Report on CEOS WGCV SAR Subgroup Activities

Presented at

CEOS WGCV 28th Plenary
Sanya, China
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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 Task: DA-06-02**
- Recent Annual Workshop/Meeting
  - 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

15th CEOS SAR CAL/VAL Workshop/Meeting (2007)

- Hosted Jointly by CSA and CEOS WGCV SAR Subgroup under "7th Advanced SAR 2007 Workshop"
- Organized by CSA, Defence Research & Development Canada, Canada Centre for Remote Sensing, CEOS and MDA
- Held on September 11 - 13, 2007 in Vancouver, Canada
- 134 Participants from 13 countries participated
- Had thirteen sessions (Plenary, Missions, Alternate Polarimetry, Polarimetry 1, Polarimetry 2, Maritime Surveillance 1, Maritime Surveillance 2, Calibration 1, Calibration 2, Emerging Applications, Interferometry, SAR Processing, SAR Technology)
  - 98 Presentations made
  - Each presentation session concluded with a discussion on a few session seed questions
- Workshop Proceedings just produced and being distributed on CD to attendees by CSA
- For details visit www.space.gc.ca/asc/eng/events/2007/asar.asp

Next CEOS SAR CAL/VAL Workshop/Meeting

- Will be hosted by DLR
- A 3-day Workshop to be held at DLR facilities in Oberpfaffenhofen, Germany in last week of October or first week of November 2008
- Back to back with TerraSAR-X/TanDEM-X Science Meeting
- Details to follow in a few weeks

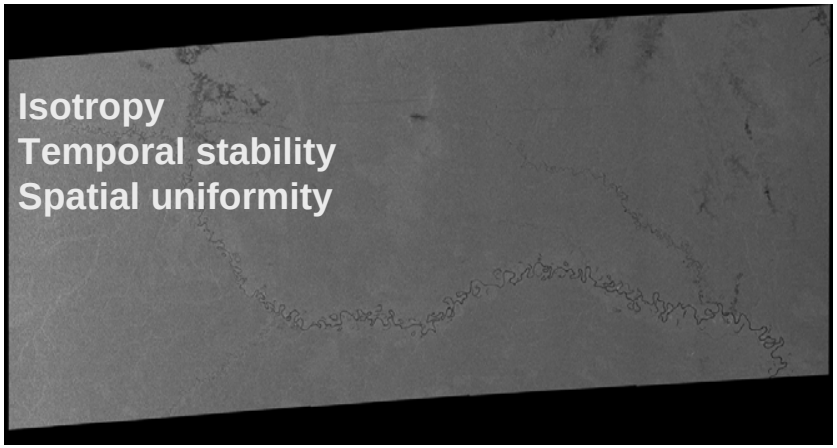
Natural Calibration Sites

- **International Amazon Rainforest Site**
  - A CEOS radiometric calibration reference site
  - 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 complimentary site to the Amazon but with reduced radiometric accuracy

Radiometric Calibration: Amazon Rainforest

Rainforest Properties

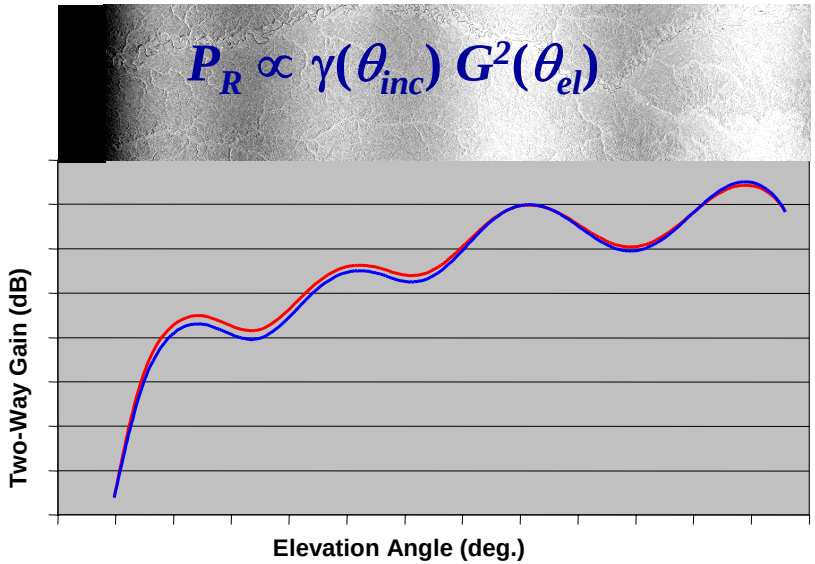


Well characterized radiometrically

Recognized distributed target reference

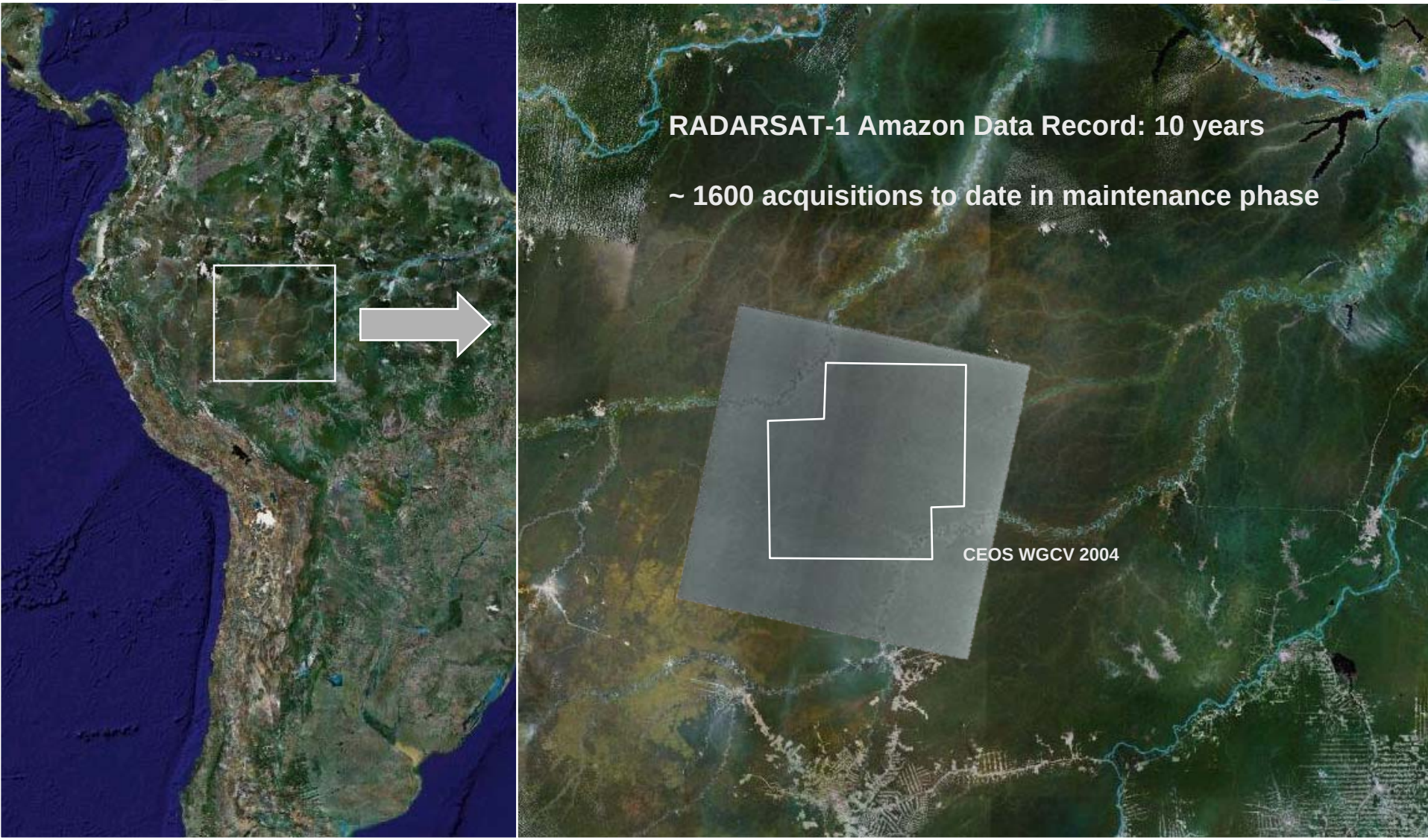
1978 Seasat (L)
1985 SIR-B (L)
1991 ERS-1 (C)
1992 ERS-2 Scatterometer (C)
1994 SIR-C (X)
1992 JERS-1 (L)
1996 RADARSAT-1 (C)
2002 ENVISAT (C)
2008 RADARSAT-2 (C)

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

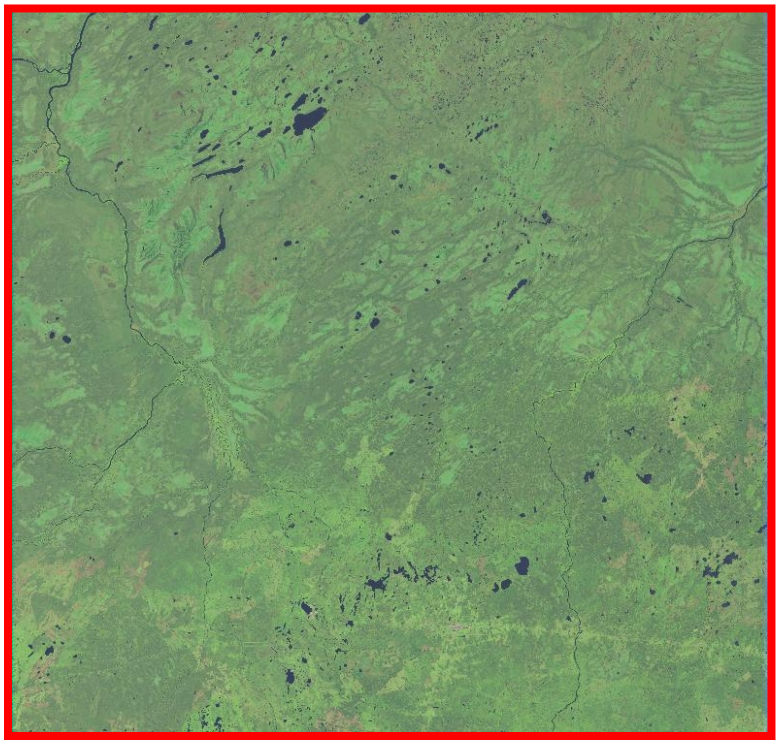
Radiometric Calibration: Amazon Rainforest

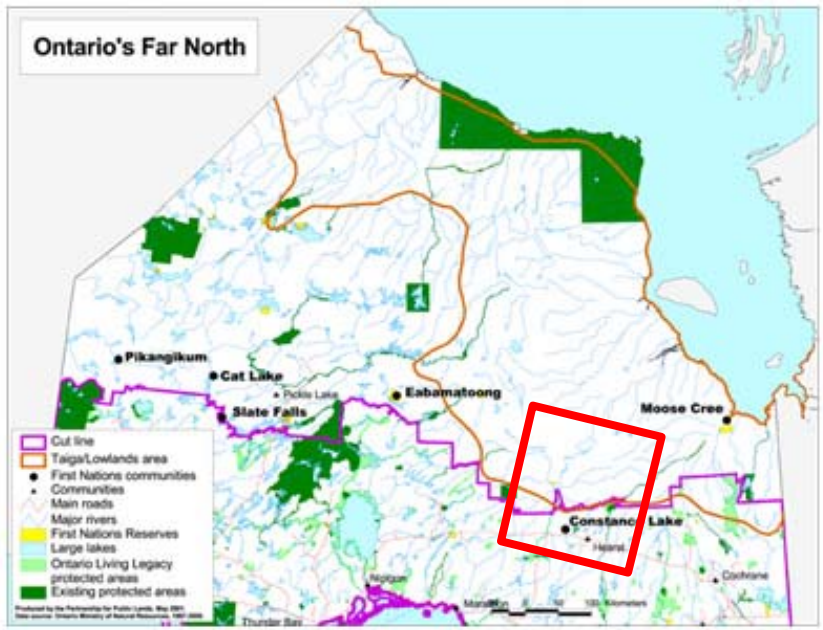


Canadian Boreal Forest - Hearst Site

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

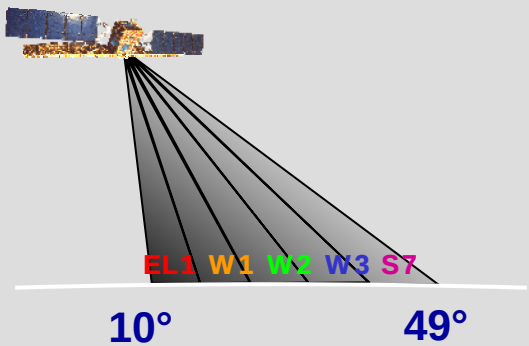
  boreal spruce, balsam fir, jack pine, poplar, birch, tamarack, cedar
- **Seasonal Variations**

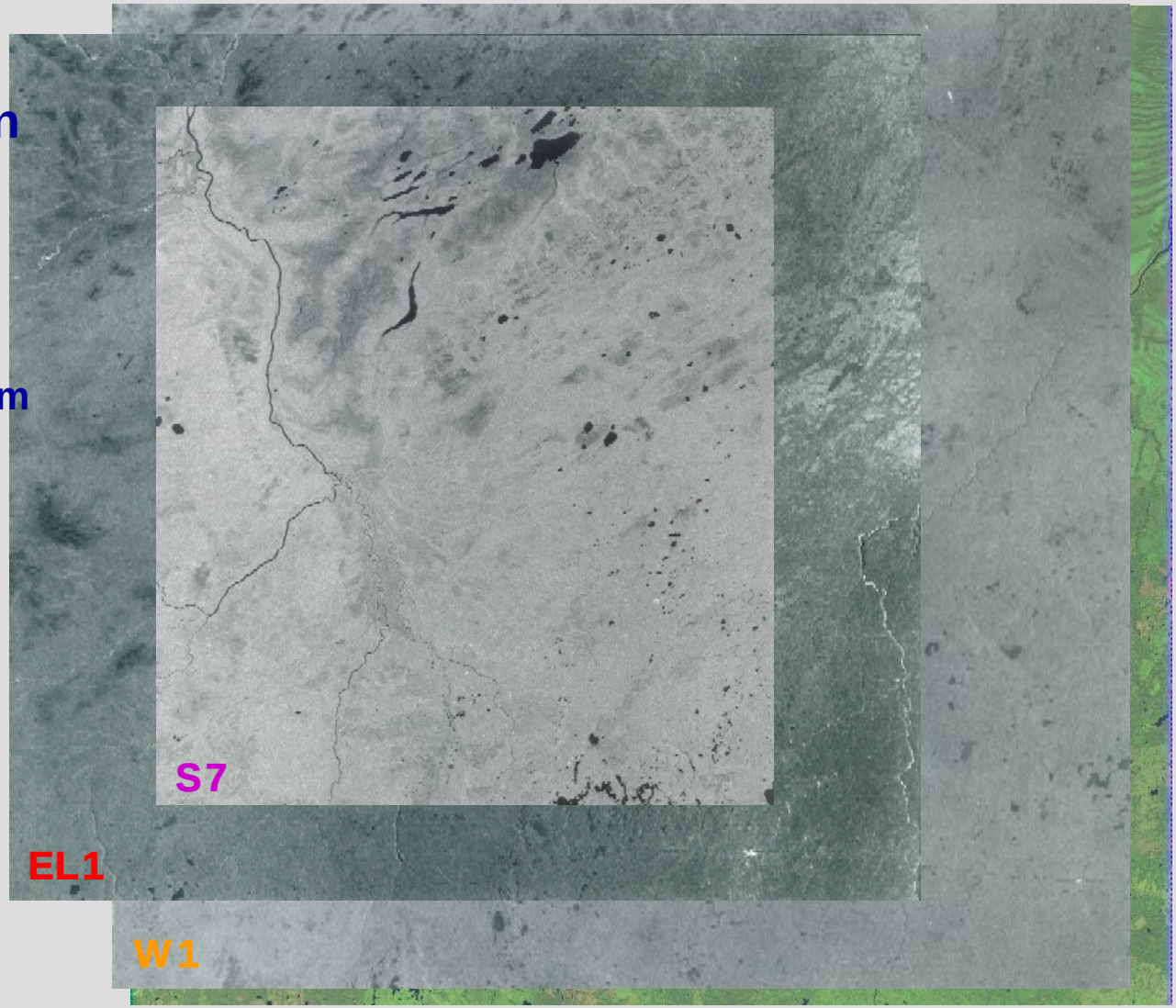


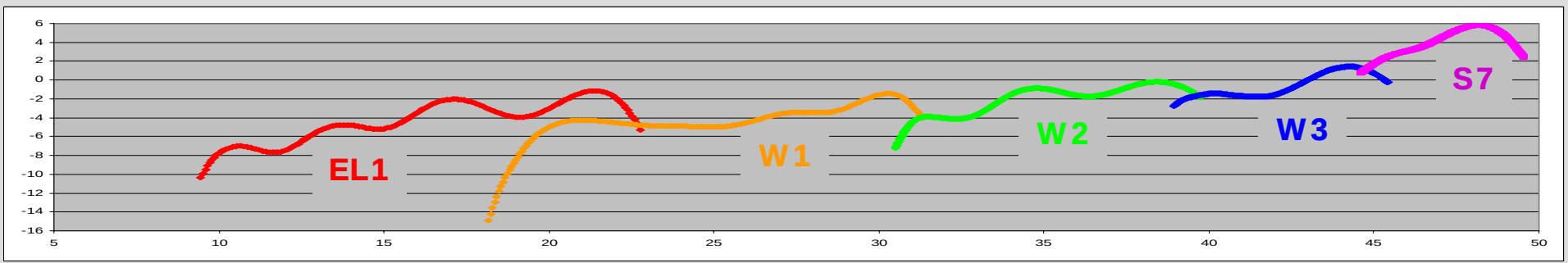


RADARSAT-1 Measurement Campaign

- Started in January 2003
- Covering entire range of incidence angles (5 beams)
- 2 to 4 products of each beam every 24-day cycle



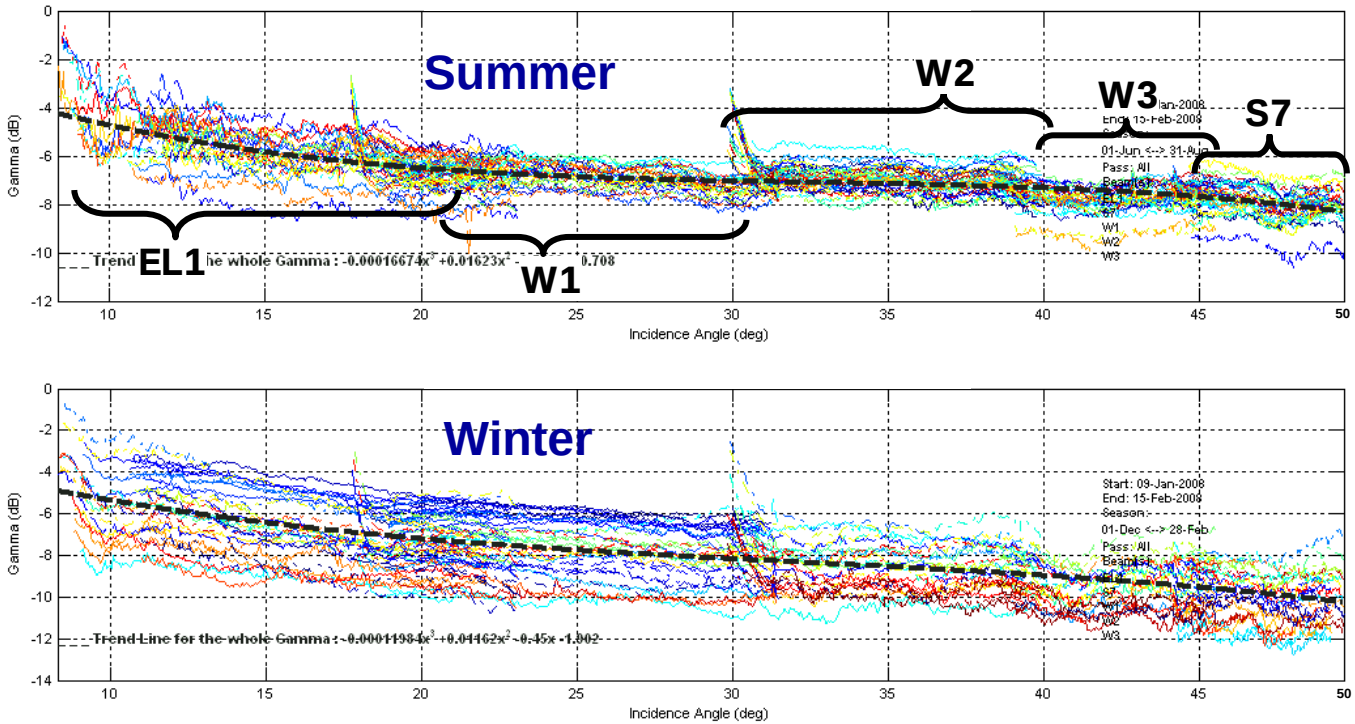


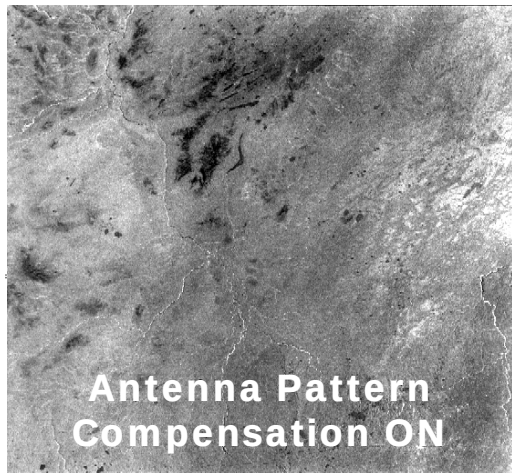


Boreal Forest: Seasonal Reflectivity

Extractions of $\gamma(\theta_{inc})$ from Boreal Forest images

- Assuming beams remain calibrated during acquisitions





γ ~ centred around Rainforest value (-6.5 dB)

γ dependence conforms to clutter models

Large variation of reflectivity levels, especially in winter

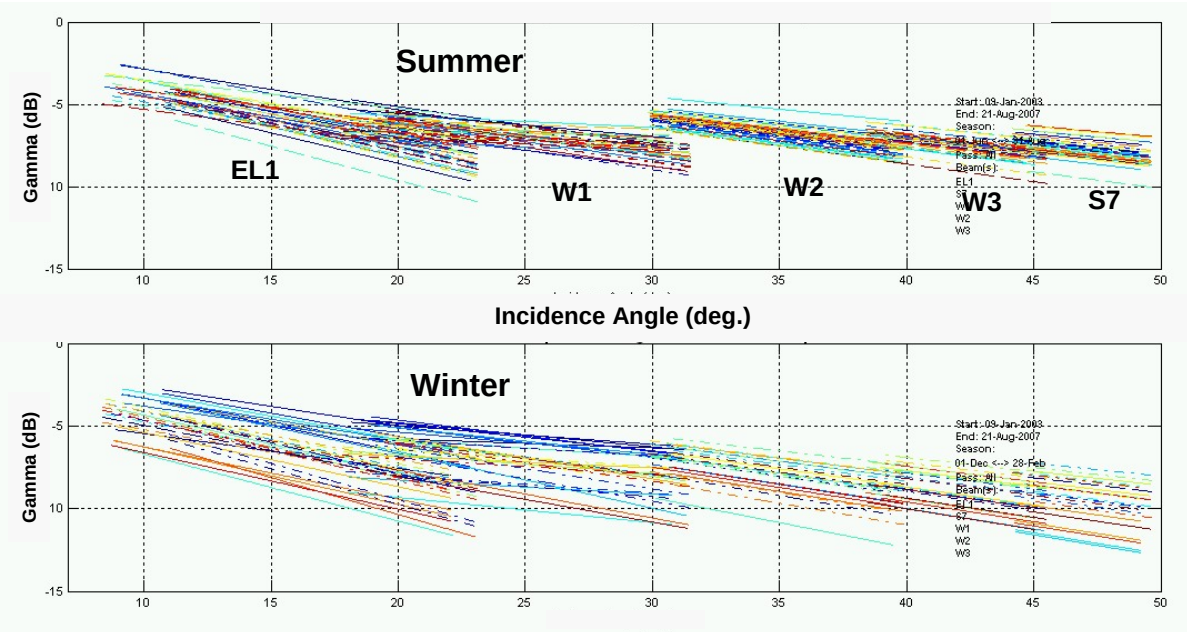
Boreal Forest: Deriving Reflectivity Estimates

Assumptions

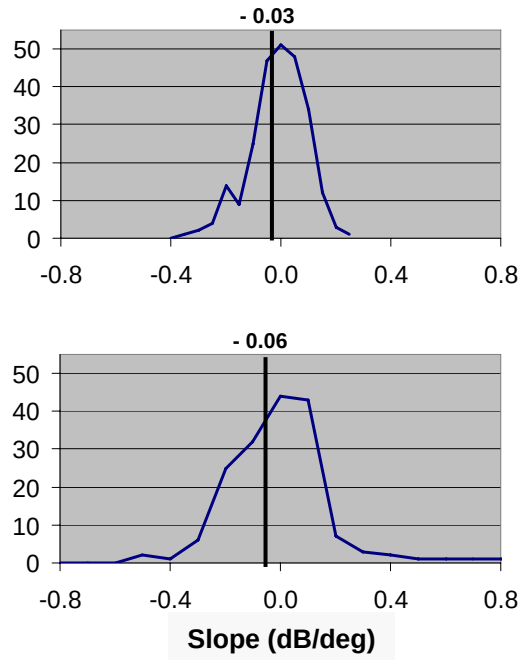
- Seasonally stable
- Linear anisotropy over each beam range

Model

$\gamma \sim k\theta_{inc}$ over incidence angle range of each tested beams



γ Slope Histograms



Elevation Beam Pattern Extraction Tests

Derived a beam-wise linear reflectivity estimate $\hat{\gamma}(\theta_{inc})$, for both reference periods

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

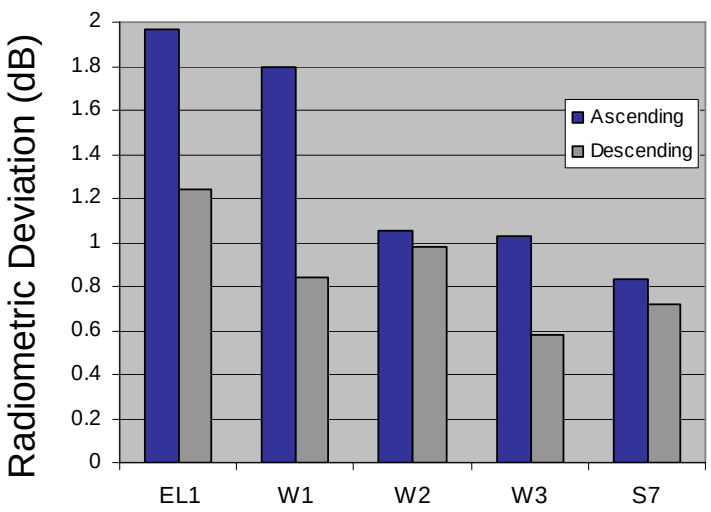
In analysis software, substitute constant Rainforest reflectivity with 'summer' or 'winter' $\hat{\gamma}$ reference, for the given beam

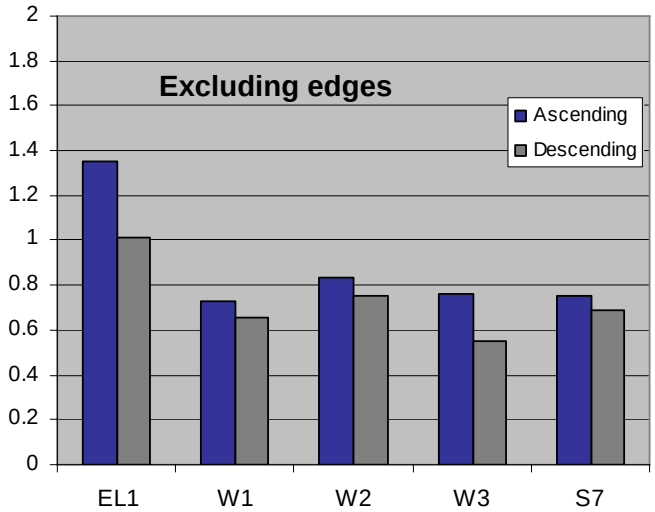
Procedure (as with Amazon imagery):

1. **Extract beam pattern**
2. **Compare with calibrated pattern in Payload Parameters File**
3. **Measure radiometric deviation: peak-peak of pattern difference (dB)**

	Average peak-peak pattern difference (dB) 100% swath	
	'Summer'	'Winter'
EL1	1.4	1.8
W1	1.1	1.5
W2	1.0	1.4
W3	0.8	1.3
S7	0.8	1.3

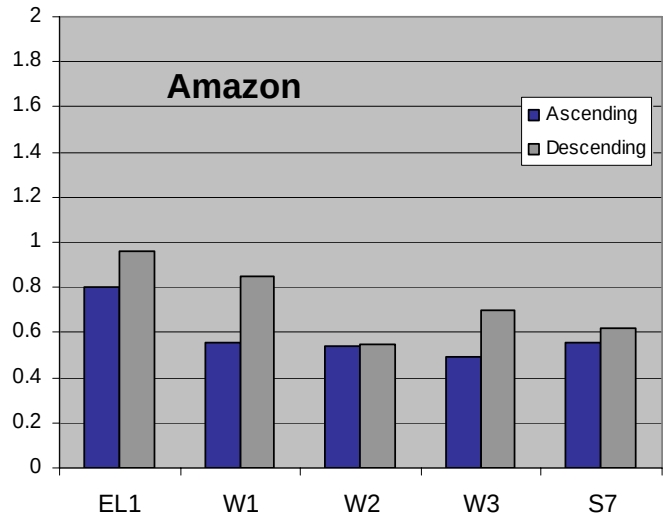
Beam Pattern Pattern Extraction Summer Results





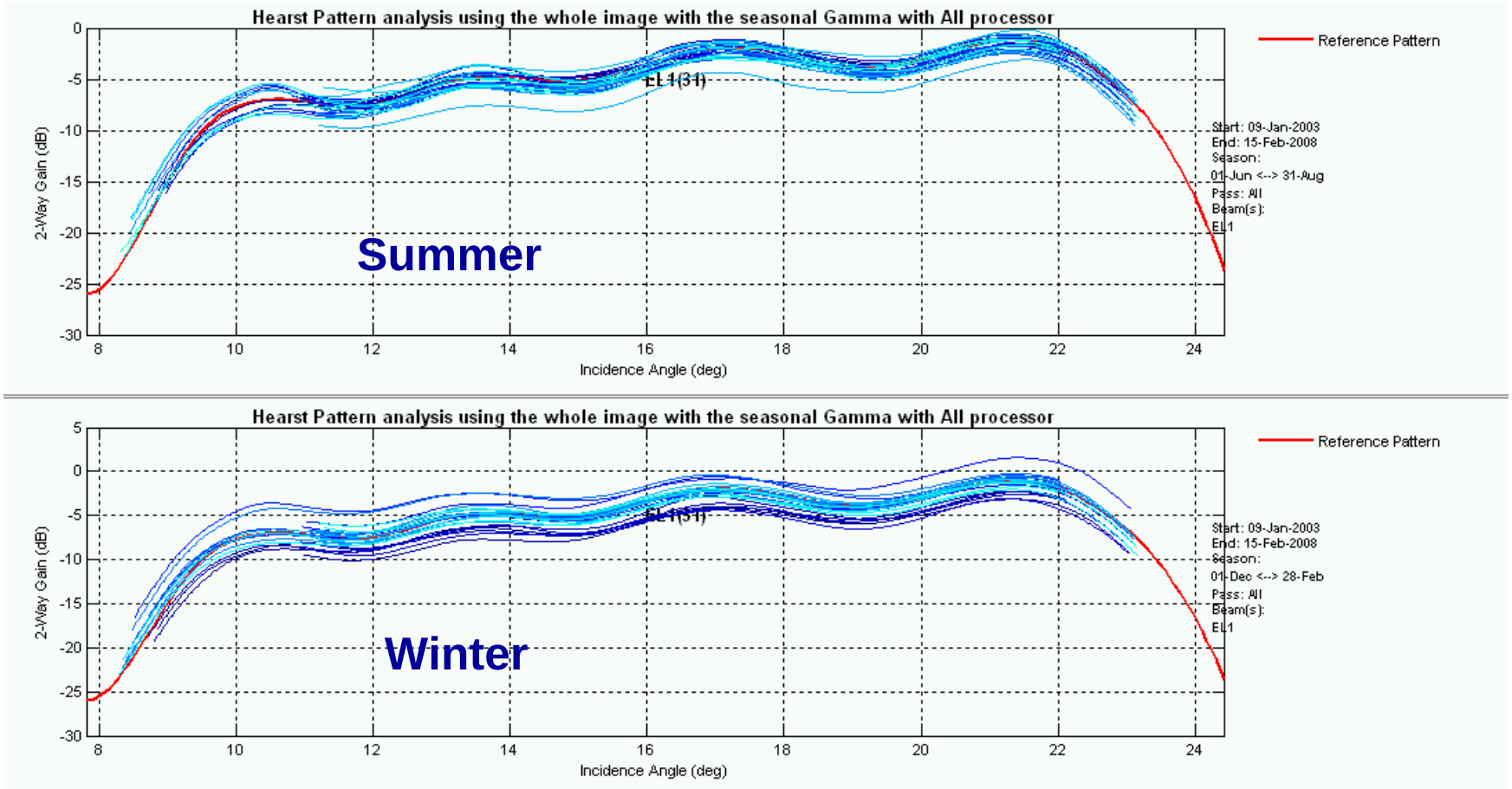
Aug 2006: beam W2 recalibration using boreal forest data (near-edge portion of pattern not seen in Amazon data)

Winter results: same trends observed, but with an average offset of +0.3 dB



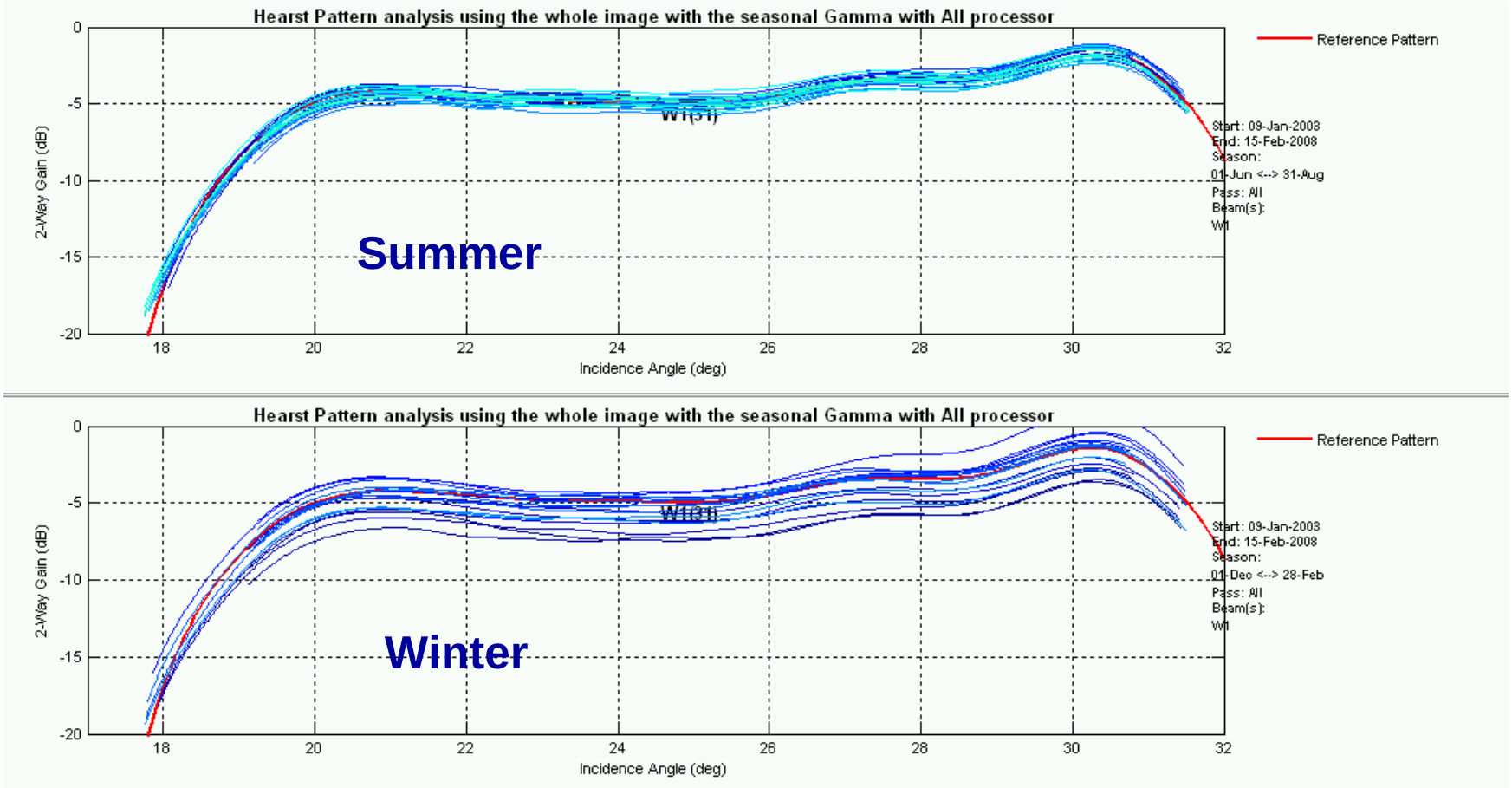
Boreal Forest Extracted Pattern Plots

EL1



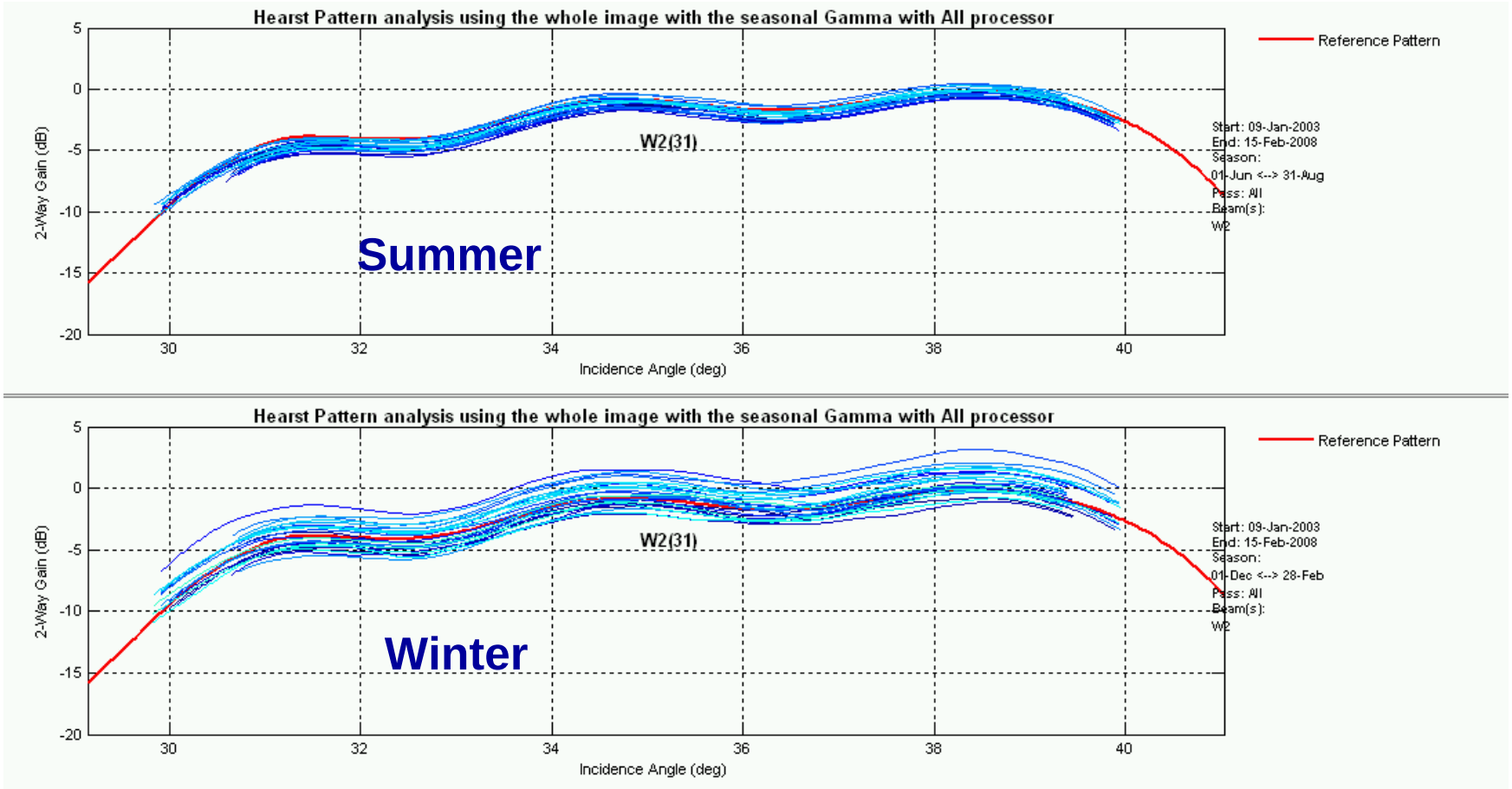
Boreal Forest Extracted Pattern Plots

W1



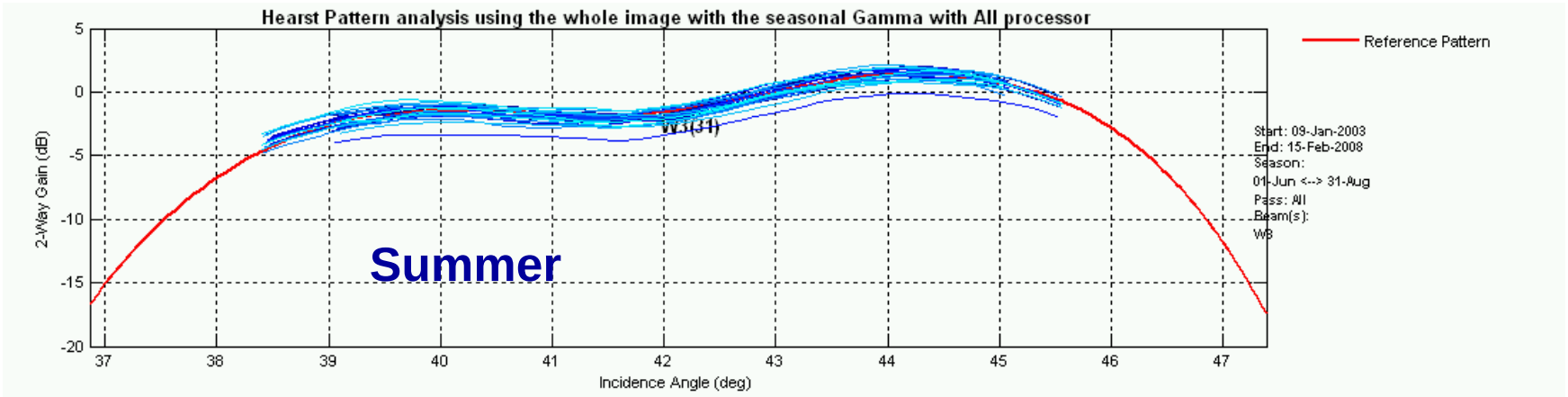
Boreal Forest Extracted Pattern Plots

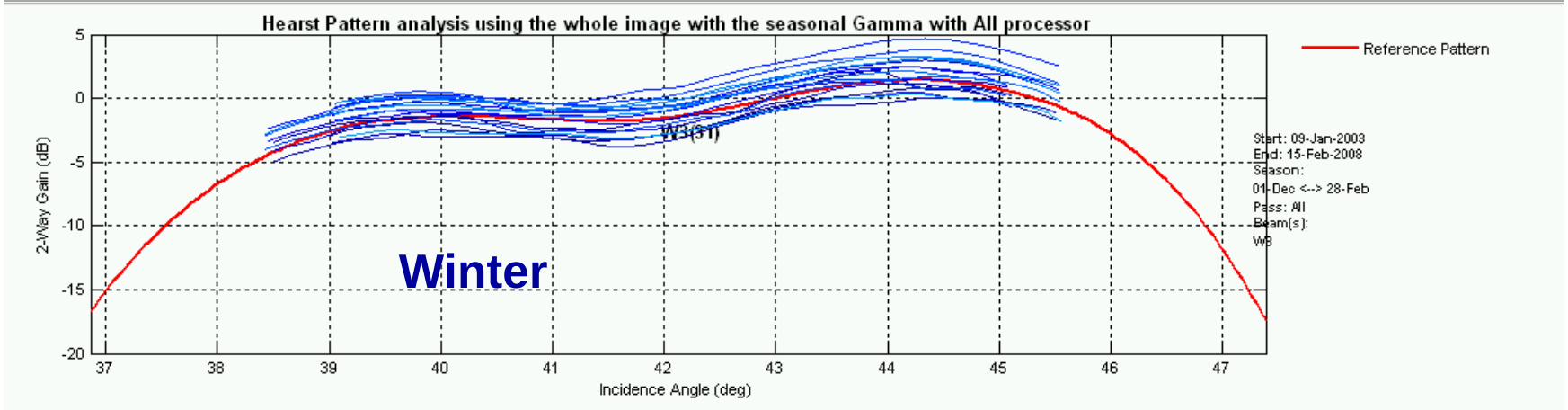
W2



Boreal Forest Extracted Pattern Plots

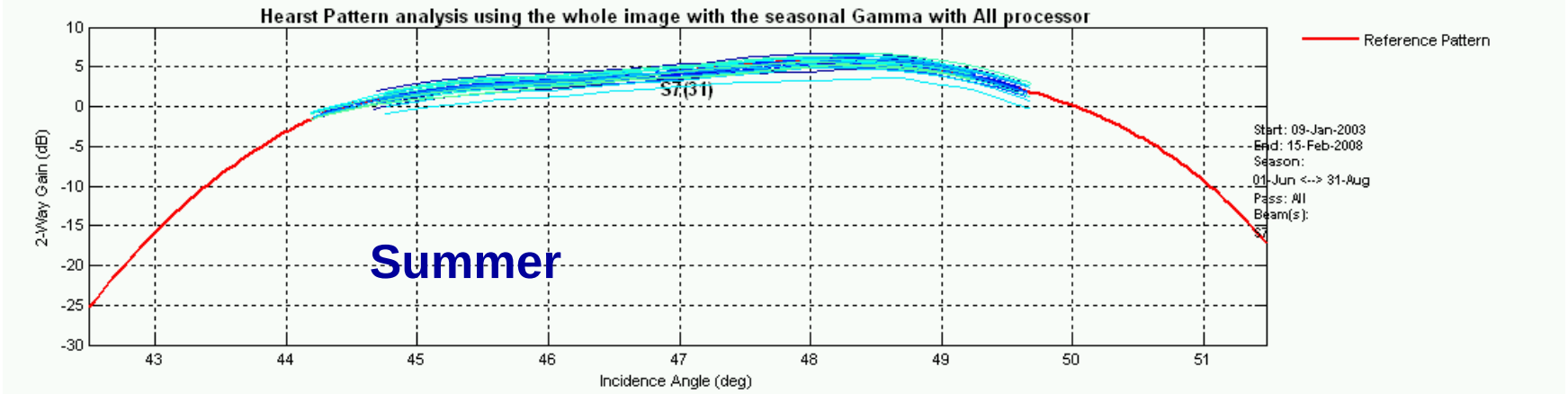
W3

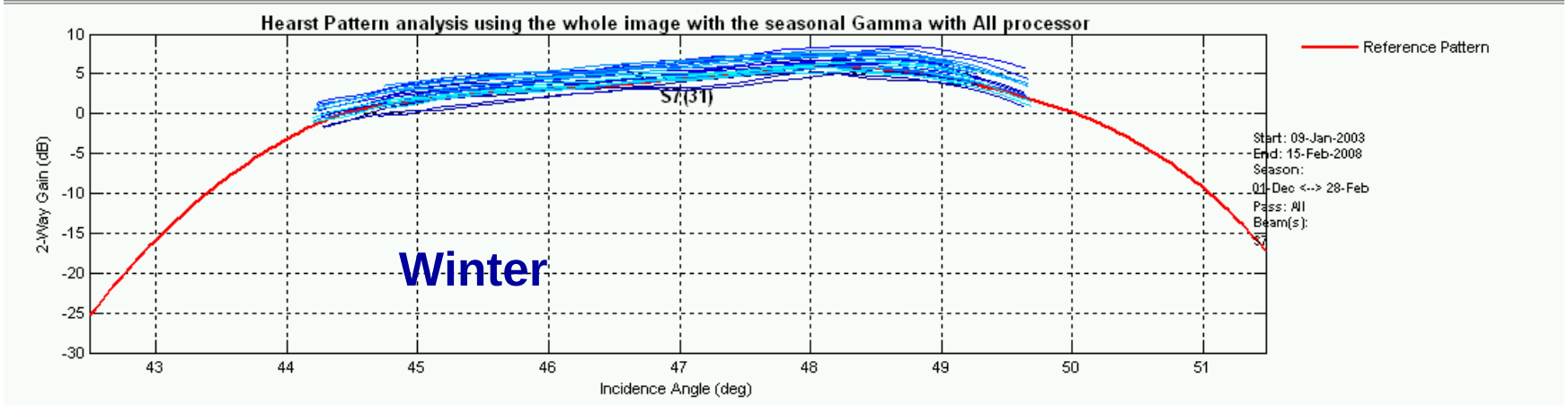




Boreal Forest Extracted Pattern Plots

S7

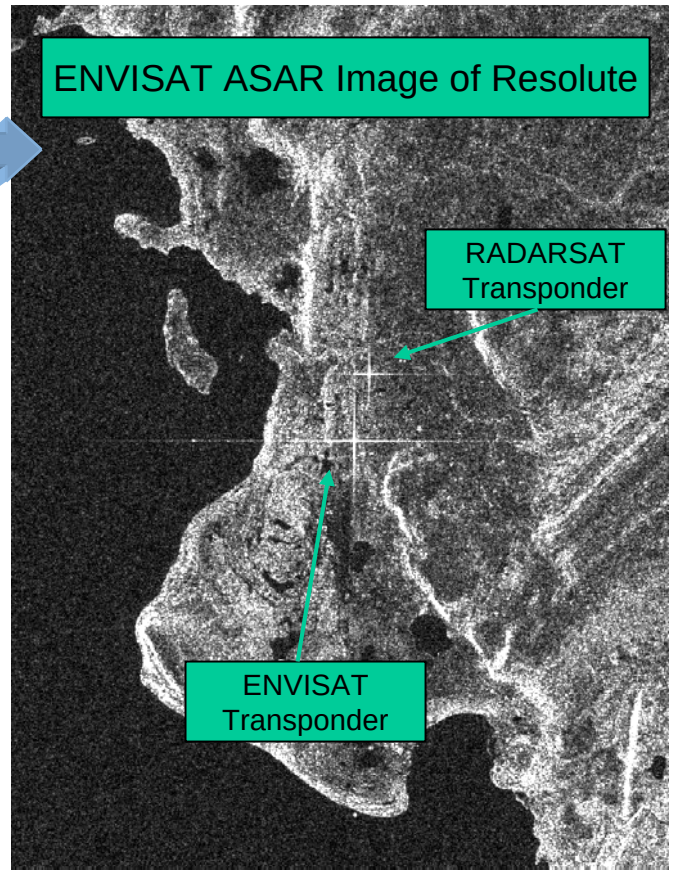




Calibration Transponder Sites

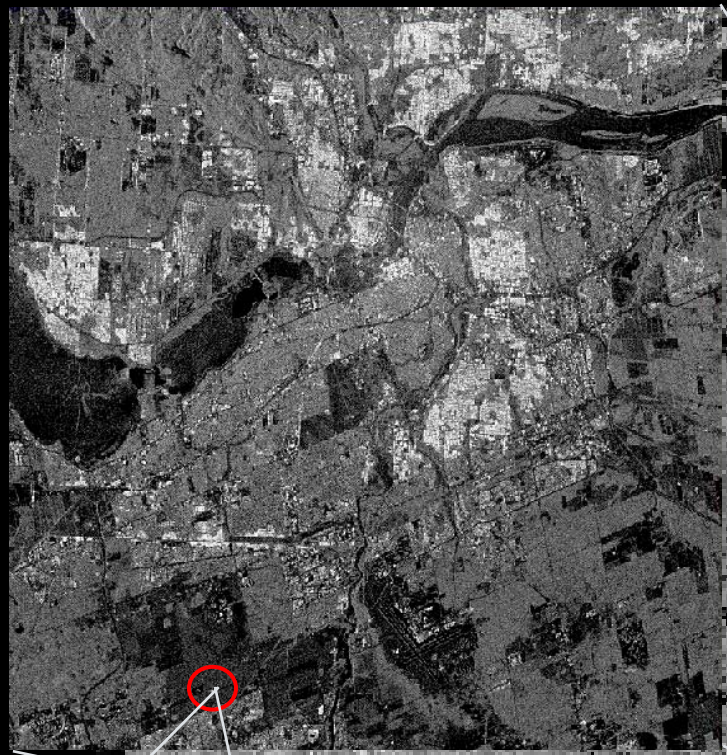
Multi-Transponder Sites in Canada

- 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 for Image Quality and Calibration Measurements

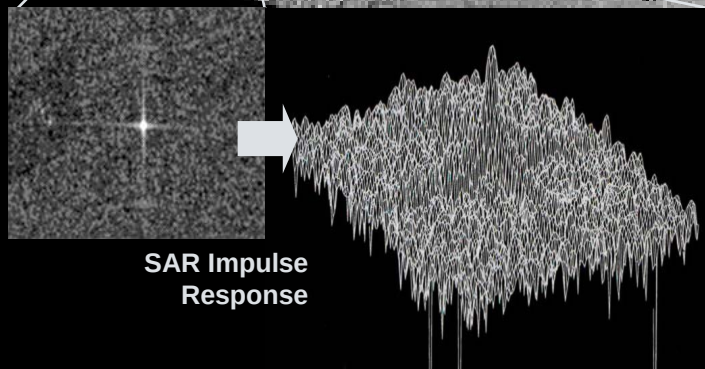


Resolute Bay

Prince Albert

Fredericton

Ottawa
(Upgraded unit for R2)



SAR Impulse Response

3 dB Width
Peak Sidelobe Ratio
Integrated Sidelobe Ratio
Location Error

Recommendation from SAR Subgroup (1)

- Since 5th Advanced SAR Workshop (2003), one action on CEOS SAR Subgroup is to determine calibration specification for Polarimetric SAR
- The subject has been debated in subsequent CEOS SAR Workshops
- In 7th Advanced SAR Workshop (2007) the group concluded the discussion by recommending the following set of calibration specification, considering measured results obtained in recent polarimetric SAR missions and emerging application needs

Recommendation from SAR Subgroup (2)

Polarimetrc SAR Specification		
Parameter	**Threshold**	**Goal**
System Stability (short and long term)	<1 dB	<0.5 dB
Cross-Talk	<-25 dB	<-35 dB
Channel Amplitude Imbalance	<0.4 dB	<0.2 dB
Channel Phase Difference	<2 to 5 deg	<1 deg
Channel Registration	<0.1 pixel	
Noise Equivalent Sigma Zero (NESZ)	X band: <-20 dB C band: <-25 dB L & P bands: <-30 dB	X band: <-23 dB C band: <-30 dB L & P bands: <-35 dB
Faraday Rotation (~2.5 deg)	Significant for L band (correction required) Insignificant for C and X bands	

GEO Task # DA-06-02 (Questionnaire)

1. **Identify current activities contributing to this task, and the significance.**

- SAR Subgroup is contributing to this GEO activity in exploring, characterizing and monitoring natural sites for calibration of Synthetic Aperture Radar (SAR) instruments. In addition a couple of man-made sites have also be developed in Canada by installing C-band calibration transponders from CSA and ESA. Other potential natural sites may also be explored.

2. **Identify actions and/or deliverables related to the activities described above (these actions will be reported to CEOS). What is the identifiable result of the action?** *(May be a multiyear activity, however please include action/deliverable to be completed in 2008).*

- SAR Subgroup has established a geographical site in Amazon as the CEOS Standard site for SAR calibration. This site is routinely used for calibration and its radiometric stability monitored. In addition, a site in Boreal forest of Canada is also being characterized at C-band. Analysis results will be reported at annual CEOS SAR Workshop.

- **Identify any issues (current/potential data gaps, data sharing problems, funding, etc)**
- Data from various SAR missions could not be freely distributed because of data policy restrictions of individual space agency/data provider. Development and maintenance of man-made sites is difficult as funding is a big issue. Resources are lacking for acquisition, processing, analysis and archive of data. Similarly, resources will be required for development and maintenance of associated analysis and information distribution tools.

4. **Identify actions and/or deliverables needed to address the issues described above (these actions will be reported to CEOS). Specify when action needs to be completed. What is the identifiable result of the action?**

- Spaces agencies need to commit resources (personnel and funding). If these resources are in place, a detailed investigation of natural sites could be done for SAR missions operating in different frequency bands and for different polarizations. Similarly, standard man-made test sites could be developed to handle multiple polarizations and frequencies.

5. **Identify key international organization(s) already assigned to work on this task from the satellite perspective. Are there any outstanding issues CEOS can help address in coordination with these organization(s).**

- Space agencies that have space SAR missions, e.g., ESA, CSA, JAXA, DLR etc. are contributing to this task more or less on an agency basis and not collectively. There should be commitment for all concerned space agencies to support the above task as a dedicated team effort.