Report on CEOS WGCV SAR Subgroup Activities

Presented at

CEOS WGCV 31st Plenary
Washington, DC
March 2–4, 2010

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Canadian Space Agency

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
  - 2009 – Hosted by JPL & NASA in Pasadena, CA, USA
  - 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

CEOS SAR Calibration and Validation Workshop 2009

- Hosted by Jet Propulsion Laboratory (JPL) and NASA
- Held on November 17-19, 2009 in Pasadena, CA, USA
- Organizing Committee:

Yunling Lou	2009 Workshop Chair
Satish Srivastava	CEOS SAR Subgroup Chair
Scott Hensley	Technical Committee
Paul Rosen	Technical Committee
Evert Ettema	Special Consultant
Annie Richardson	General Logistics
Roger Chao	Audio-Visual
Sarah Gibas Flores	Website
Yang Zheng	Publication
Bruce Chapman	Paper Review

CAL/VAL Workshop Objectives

- Set up and characterize standard calibration and validation reference sites to facilitate inter-sensor comparison
  - Sites to include both natural and man-made targets
  - Provide an easily accessible source of reference calibration data to data providers
  - Demonstrate mutual compatibility between different SAR systems
  - Demonstrate quantitative and qualitative integrity of SAR data
  - Additional resource sharing opportunities?
  - Refresh a list of calibration sites and efforts for various SAR missions
- Develop calibration specification, requirements and techniques for polarimetry, interferometry, and POLInSAR
  - Calibration requirements should be application specific and driven by geophysical product generation
  - Identify holes in the calibration requirements for future mission implementations
  - Collect calibration and validation requirements and recommendations for the CEOS SAR Committee

Workshop Program Overview

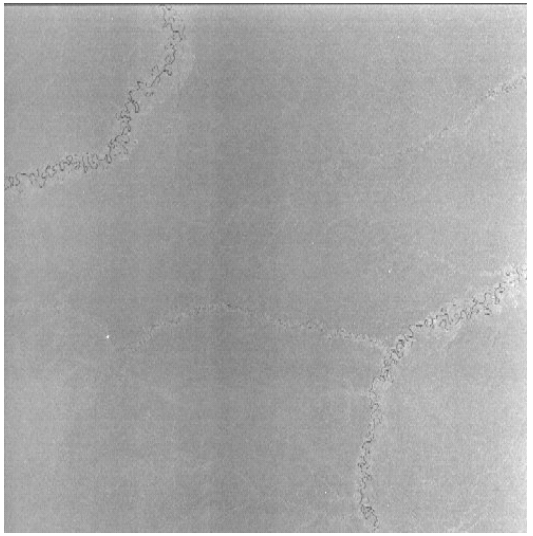
- There were five sessions covering the following topics:
  - Ongoing Missions
  - Calibration Techniques
  - Airborne Missions
  - Calibration Requirements
  - Future Missions
- Workshop was discussion-oriented
- Plenary Session on Thursday (Nov. 19) morning
  - Summarized actions and recommendations by session
- 30 Papers were presented
- 51 Participants
- CD containing the Workshop Proceedings will be released in March 2010
- Visit: http://uavsar.jpl.nasa.gov/ceos2009/postWorkshop.html

Next CEOS SAR CAL/VAL Workshop/Meeting

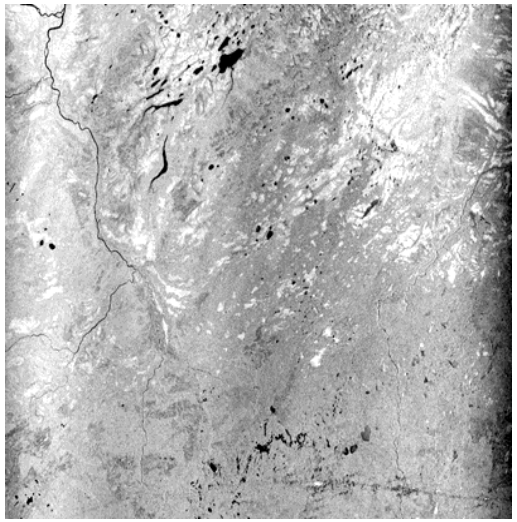
- Will be hosted by University of Zurich
- A 2-day Workshop to be held in Zurich, Switzerland on August 26-27, 2010
- First Announcement to follow soon

Natural Calibration Sites

- **International Amazon Rainforest Site**
  - CEOS radiometric calibration reference site (SAR WGCV 2004)
  - Data routinely collected for calibration monitoring of SAR satellites
  - Radiometry of the site is stable, i.e.: long-term RADARSAT-1 records show repeatable and well-characterized seasonal deviations of 0.2 dB pk-pk
  - Recent SAR (RADARSAT-2) and radiometer systems allowed to identify a slight anisotropy in C-band, from 20° to 50° incidence (WGCV SAR Workshop 2009 Pasadena):
    - The -6.5 dB constant gamma assumption is now being superseded by a linearly decreasing Gamma from about -5.9 to -6.7 dB between 20° and 50° incidence (T. Luscombe)
- **Specific areas of the Congo basin have been identified for their potential as a possible alternative**

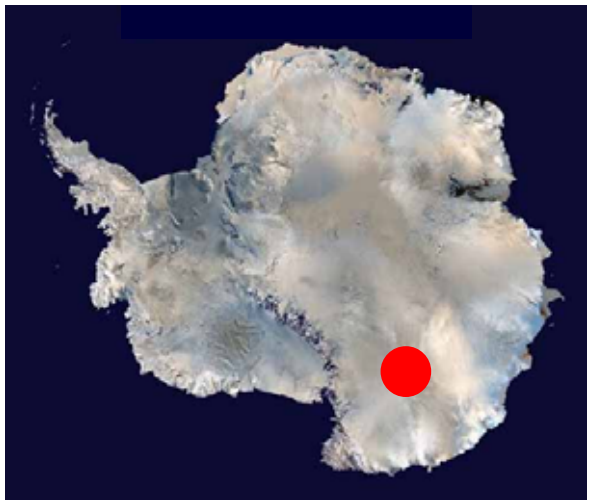


Natural Calibration Sites



- **Canadian Boreal Forest Site**
  - **Useable for RADARSAT-1 elevation beam pattern shape monitoring, but with reduced radiometric accuracy compared to tropical forest**
  - **Site is seasonally dependent: adapted backscatter models are used for different periods of the year**
  - **Summer yields good radiometric accuracy at (C-band, RADARSAT-1)**

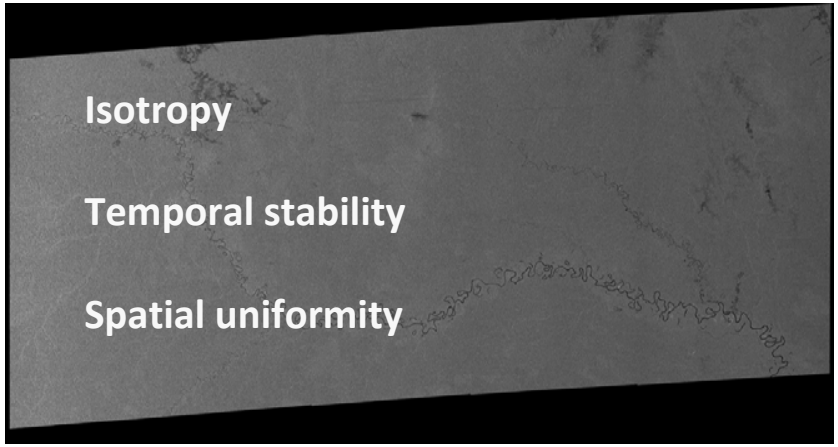
Natural Calibration Sites



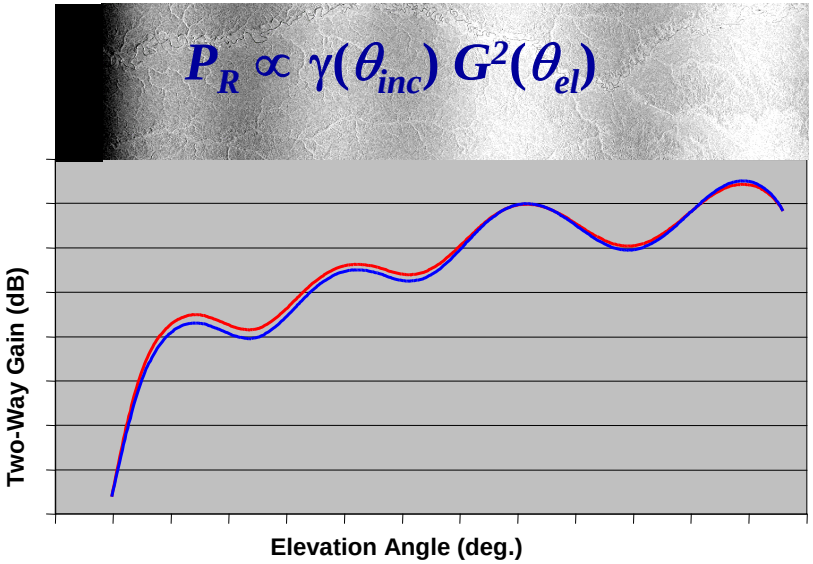
- **Antarctica – Dome-C Site**
  - Radiometric characterization continued at C-band with RADARSAT-2
  - A first backscatter model was derived
  - Radiometric accuracy was assessed from elevation beam pattern shape test measurements on small swaths
  - Very good potential for co-pol. C-band signals
  - Cross-pol. backscatter level low

International Amazon Rainforest Site

Properties



Use of Amazon imagery (uncorrected)

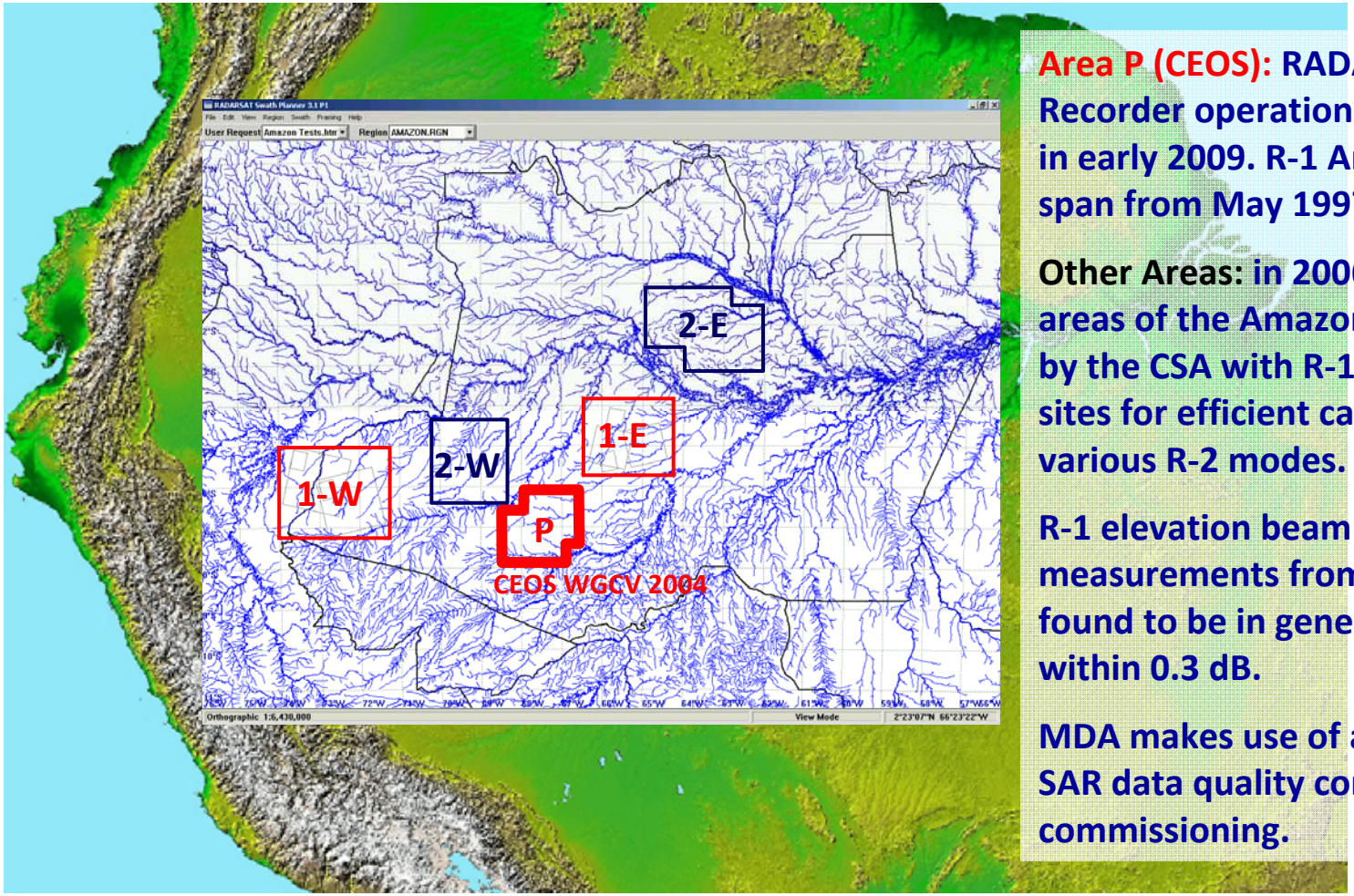


Well characterized radiometrically

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)

- Extraction of in-flight elevation beam pattern from 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

International Amazon Rainforest Site
Greater Amazon



Area P (CEOS): RADARSAT-1 On-Board Recorder operations were terminated in early 2009. R-1 Amazon data records span from May 1997 to Aug 2008.

Other Areas: in 2006-07, alternate areas of the Amazon basin were tested by the CSA with R-1, to validate extra sites for efficient calibration of the various R-2 modes.

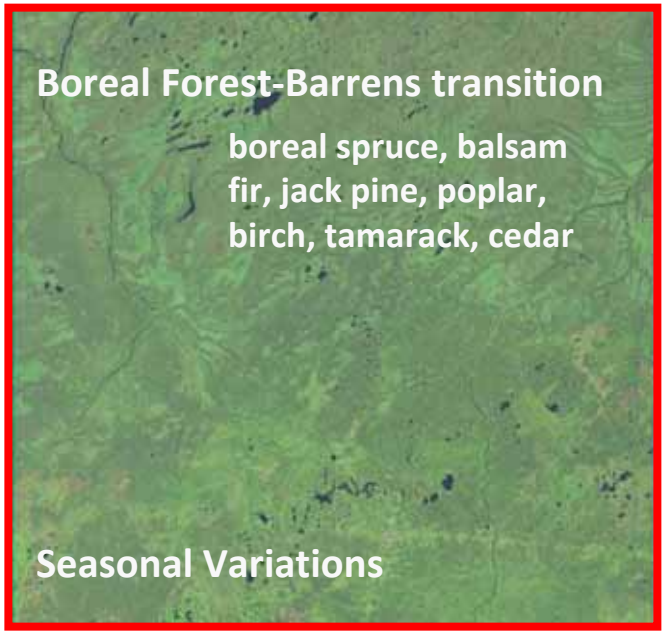
R-1 elevation beam pattern measurements from all areas were found to be in general agreement to within 0.3 dB.

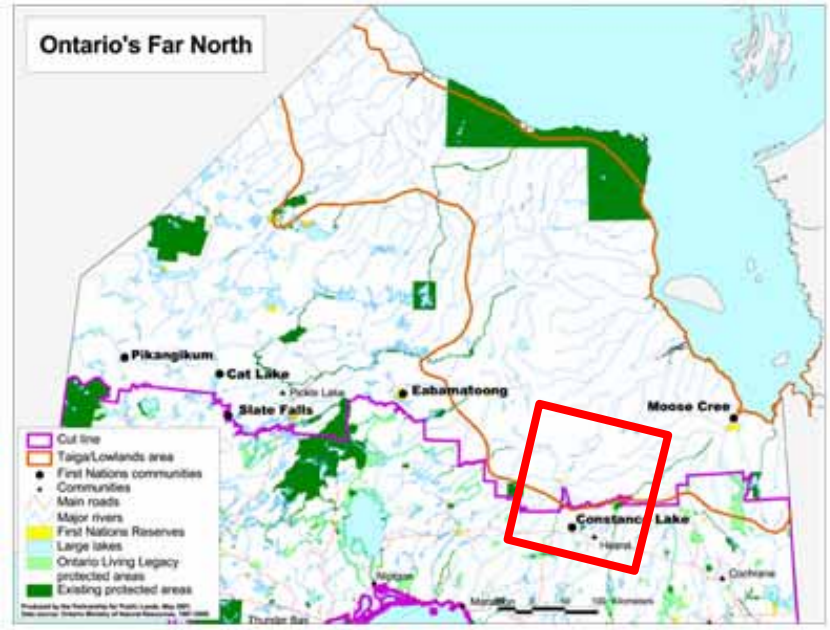
MDA makes use of all 5 areas for R-2 SAR data quality control since commissioning.

Canadian Boreal Forest Site

(Ontario, Hudson Bay basin)

- Since termination of RADARSAT-1 OBR operations, Amazon is no longer accessible to this satellite
- The Boreal Forest site is now the prime site for the radiometric monitoring of RADARSAT-1 (within reach of Canadian receiving facilities)
- The site has been characterized and exploited for 6 years





Canadian Boreal Forest Site
(Ontario, Hudson Bay basin)

Boreal Forest project - timeline

2002:
Following the R-1 Extended Mission Review, OBR was addressed as a concern and investigations began for alternate distributed target sites within Canadian masks.

2003:
Radiometric assessments were made of Tundra, Taiga and boreal forest areas. A boreal forest area in the Hudson Bay basin, Ontario, was selected for further experiments.

2003-2004:
First derivation of the area's reflectivity (gamma).

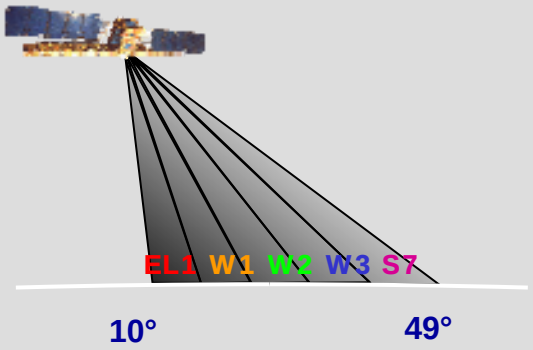
June-2004 to Jan-2009:
Radiometric accuracy measurement of scenes, based on seasonal gamma models for winter and summer.

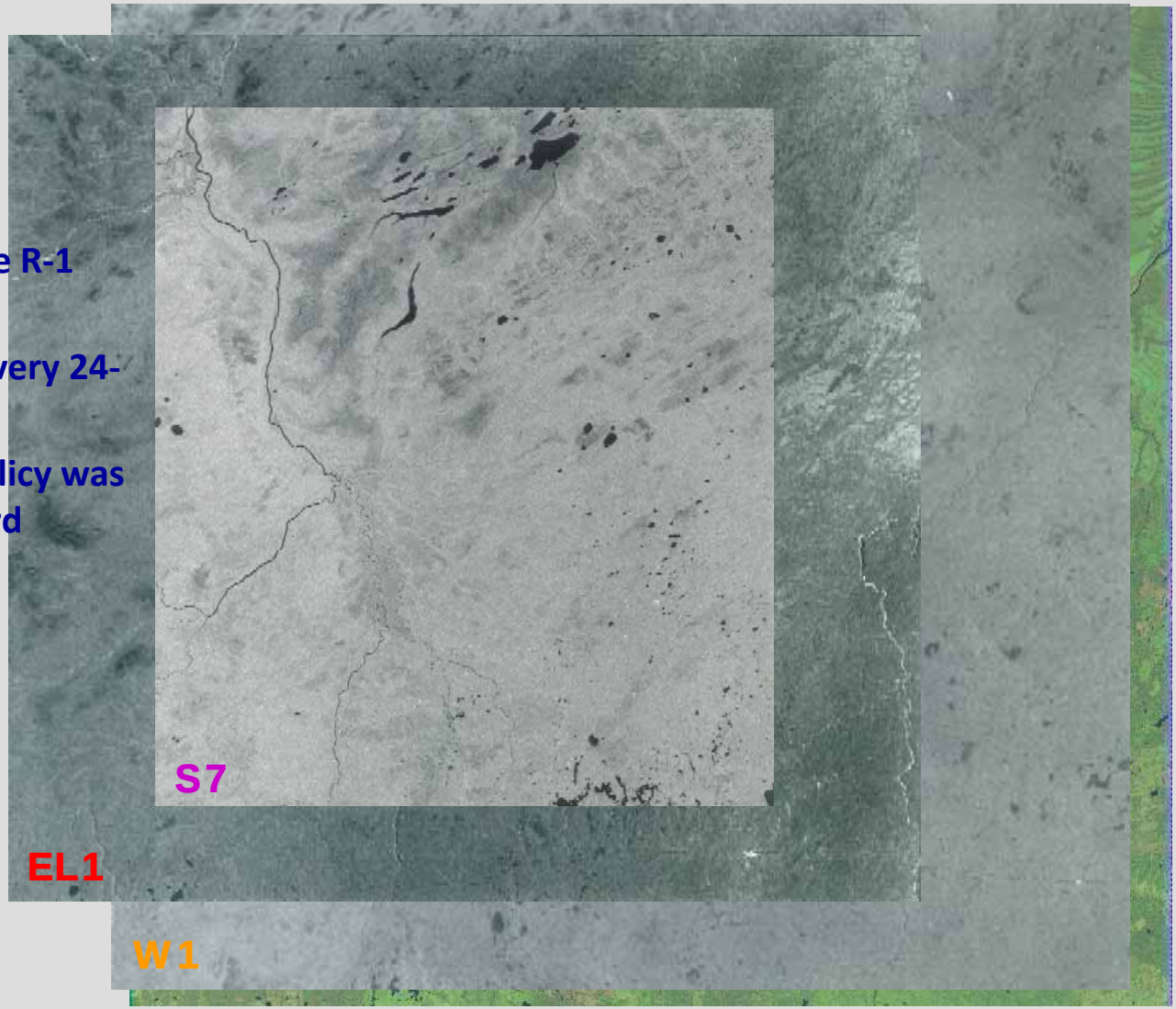
Jan-2009-Mar 2009:
Monthly gamma models derived from 2003-2008 data.

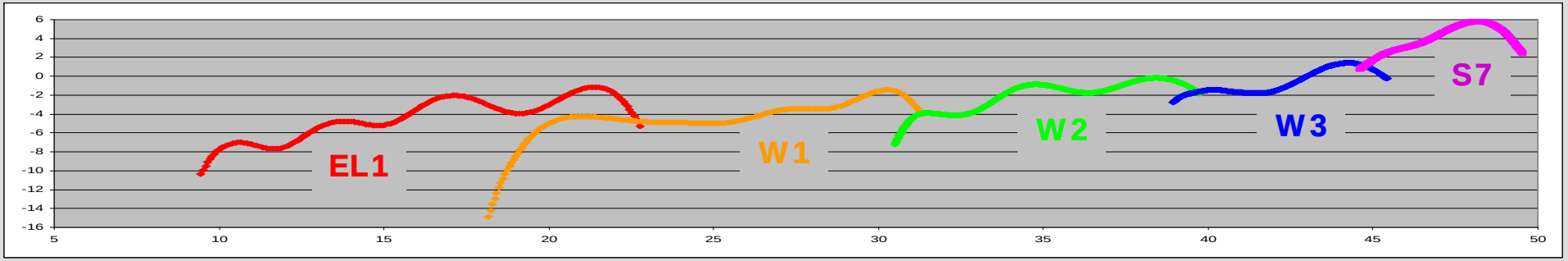
Mar-2009-today:
Routine radiometric accuracy measurements of R-1 scenes, based on monthly gamma models.

RADARSAT-1 Boreal Forest Acquisition Campaign

- Started January 2003
- Using beams covering the entire R-1 incidence range
- 2 to 4 products of each beam every 24-day cycle
- In summer 2008, acquisition policy was expanded to include all Standard beams (S1-S7)
- 1100 acquisitions to date







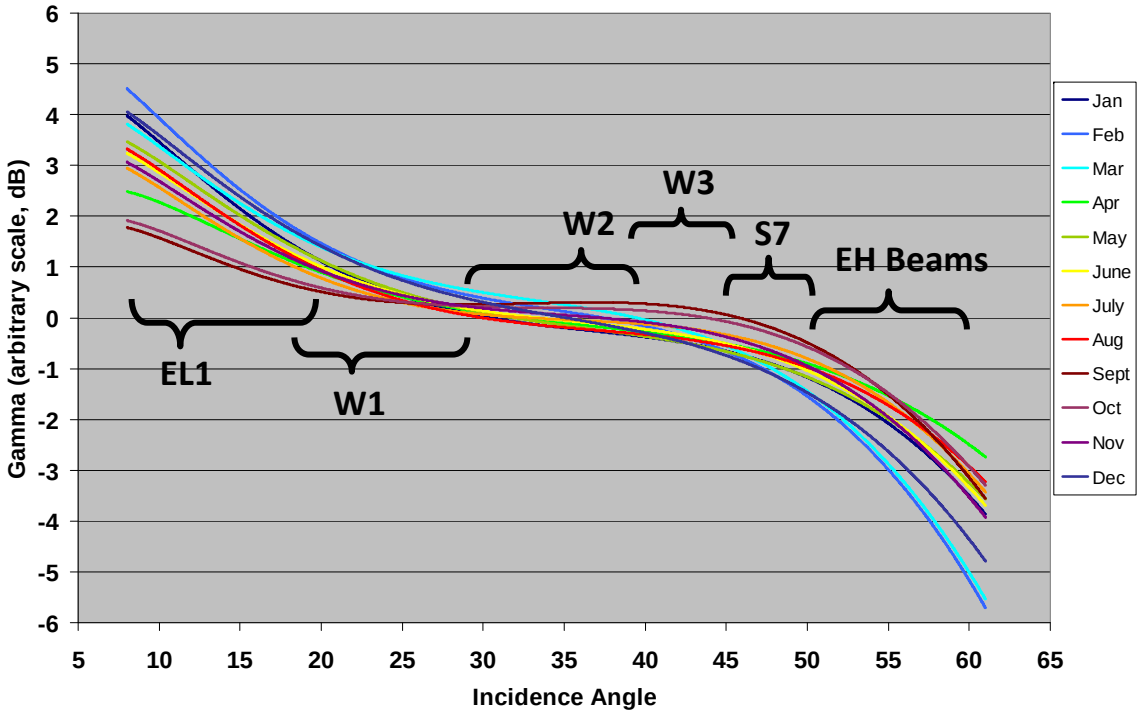
Boreal Forest: refinement of the backscatter model of the area (2009)

Modeling the area's backscatter enables exploiting the site for monitoring R-1 elevation beam patterns, assuming a useable backscatter model

Until 2009, 2 backscatter models were used ('winter' and 'summer') to overcome part of the temporal variations of the local backscatter

In 2009, the 6-yr boreal forest data collection was deemed sufficient to create 12 monthly backscatter models, to better mitigate temporal / seasonal variations

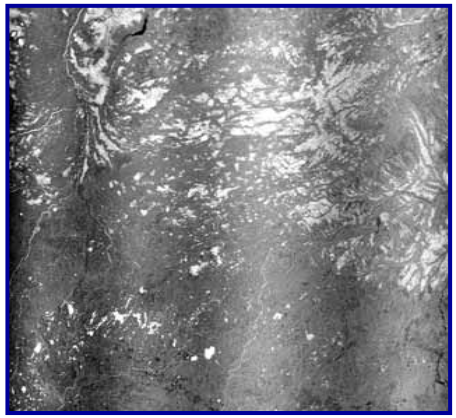
Gamma measurements from 2003 to 2009 were grouped according to their acquisition month, then averaged and fitted, …



Elevation Beam Pattern Monitoring
Achievable radiometric accuracy

Achievable radiometric accuracy of the site was evaluated from R-1 beam patterns measurements of well-calibrated beams. Data acquired since 2005 were used, using the proper monthly backscatter model:

1. **Remove proper reflectivity model of the area from uncorrected image data**



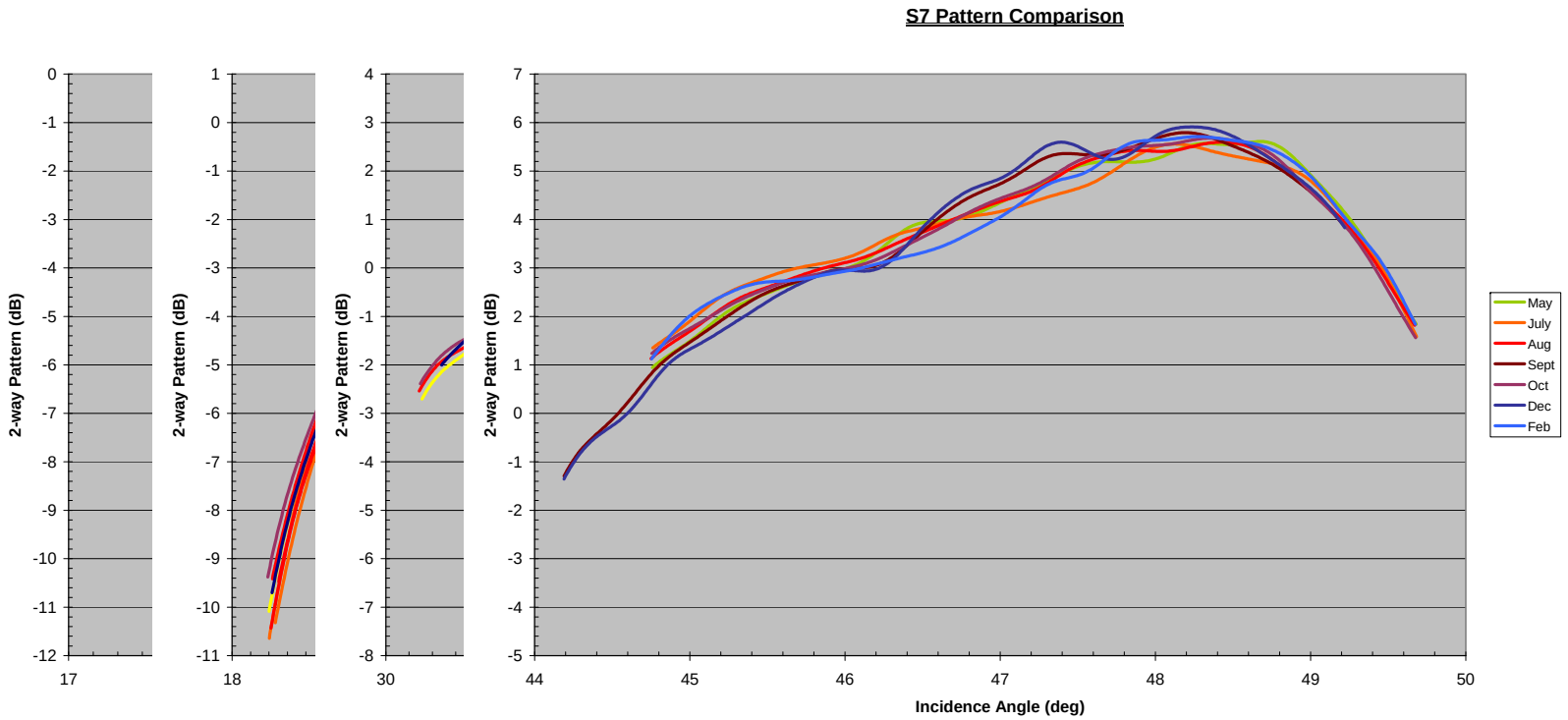
2. **Extract pattern measurement from image**
3. **Compare with reference pattern and measure deviation peak-peak of pattern difference (radiometric accuracy, dB)**

	Achievable radiometric accuracy since 2005 (dB) Boreal forest (Amazon)
EL1 (10-22°)	1.3 (1.2)
S1 (19-27°)	0.9 (1.0)
S2 (24-31°)	1.1 (0.5)
S3 (31-37°)	0.7 (0.4)
S4 (33-39°)	1.0 (0.8)
S5 (36-42°)	1.2 (0.8)
S6 (42-46°)	0.9 (0.6)
S7 (45-49°)	0.8 (0.6)
W1 (19-30°)	1.7 (0.8)
W2 (30-39°)	1.3 (0.5)
W3 (39-45°)	1.1 (0.7)
Overall (10-49°)	1.1 (0.8)

Steep pattern edges: 0.7 dB excluding edges

Exploiting the Boreal Forest for Elevation Beam Pattern Estimates

- **The monthly-based Boreal Forest methodology is now operationally used to monitor the elevation beam patterns of RADARSAT-1**
- **Radiometric accuracy: standard deviation improvement of 0.3 dB compared to the seasonal approach**



Exploiting the Boreal Forest for Elevation Beam Pattern Estimates

Monitoring R-1 using R-2 boreal forest data

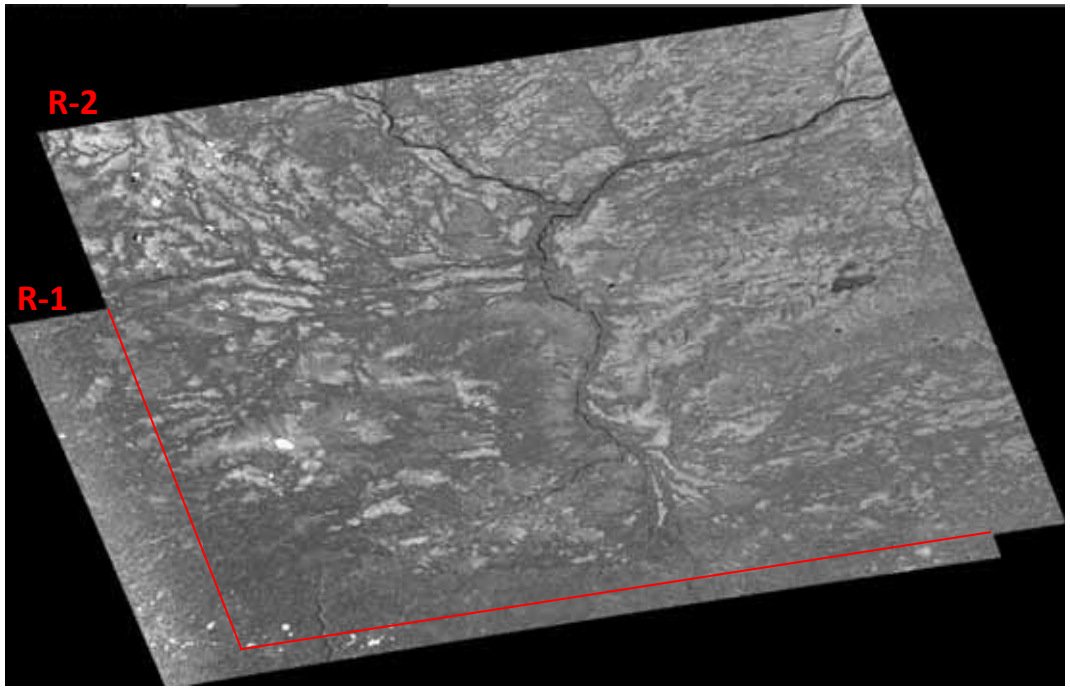
- A pair of twin R1-R2 images is acquired, same beam, location and time period;
- The R2 beam pattern is removed from the calibrated R2 image;
- The obtained scene backscatter is subtracted from the R1 image, canceling scene-specific constraints ⇨ R1 beam pattern.

The interval between the 2 acquisitions is a multiple of 12 days, so a viable R1-R2 pair is difficult to obtain, due to changing conditions at the site and planning constraints

Range offset between datasets does not allow for a full range measurement

Accuracy appear 0.3 dB better than relying on the site alone

Results ultimately depends on the R-2 calibration



Antarctica: Dome-C and RADARSAT

Dome-C campaign - timeline

March 2008:
RADARSAT-1 preliminary campaign

- Circumscribe area with uniform terrain and assess temporal stability around Concordia station
- Terminated due to end of OBR operations

August 2008:
RADARSAT-2 campaign

- Characterize anisotropy by acquiring Fine resolution data at all available incidence angles in a limited area
- Further assess the largest extent of the potentially useable area (flatness)

Fall 2008 and spring 2009:

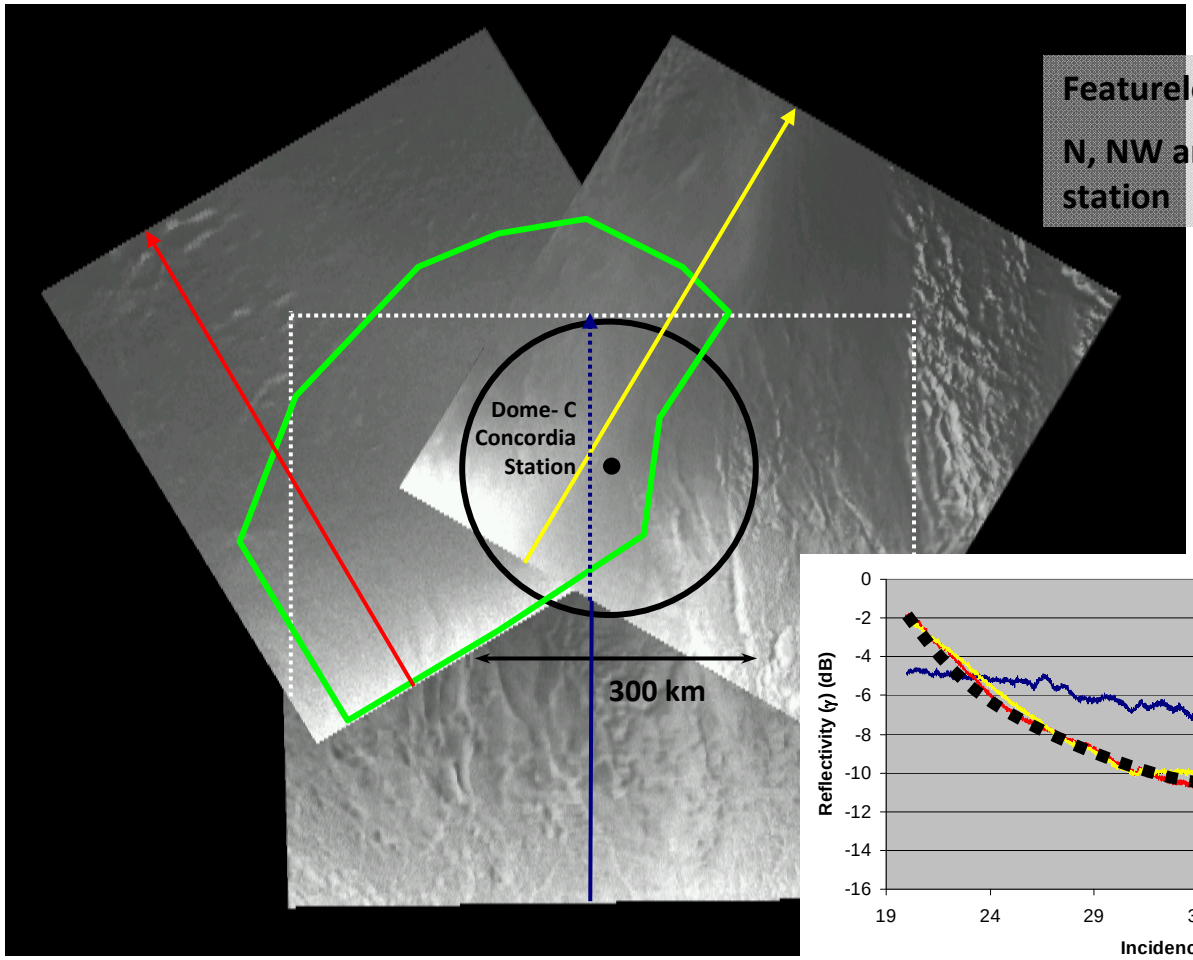
- Acquisition of dual pol HH-HV data
- Search for seasonal variations

Fall 2009:

- Creation of a backscatter model of the area surrounding Concordia station
- Use of the backscatter model to perform elevation beam pattern measurements to evaluate achievable radiometric accuracy of the area

Dome-C Area

R-2 SCWA HH data - Backscatter profiles



Featureless terrain:

N, NW and SW of Concordia station

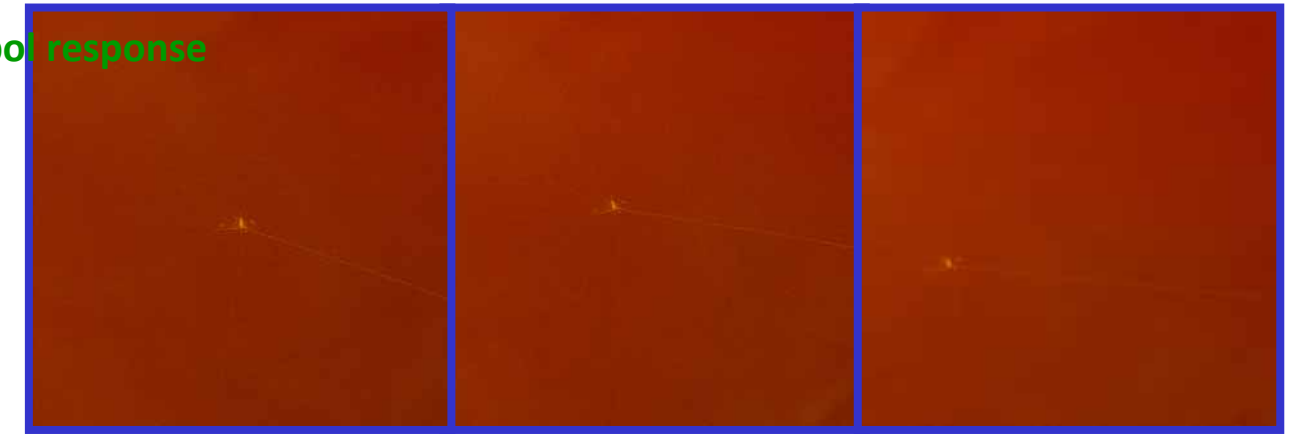
Dome-C Area: Dual-Pol. Fine R-2 Campaign at Concordia Station

HH Red

HV Green low cross-pol response

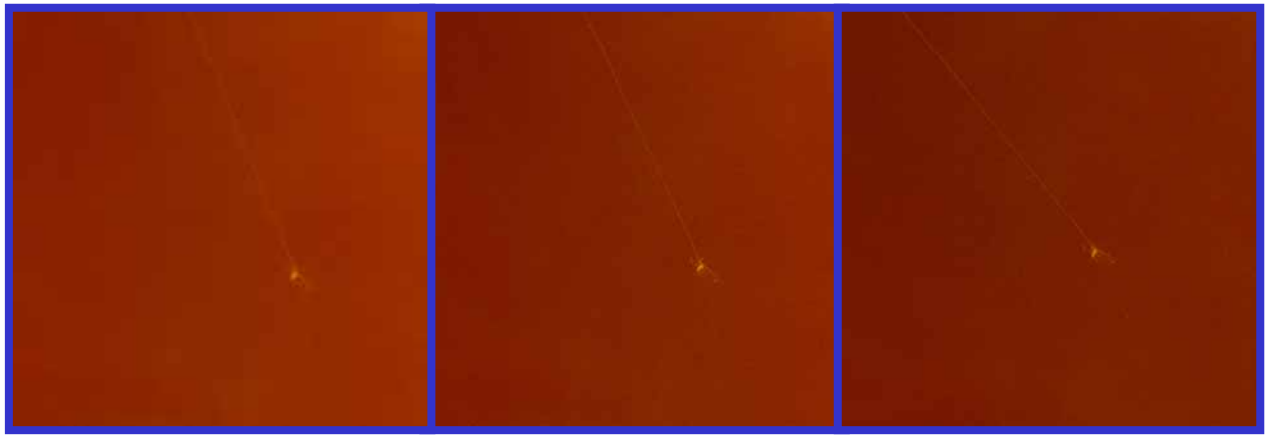
Ascending

Various incidence angles



Descending

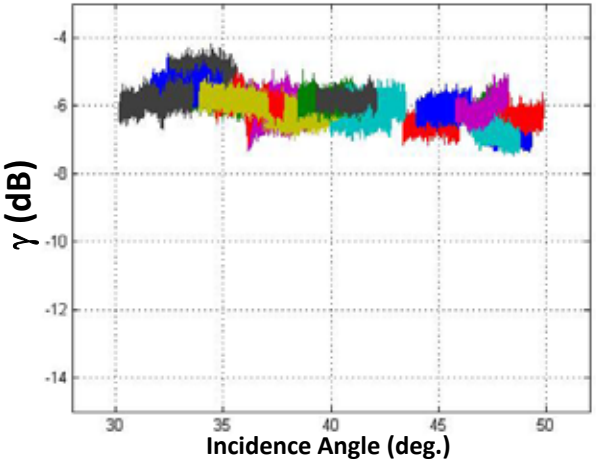
Various incidence angles



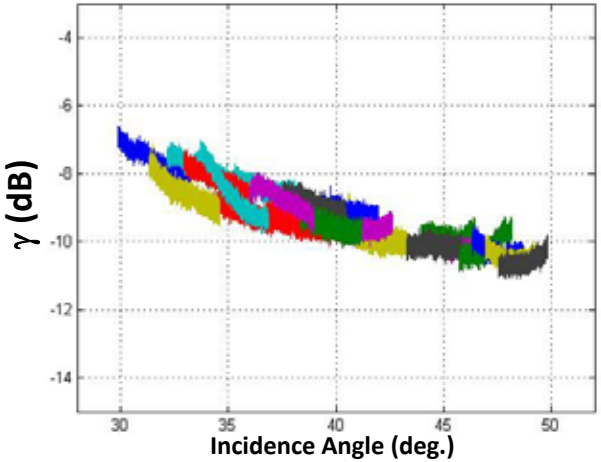
Regional Backscatter Profiles from R-2 Data: Amazon vs Dome-C

Backscatter profiles from R-2 Fine beams, HH

Amazon



Dome-C



A backscatter model was derived for Fine beam pattern measurement tests at Dome-C using Co-Pol. Fine datasets acquired in vicinity of the Concordia station:

- **Model covers the R-2 Fine beams incidence range: 30-50°**

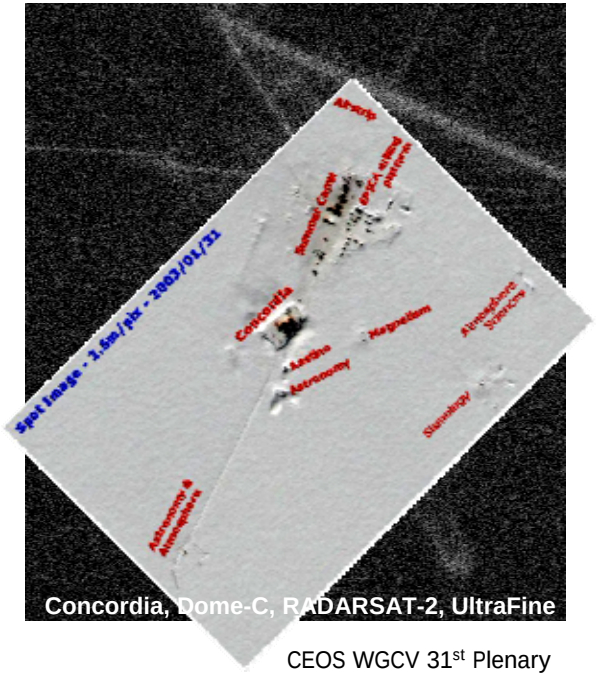
Dome-C RADARSAT-2 Campaign

Achievable radiometric accuracy for beam pattern measurements, Concordia station area, Fine beam swath (50 X 50 km):

- **Measurements give an average radiometric deviation of 0.41 dB, Amazon measurements on similar beams give 0.39 dB**
- **Commensurate with Amazon area for HH co-pol. data**
- **Standard deviation at both areas is around 0.25 dB**
- **Cross-pol HV response too low for calibration monitoring purposes, at -18 dB**

Next steps:

- **More data required to characterize a larger area and a wider incidence angle range**
- **Extend the incidence angle range of backscatter model**
- **Beam pattern measurement tests for larger swath beams**
- **VV-VH dual-pol acquisitions**



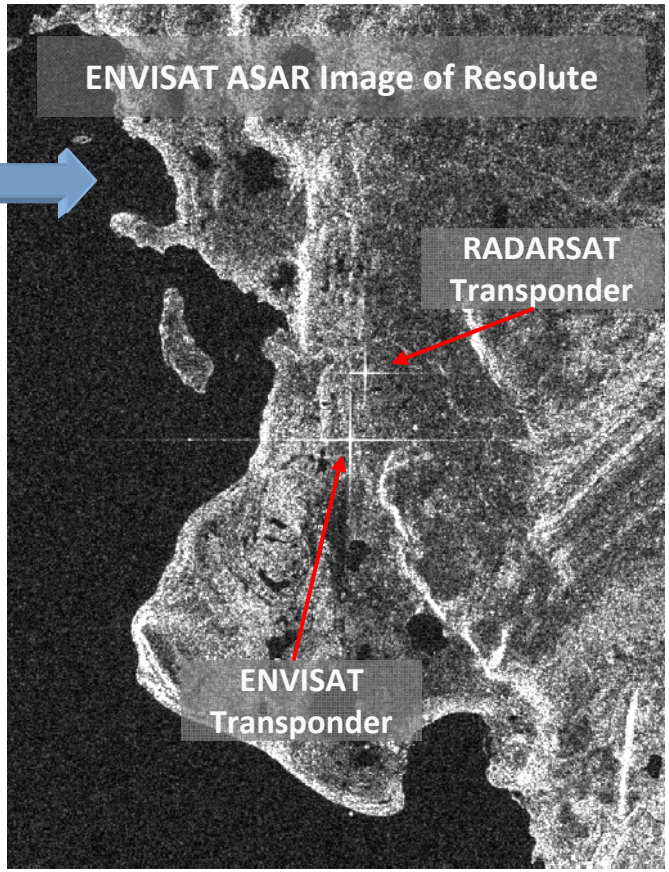
Concordia, Dome-C, RADARSAT-2, UltraFine

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)

Recommendations from SAR Subgroup (1)

- High resolution SAR satellites are becoming surveying instruments for Level 2 geophysical applications
  - There should be SAR image products removing terrain-related errors from radiometric calibration
    - Using integrated areal measures for normalization instead of local incidence angle
  - High resolution DEM would be useful for characterizing radiometric and geometric calibration 'super sites'
  - For geophysical applications, a table of SAR calibration requirements vs applications should be developed (soil moisture, biomass, wind speed retrieval)
    - Attempt at standardizing Level 2 requirements should be made
    - Soil moisture versus penetration depth, biomass of forests, etc.
    - Consultation with the Land Product Validation and Terrain Mapping Subgroups
- Revamp CEOS SAR Subgroup web site with information on missions, calibration sites, Site characteristics, calibration requirements and Educational material (Being led by ASF, University of Fairbanks)

Recommendations from SAR Subgroup (2)

- While compliant to mission requirements, ghosts / ambiguities effects may still be visible because of low noise levels achieved by new SAR satellites
  - –Users unfamiliar with radar imagery should be pointed to a CEOS web based resource for on-line educational purposes (to be developed)
  - Requirements on pulse leakage and/or leakage artefact could be recommended
  - –To minimize visible ambiguities, requirements on beam pattern side lobes should be function of other system parameters (noise level, PRF)
  - –The performance of the main stages of SAR processing should be included in calibration/validation discussions (range and azimuth compression, windowing, etc.)