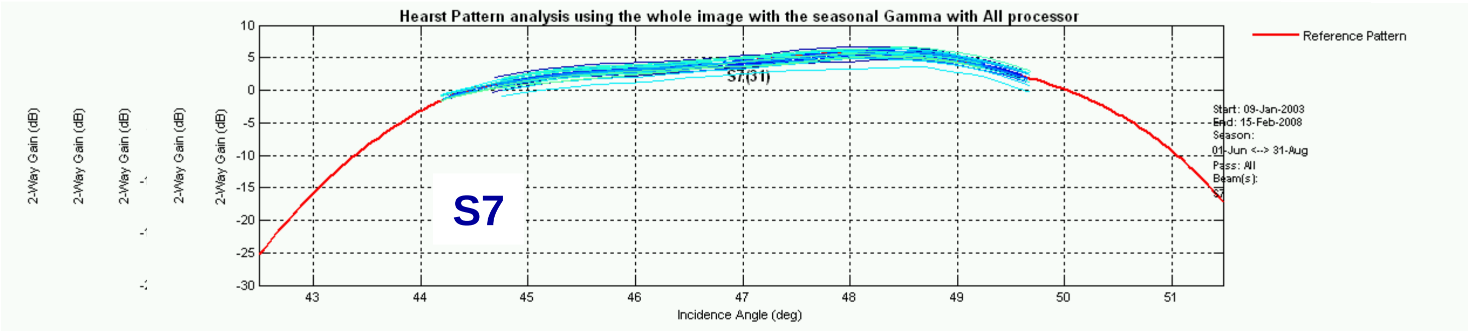
- **Latest results further confirm long-term stability of the radiometric measurements, and the validity of overcoming seasonal variations with sufficient averaging**
- **As the tested beams were considered calibrated during the campaign, these results represent the achievable radiometric accuracy of the area, for a seasonal-based approach (Amazon allows <1 dB accuracy, entire swath)**
- **Best confidence is for summer results, excluding edges. On average, summer results outperform winter by 0.3 dB**

	Average peak-peak pattern difference (dB)			
	'Summer'		'Winter'	
	Entire Swath	Excluding Edges	Entire Swath	Excluding Edges
EL1	1.6	1.2	1.9	1.2
W1	1.4	0.7	1.5	0.9
W2	1.0	0.7	1.4	1.1
W3	0.8	0.7	1.3	1.1
S7	0.8	0.7	1.2	1.0

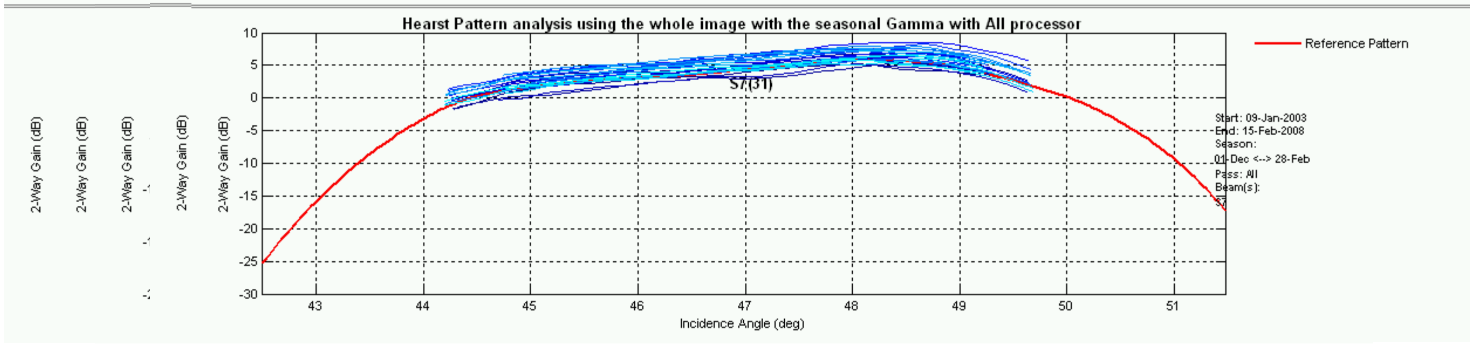
Elevation Beam Pattern Estimates

- **This seasonal-based Boreal Forest methodology is operationally used to monitor central part of elevation beam patterns within the following achievable radiometric accuracies:**
  - **Summer:** **1.2 dB for incidence angle 10.4 to 20 deg, 0.7 dB for 20 to 49 deg**
  - **Winter:** **1.2 dB for incidence angle 10.4 to 20 deg, 1.0 dB for 20 to 49 deg**
- **Transitional seasons (spring, fall) were so far discarded due to larger backscatter variations induced by freeze-thaw periods**

Summer



Winter



Boreal Forest: Current Developments

The Boreal Forest site is a favorable platform for searching more site-independent, robust methods for antenna beam pattern measurements

Search for increased time-adaptiveness:

- **The collection of gamma reflectivity profiles of the area, from 2003 to 2009, was separated in groups according to the month during which they were acquired, so 12 new terrain reflectivity profiles were then derived for beam pattern shape measurements**
- **It is hoped this method will overcome the larger month-to-month backscattering profile variations, and may allow year-round utilization of the site**
- **Monthly-based beam pattern estimates are now being compiled from scenes acquired from 2004 onwards.**
- **Achievable radiometric accuracy figures are to be derived from the monthly-based approach, will be compared with the results from the seasonal method summer and winter months.**

Boreal Forest: Current Developments

The Boreal Forest site is a favorable platform for searching site-independent, more robust methods for antenna beam pattern measurements

RADARSAT-1 / RADARSAT-2 Cross calibration approach:

- **Requires knowledge of R2 beam patterns**
- **Twin R1/R2 datatakes of the same beam modes are acquired, over the exact same area, at around the same time period**
- **Assuming that RADARSAT-2 is calibrated, the R2 beam pattern is subtracted from the R2 image, giving the 'true' backscattering profile of the site.**
- **This profile is then used for R1 beam pattern shape measurements**
- **Methodology to be further defined and achievable accuracy to be evaluated**

Dome-C RADARSAT-2 Campaign

RADARSAT-1 preliminary campaign (March 2008):

- Results showed good repeatability for backscattering measurement over small swaths
- For small swaths, beam pattern measurement tests suggests potentially good achievable radiometric accuracy
- For larger swaths acquired, the found backscattering variations are likely caused by terrain non-uniformities
- More data was required and campaign terminated due to unavailability of OBR

A RADARSAT-2 campaign was initiated in August 2008

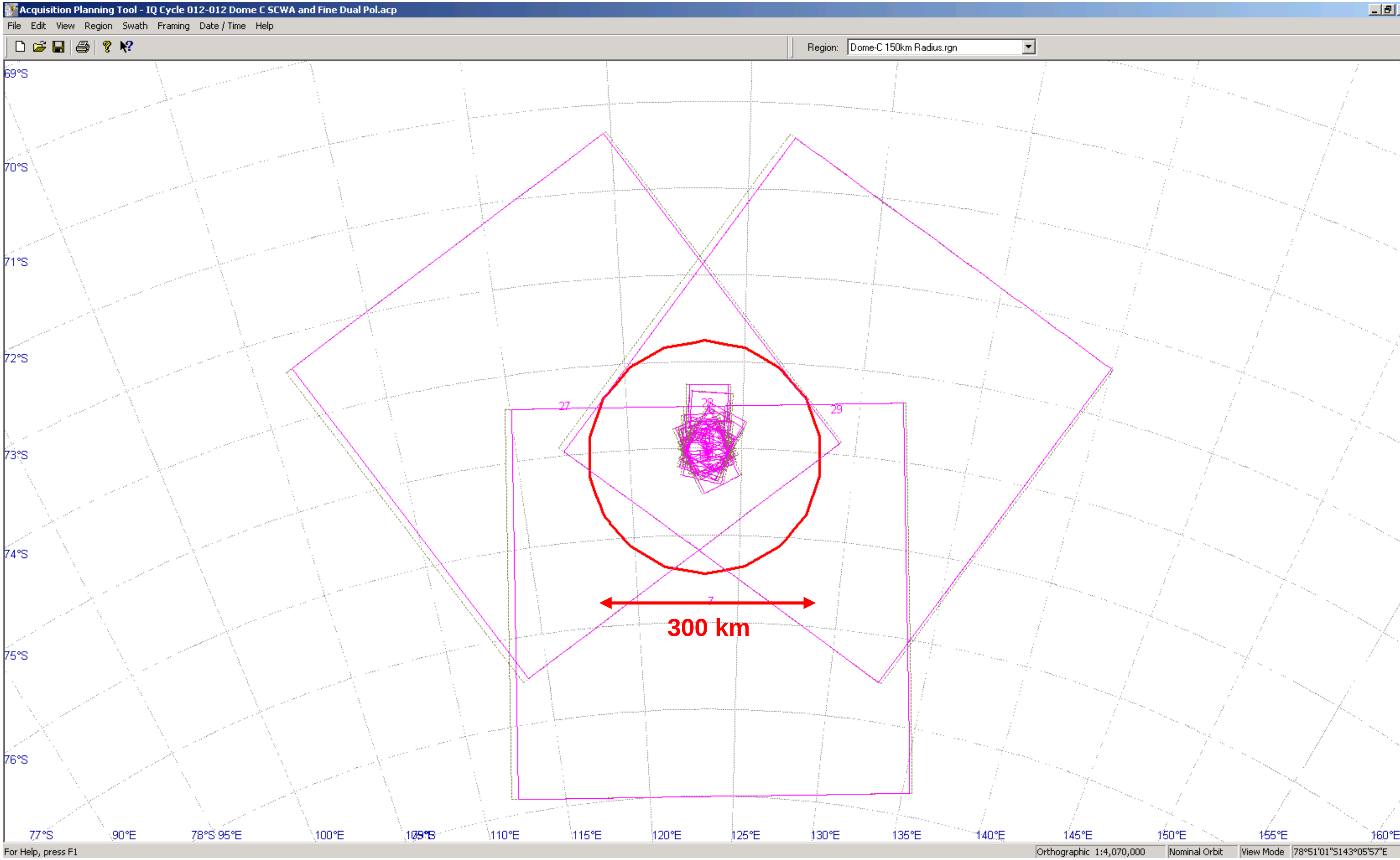
Objectives:

- Further examine the backscattering properties of the area (C-band) as a function of incidence angle
- Verify if there are backscattering changes with image orientation
- If a sufficiently large area with no spatial dependence is found, attempt derivation of backscattering models for extended antenna beam pattern measurement tests with RADARSAT-2

Acquisitions centered around the Dome-C Concordia Station:

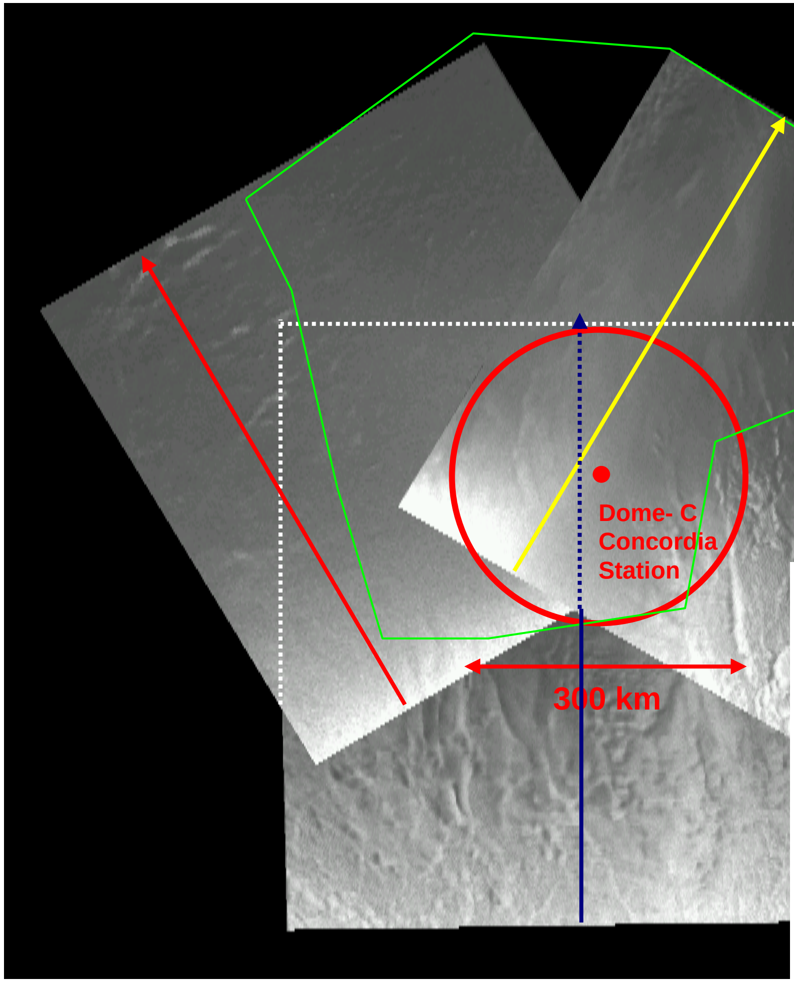
- Regional coverage made with ScanSAR images (500 km swaths).
- Local coverage made with Fine beams (40 km swaths)

Dome-C RADARSAT-2 Campaign



Dome-C RADARSAT-2 Campaign

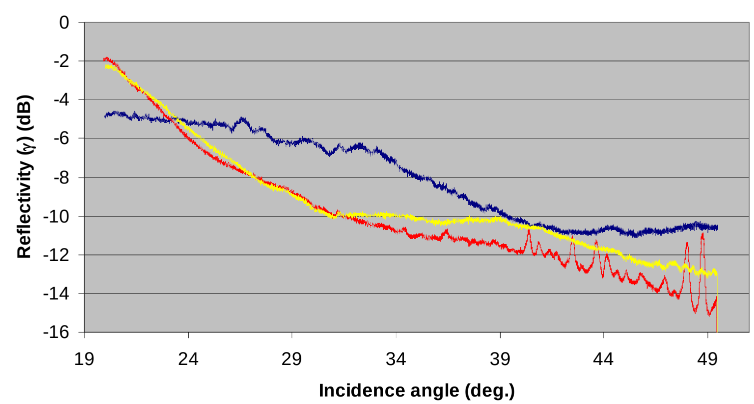
Backscatter profiles from ScanSAR data



Direct correlation between terrain features and γ profile irregular variations

Featureless terrain: approximately 100 to 500 km around the Concordia Station

Area N, NW and NE of Concordia site to be assessed



Dome-C RADARSAT-2 Campaign

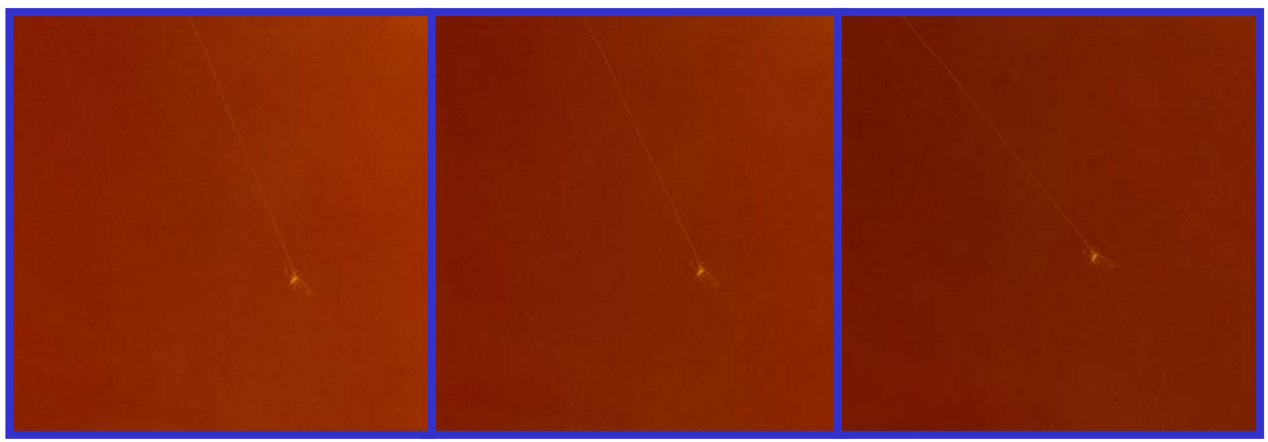
Fine data acquisitions around Concordia Station

HH Red

HV Green

Ascending

Various incidence angles

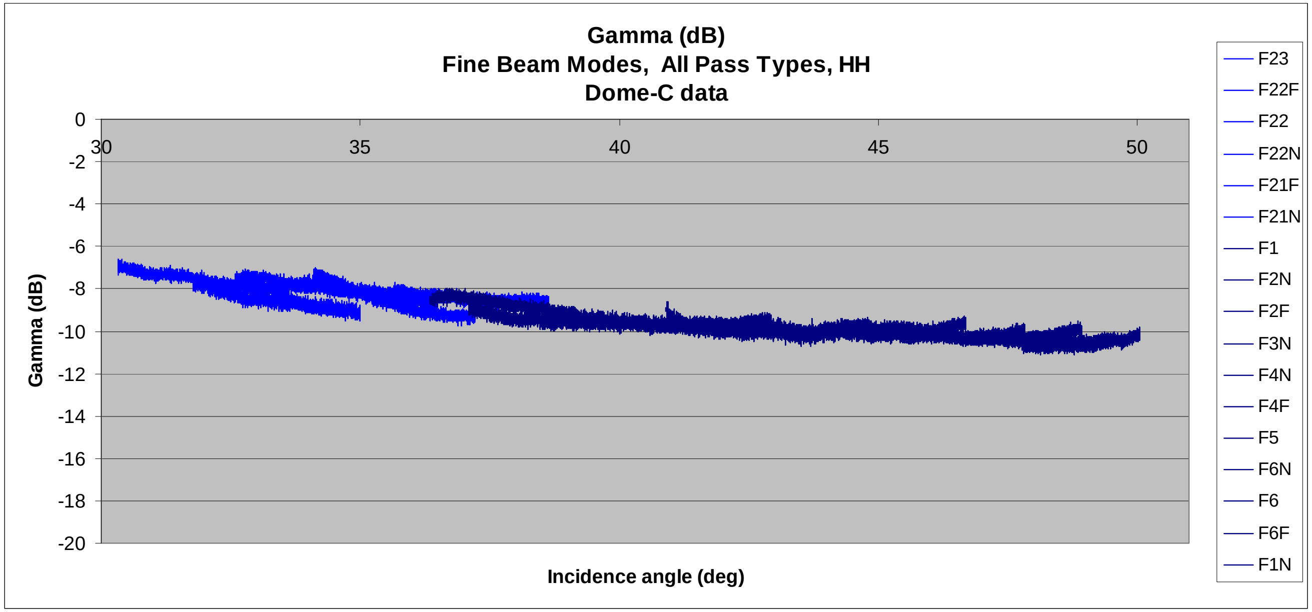


Descending

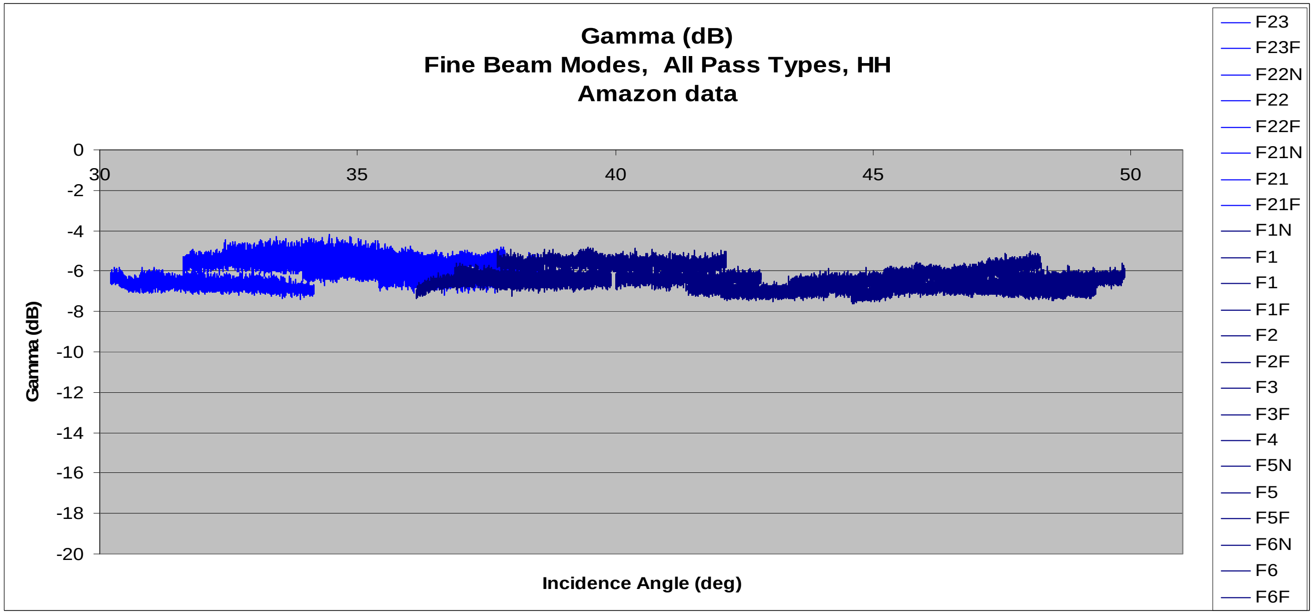
Various incidence angles

Dome-C RADARSAT-2 Campaign

Fine data acquisitions around Concordia Station



Similar modes acquired, Amazon (primary calibration site)



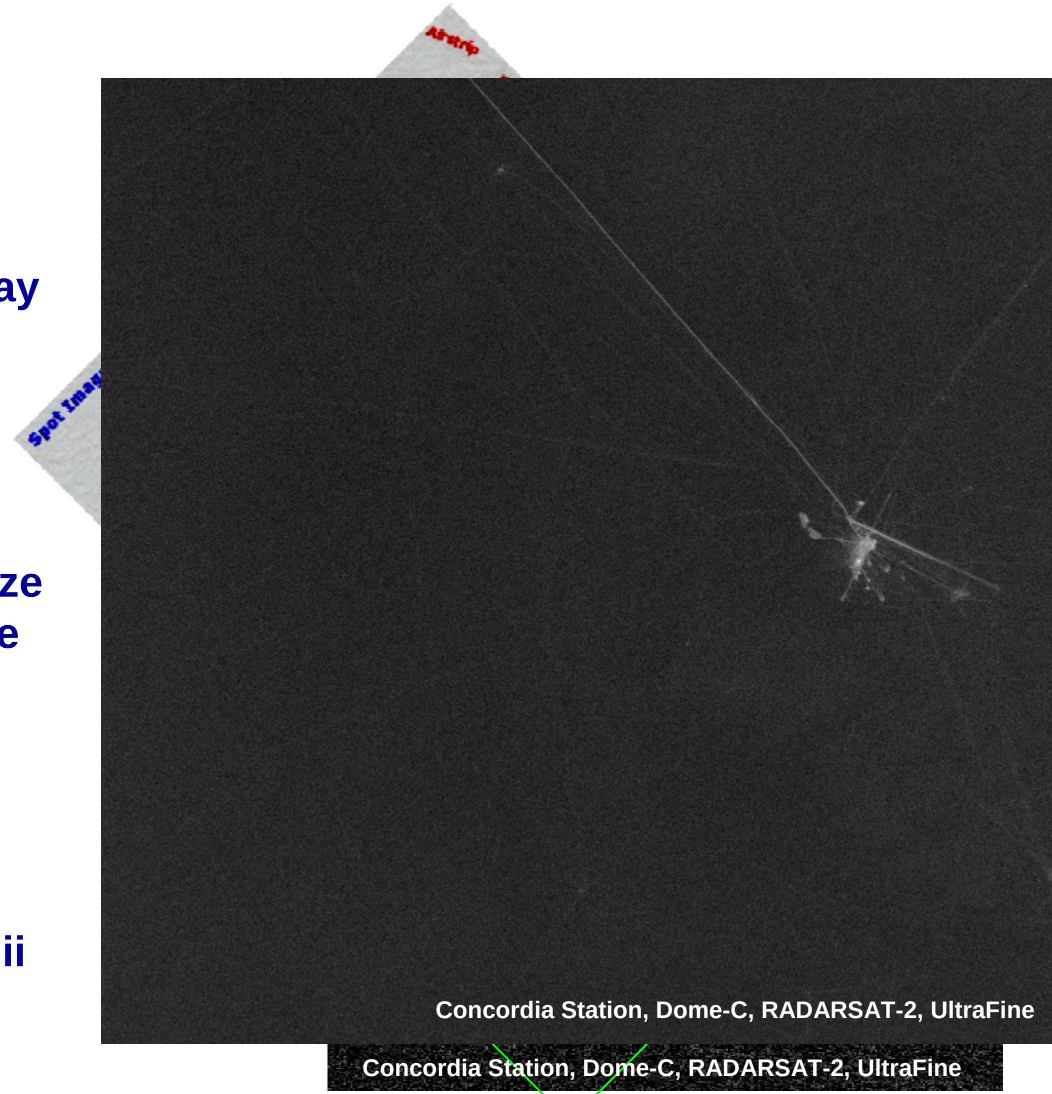
Agence spatiale Canadienne

Canadian Space Agency

Dome-C RADARSAT-2 Campaign

Fine beam results:

- Indicate a smooth, well defined backscatter profile with negative slope (HH)
- Cross-pol (HV) response may be too weak for calibration purposes, at around -17 dB



Concordia Station, Dome-C, RADARSAT-2, UltraFine

Concordia Station, Dome-C, RADARSAT-2, UltraFine

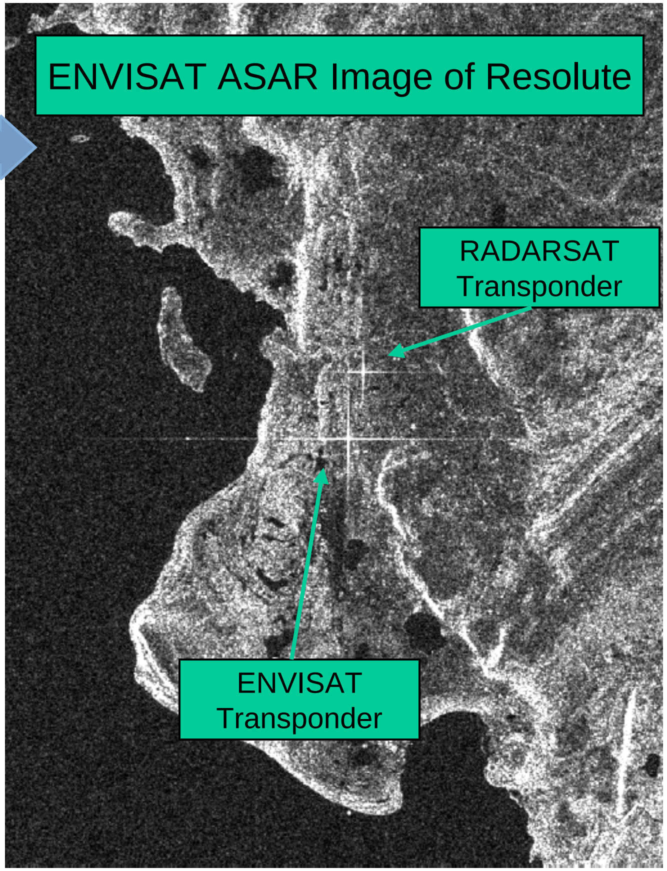
Dome-C campaign ongoing

- Acquisition of mid-swath size (100 km) data of all available incidence angles to consolidate backscattering compilation
- Planning of ultra-fine resolution data to verify mean-scale dunes / sastrugii presence and composition

Calibration Transponder Sites

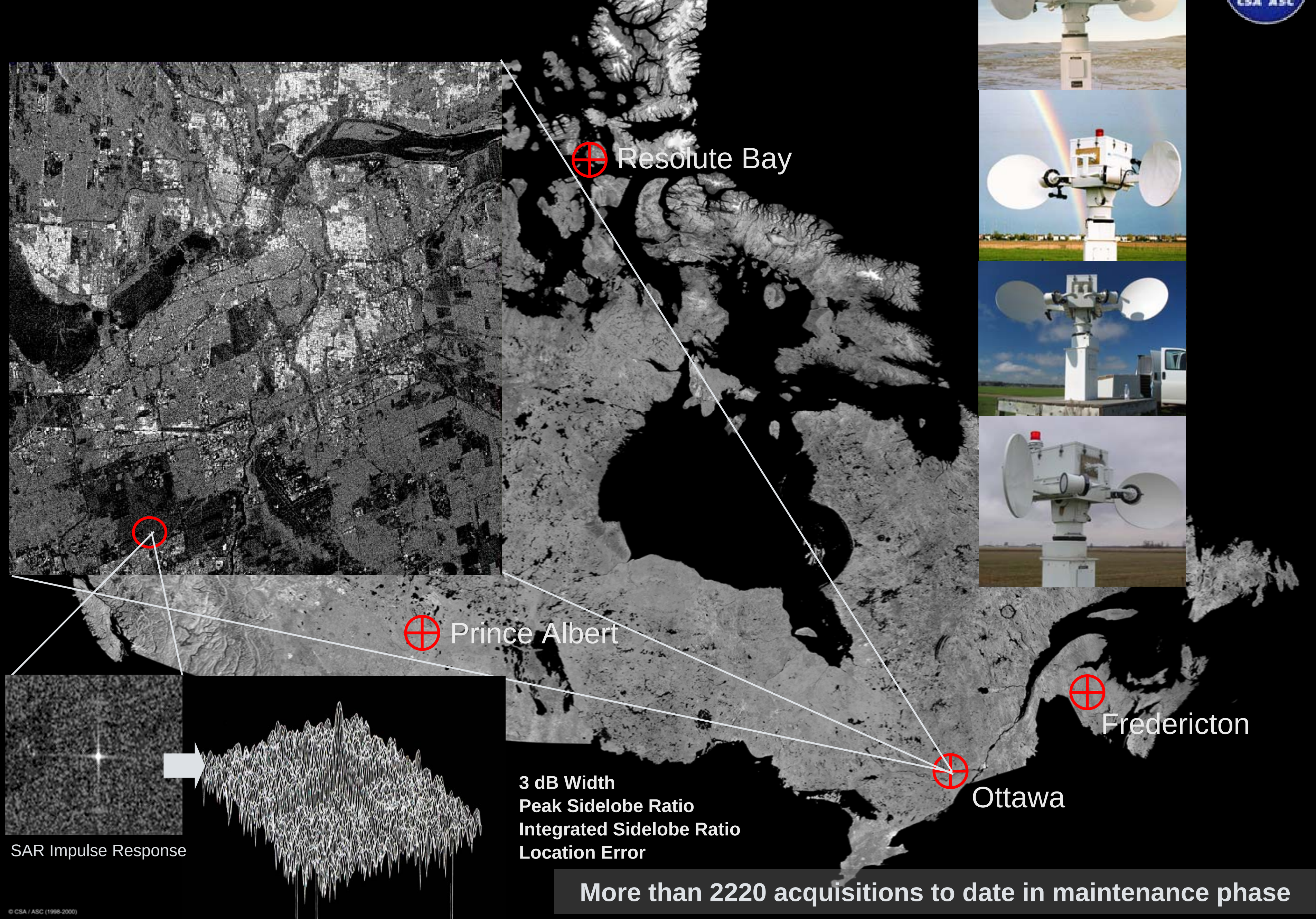
Multi-Transponder Sites in Canada

- In Fall 2006, ESA relocated an ENVISAT ASAR Transponder in Resolute Bay in vicinity of a RADARSAT Transponder
- Both transponders can be used simultaneously by ENVISAT
- In 2007 another ENVISAT ASAR Transponder was relocated in Ottawa, again in vicinity of another RADARSAT Transponder



- Two potential sites in Canada for inter-sensor comparisons for C-band SARs (e.g., RADARSAT-1, RADARSAT-2, ENVISAT)

RADARSAT-1 Precision Transponders
Point Target Monitoring



SAR Impulse Response

3 dB Width
Peak Sidelobe Ratio
Integrated Sidelobe Ratio
Location Error

More than 2220 acquisitions to date in maintenance phase

Recommendations from SAR Subgroup

- High resolution satellites are becoming surveying instruments posing strong requirements on orbit knowledge and maintenance:
  - Absolute orbit knowledge needed well beyond SAR resolution cell size; better at wavelength accuracy
  - Relative orbit knowledge needed at sub-wavelength accuracy
  - Controlled orbital spread required for advanced applications such as tomography and polarimetry
- Under sampled image products cause a performance loss in the impulse response function (IRF) impacting PSLR and resolution:
  - Space agency should only deliver products which are appropriately sampled even at the expense of an increased product file size