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Sea Ice Monitoring Using ENVISAT ASAR AP Data
Summary of Results

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ACRONYMS AND ABBREVIATIONS

AP	Alternating Polarization
ASAR	Advanced Synthetic Aperture Radar
CIS	Canadian Ice Service
CSA	Canadian Space Agency
EOADP	Earth Observation Application Development Program (funded by CSA)
ESA	European Space Agency
ENVISAT	ENVIronmental SATellite
FYI	First Year Ice
HH	Horizontal polarization
HV	Horizontal Vertical polarization
LUT	Look-Up Table
MDA	MacDonald, Dettwiler and Associates Ltd.
NESZ	Noise Equivalent Sigma Zero
RGB	Red, Green and Blue
SAR	Synthetic Aperture Radar
VH	Vertical Horizontal polarization
VV	Vertical polarization

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1 INTRODUCTION

Spaceborne Synthetic Aperture Radar (SAR) systems represent the single most important data source for the Canadian Ice Service (CIS). RADARSAT-1 data are currently used for operational monitoring. RADARSAT-2 will provide a continuation of the service with improvements in the amount of information that will be retrievable due to dual polarization and polarimetric capabilities of the sensor. Multi-polarization SAR data has in fact been available since early 2003, from the Advanced Synthetic Aperture Radar (ASAR) on the ESA ENVISAT. In Alternating Polarization (AP) mode ASAR can provide any two polarizations over standards swaths up to 100 km wide. Initial analysis of AP data at MDA has demonstrated improved capabilities for separating sea ice from open water and for identifying different ice classes, as compared to using single polarization data [R-3]. This initial work was based on a limited data set and part of the recommendations was to verify results using a larger, more representative data set.

1.1 Project Objective

The objective of this study was to use a more extensive, spatial and temporal, set of ENVISAT ASAR AP data to further validate and extended the EOADP analysis on how best to use dual polarization data for operational monitoring of sea ice, specifically to:

- more fully evaluate the additional information provided by the cross-polarization channel for ice type classification and ice edge detection
- determine how this additional information can be most appropriately visualized for operator interpretation
- investigate how classification and visualization are affected by incidence angle
- identify implications for exploitation of RADARSAT-2 dual polarimetric data

1.2 Project Tasks

The work was broken down into two main workpackages

1. Data Analysis:
    - calibration of the data based on ESA information
    - statistical analysis of the data to evaluate the additional information provided by the cross-polarization channel for ice type classification and ice edge detection and whether it can be exploited by automatic classification
    - determining how these new capabilities are affected by variation of backscatter with incidence angle
    - identifying implications for exploitation of RADARSAT-2 dual polarimetric data
2. Visualization:
    - selection of appropriate data ranges (based on statistics gathered during data analysis) for scaling
    - selection of appropriate parameters and development of parameter normalization scheme
    - generating example visualizations covering as comprehensive a variety as the data permits, of ice types and sea states over a range of incidence angles
    - comparison of how visualization of the same ice types varies with incidence angle
    - obtaining end-user feedback from the CIS on proposed visualization schemes

1.3 Document Scope

This document summarizes the main project results and conclusions.

Detailed project results are provided in a Power Point presentation titled “Sea Ice Monitoring Using ENVISAT ASAR AP Data”. The Power Point presentation represents the main project deliverable. It contains the following Sections:

- Review of project objectives
- Review of data available
- Environmental information

- Data visualization & ice chart information
- Discussion of incidence angle effects
- Alternative visualizations
- Data calibration
- Data classification
- Conclusions

1.4 Document Structure

Section 2, lists reference documents.

Section 3, summarizes the project conclusions.

Appendix A, provides an overview of the image data available.

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2 DOCUMENTS

2.1 Reference Documents

R-1	RX-RP-51-2570	Multi-polarimetric SAR products for operational sea ice monitoring, MacDonald Dettwiler, Final Report, Issue/Revision 2/1, November 2001.
R-2	RX-RP-51-3699	Analysis of CV-580 Fully Polarimetric Data of Sea-Ice, MacDonald Dettwiler, Final Report, Issue/Revision 3/1, October 2003.
R-3	RX-RP-51-4919	Utilisation of Multi-Polarisation and Polarimetric Data for Sea-Ice Monitoring in an Operational Environment, MacDonald Dettwiler, Final Report, Issue/Revision 1/0, November 2003.

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3 SUMMARY OF RESULTS AND CONCLUSIONS

3.1 Data Analysis

- The data set covers a wide variety of environmental conditions including low and high wind, melting and freezing conditions.
- The Ice charts identify mostly thick FYI and old ice for the region of interest. Some scenes contain areas of open water.
- The dynamic range of cross-pol data is significantly smaller than that of co-pol data.
- The lower limit for cross-pol data is clearly limited by the NESZ of the system.

3.2 Common Scaling

- A common scaling scheme is proposed for visualization:
- Co-pol: -10 dB to -22 dB
- X-pol: -19 dB to -25 dB
- This results in colour consistency but reduces individual scene contrast, particularly in high incidence scenes at steep incidence (IS1).
- Both common and scene specific visualizations should be offered with a toggle switch.
- Channel ratios are not recommended; tradeoffs between processing requirements and information gain need to be investigated.

3.3 Backscatter Analysis

- NESZ variations are observed over low backscatter areas, particularly in cross-pol scenes. One example over open water shows a 4 dB variation in HV (IS4).
- If NESZ variation is ignored, the cross-polarized backscatter appears to be mostly determined by ice type and temperature. There is no visible variation in these signatures with incidence angles.
- Available VV signatures are on the upper end of the linear scale proposed for visualization. The example data are not representative (include 2 IS1 scenes), nevertheless, a separate VV scale is suggested.

3.4 Calibration

- ASAR and RADARSAT-2 data calibration is a well defined process, all information is provided in the header.
- RADARSAT-2 calibration simply involves applying a range dependent Look-Up Table (LUT) to the image.
- The same LUT is used for both polarization channels and the LUT is fixed for any given beam.
- Hence, the data is relatively calibrated both from channel to channel and from acquisition to acquisition.

3.5 Classification

- The classification shows good results for most images, results correspond well to the RGB images.
- Problems encountered include the NESZ variation over the swath, which results in classification artifacts for scenes with low backscatter. These artifacts are clearly visible and can be accounted for in result interpretation.
- One scene with generally high backscatter (due to mostly old ice) shows an unsatisfactory classification result as leads are overestimated.
- Generally, a blind 4-class classification gives good results, which need to be interpreted by an analyst. The classifier can potentially be used for ice type concentration measurements.

A AVAILABLE DATA

Table A-1 Summary of Image Data Provided by Environment Canada

Date	Image Name			RSAT CEOS	RSAT JPG	Image Anal Chart	Daily Ice Chart	Weekly Regional Chart	Monthly Regional Chart	CFR (Aircraft) Chart
03/04/2003	ev_05698_03AR03_0338_020141.img	HV	HH						EArcticR_CO_01apr2003_1800_S.gif	
									WArcticR_CO_01apr2003_1800_S.gif	
08/05/2003	ev_06199_08MY03_0338_020143.img	HV	HH	R1_030506_230913_01.sard.avg	R1_030506_230913_01.jpg			WArcticR_CO_01may2003_1800_S.gif		
								EArcticR_CO_01may2003_1800_S.gif		
								WArcticR_CO_15may2003_1800_S.gif		

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Date	Image Name			RSAT CEOS	RSAT JPG	Image Anal Chart	Daily Ice Chart	Weekly Regional Chart	Monthly Regional Chart	CFR (Aircraft) Chart
								EArcticR_CO_15may2003_800_S.gif		
12/06/2003	ev_06700_12JN03_0338_020146.img	HV	HH	R1_030612_232854.sard.avg	R1_030612_232854_01.jpg			WArcticR_CO_15jun2003_1800_S.gif		
					R1_030612_233010_02.jpg			EArcticR_CO_15jun2003_1800_S.gif		
20/06/2003	ev_06814_20JN03_0247_020147.img	VH		R1_030619_232604_02.sard.avg	R1_030619_232604_02.jpg			WArcticR_CO_23jun2003_1800_S.gif		
								EArcticR_CO_23jun2003_1800_S.gif		
				R1_030620_225704_02.sard.avg	R1_030620_225704_02.jpg			WArcticR_CO_23jun2003_1800_S.gif		
								EArcticR_CO_23jun2003_1800_S.gif		
17/07/2003	ev_07201_17JL03_0338_020150.img	HV	HH	R1_030717_230918_02.sard.avg	R1_030717_230918_02.jpg		Resolute_CO_19jul2003_1800_S.gif	WArcticR_CO_14jul2003_1800_S.gif		
								EArcticR_CO_14jul2003_1800_S.gif		

Date	Image Name			RSAT CEOS	RSAT JPG	Image Anal Chart	Daily Ice Chart	Weekly Regional Chart	Monthly Regional Chart	CFR (Aircraft) Chart
								WArcticR_CO_21jul2003_1800_S.gif		
								EArcticR_CO_21jul2003_1800_S.gif		
25/07/2003	ev_07315_25JL03_0247_020153.img	VV	VH	R1_030724_230443.sard.avg	R1_030724_230443_01.jpg	WIS135_CO_24jul2003_2300_S.gif	Resolute_CO_24jul2003_1800_S.gif			
					R1_030724_230559_02.jpg		Resolute_CO_25jul2003_1800_S.gif			
27/07/2003	ev_07344_27JL03_0324_020156.img	VH		R1_030726_234659_01f.sard.avg	R1_030726_234659_01f.jpg	WIS135_CO_26jul2003_2346_S.gif	Resolute_CO_26jul2003_1800_S.gif			
				R1_030727_132145_01f.sard.avg	R1_030727_132145_01f.jpg	WIS135_CO_27jul2003_1321_S.gif	Resolute_CO_27jul2003_1800_S.gif			27072003_WIS301C_9131.gif
03/08/2003	ev_07444_03AG03_0304_020159.img	VV	VH	R1_030802_234248_01f.sard.avg	R1_030802_234248_01f.jpg	WIS135_CO_02aug2003_2341_S.gif	Resolute_CO_02aug2003_1800_S.gif			
				R1_030803_131726_01.sard.avg	R1_030803_131726_01.jpg		Resolute_CO_03aug2003_1800_S.gif			

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Date	Image Name			RSAT CEOS	RSAT JPG	Image Anal Chart	Daily Ice Chart	Weekly Regional Chart	Monthly Regional Chart	CFR (Aircraft) Chart
				R1_030803_231324_03.sard.avg	R1_030803_231324_03.jpg	WIS135_CO_03aug2003_2310_S.gif	Resolute_CO_04aug2003_1800_S.gif			
21/08/2003	ev_07702_21AG03_0339_020162.img	HV	HH	R1_030820_231739_02.sard.avg	R1_030820_231739_02.jpg	WIS135_CO_20aug2003_2316_S.gif	Resolute_CO_20aug2003_1800_S.gif			
				R1_030821_125236_01.sard.avg	R1_030821_125236_01.jpg	WIS135_CO_21aug2003_1252_S.gif	Resolute_CO_21aug2003_1800_S.gif			
31/08/2003	ev_07845_31AG03_0324_020165.img	VV	VH	R1_030830_232555_01f.sard.avg	R1_030830_232555_01f.jpg	WIS135_CO_30aug2003_2327_S.gif	Resolute_CO_30aug2003_1800_S.gif			
				R1_030831_130054_01f.sard.avg	R1_030831_130054_01f.jpg	WIS135_CO_31aug2003_1400_S.gif	Resolute_CO_31aug2003_1800_S.gif			
				R1_030831_225644_01f.sard.avg	R1_030831_225644_01f.jpg	WIS135_CO_31aug2003_2253_S.gif				
05/10/2003	ev_08346_05OT03_0324_020169.img	VV	VH	R1_031004_230450.sard.avg	R1_031004_230450_02.jpg	WIS135_CO_04oct2003_2304_S.gif	Resolute_CO_04oct2003_1800_S.gif			
					R1_031004_230606_03.jpg					
				R1_031005_124009_01.sard.avg	R1_031005_124009_01.jpg	WIS135_CO_05oct2003_1240_S.gif	Resolute_CO_05oct2003_1800_S.gif			

Date	Image Name			RSAT CEOS	RSAT JPG	Image Anal Chart	Daily Ice Chart	Weekly Regional Chart	Monthly Regional Chart	CFR (Aircraft) Chart
18/10/2003	ev_08532_18OT03_0316_020172.img	VV	VH	R1_031017_232543.sard.avg	R1_031017_232543_02.jpg	WIS135_CO_17oct2003_2325_S.gif	Resolute_CO_17oct2003_1800_S.gif			
					R1_031017_232659_03.jpg					
				R1_031018_130047_01.sard.avg	R1_031018_130047_01.jpg	WIS135_CO_18oct2003_1300_S.gif	Resolute_CO_18oct2003_1800_S.gif			
30/10/2003	ev_08704_30OT03_0338_020226.img	HV	HH	R1_031031_231742_01f.sard.avg	R1_031031_231742_01f.jpg			WArcticR_CO_27oct2003_1800_S.gif		
								EArcticR_CO_27oct2003_1800_S.gif		
05/11/2003	ev_08798_05NV03_1723_020229.img	HH		R1_031104_230012.sard.avg	R1_031104_230012_01.jpg			WArcticR_cCO_03nov2003_1800_S.gif		
					R1_031104_230127_02f.jpg			EArcticR_CO_03nov2003_1800_S.gif		
								WArcticR_cCO_03nov2003_1800_S.gif		
09/11/2003	ev_08847_09NV03_0324_020232.img	VV	VH	R1_031108_224435_02.sard.avg	R1_031108_224435_02.jpg			EArcticR_CO_03nov2003_1800_S.gif		

Date	Image Name			RSAT CEOS	RSAT JPG	Image Anal Chart	Daily Ice Chart	Weekly Regional Chart	Monthly Regional Chart	CFR (Aircraft) Chart
				R1_031109_23550 8_01f.sard.avg	R1_031109_23550 8_01f.jpg			WArcticR_CO_ 10nov2003_ 1800_S.gif		
								EArcticR_cCO_ 10nov2003_ 1800_S.gif		

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