Canada Centre for Remote Sensing
Surveys, Mapping and
Remote Sensing Sector

RADAR DATA DEVELOPMENT PROGRAM

Proceedings of the RDDP Workshop

GANANOQUE, JANUARY 26-28, 1993

Energy, Mines and Resources Canada / Énergie, Mines et Ressources Canada

Canada

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Canada Centre for Remote Sensing
Surveys, Mapping and Remote Sensing Sector
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Contents

Foreword

The participants of the Canadian Radar Data Development Program (RDDP) reconvened for their second national workshop meeting in Gananoque, Ontario, from January 26 to 28, 1993 to discuss current activities and future plans. As indicated by the title, this volume contains the proceedings of the RDDP Workshop and focuses on topics of interest to the radar remote sensing research and applications community at this time of preparation for the Canadian RADARSAT.

In their introductory presentations Drs. Leo Sayn-Wittgenstein, Robert O'Neil and Ronald Brown highlight current CCRS activities, preparations for RADARSAT and actual SAR applications development issues as they relate to the RDDP.

The RDDP discipline coordinators at the Canada Centre for Remote Sensing then provide overviews of their fields, *i.e.* Agriculture, Forestry, Hydrology, Geology, Ice, and Oceans, and present a series of recommendations resulting from discussions among the participants in the workshop meetings.

The RDDP workshop program was enhanced by a series of special presentations on the airborne SAR program at CCRS, SAR calibration issues, as well as RADARSAT processing and product development plans.

These Workshop Proceedings are part of the RDDP's ongoing endeavor to achieve and maintain good communications with the research and applications development communities in government, academia, and the private sector.

Introductory Remarks

by

Leo Sayn-Wittgenstein
Director General
Canada Centre for Remote Sensing / EMR Canada

Purpose of the Workshop

- Take stock of the present situation and recommend priorities for the two years left before the launch of RADARSAT[1]
- RDDP has to focus on applications which have a high probability of using RADARSAT operationally

Objectives of RADARSAT[2]

1. To build and operate a satellite carrying a Synthetic Aperture Radar (SAR) and to establish a Canadian Mission Control Facility
2. To provide data for resource management and maritime safety
3. To market RADARSAT data globally
4. To make SAR data available for research, to map the world with stereo radar, to map Antarctica in two seasons

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[1] Particular emphasis is on the development of promising applications of RADARSAT SAR data.

[2] RADARSAT is a $500M program initiated and approved by the Government of Canada.

RADARSAT is a Partnership.

CSA

- Development, launch and operation of satellite
- Coordination of Long–Term Space Plan

CCRS

- Ground system (data reception, archive, and access to archive)
- Development of applications and supporting airborne data acquisition and research
- Liaison with user community[3]

Provinces

- Contributing and participating provinces
- Major users of data

RSI

- Marketing of RADARSAT data
- International reception agreements

[3] Partnerships with industry are emphasized.

NASA

- Launch of satellite plus access to data

The remote sensing industry, the value added companies, and the academic community participate in applications and research.

Environment at CCRS

- CCRS promotes and demonstrates the use of remotely sensed data and ensures the availability of data and methods for their use.
- CCRS, SMRS and EMR are only small users of data.
- Financial restraint at CSA and CCRS
- Reductions in A–base and pressure for cost recovery at EMR
- CSA and CCRS have defined their division of responsibilities and operate as partners.
- CCRS is increasing its role in international applications and market development[4].
- Time before the launch of RADARSAT is running out.

[4] This move applies for the entire SMRS Sector of EMR Canada.

Relevant CCRS Activities

1. Support RADARSAT operations

- Substantial participation in design studies, and systems development
- Planning and development for RADARSAT calibration
- Reception and archiving of data at the Canadian Ground Stations

2. Manage the Radar Data Development Program

3. Participate in development of Long-term Space Plan

- Earth Observation Working Group:
  - RADARSAT Data Utilization Program (RDUP)
  - new information systems exploiting RADARSAT
- RADARSAT II and III.

4. Participate in or lead new initiatives

Immediate CCRS Initiatives

- GlobeSAR[5] and completion of SAREX 92.

- RADARSAT A/O (RADARSAT Data Validation Program)

  - international scientific: managed by NASA
  - commercial: managed and supported by RSI
  - Canadian: managed by CCRS with support from LTSP.

- Restructure CCRS Technical Working Groups. NPCC and CCRS WG's provide interface with user community. WG's will be restructured to emphasize RADARSAT responsibilities.

- CCRS looks forward to sharply defined priorities emerging from this Workshop.

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[5] Substantial financial contributions from other sources than CCRS budgets are required in order to initiate and complete this project.

The Radar Data Development Program Prepares for RADARSAT

by

Robert O'Neil
Director, Major Projects Office
Canada Centre for Remote Sensing

Principal Issue Confronting the Community

- Effective Data Utilization

- Partners have different perspectives:

    - RADARSAT Project Office (RPO) - general, global

    - RADARSAT International (RSI) - ground stations (reception fees), commercial data sales (royalties), processing services (in Canada), potential value-added products and services

    - CCRS - the Canadian Community

    - NASA/NOAA - internal projects (research and operational)

Presentations by the RDDP Discipline Coordinators

- Statement of where each discipline stands in Canada

- Identification of the most promising applications and likely real users

- Propose specific steps needed for data to be used early in the RADARSAT I era

Evolution of an Idea[1]

→ scientific research

→ applications development

→ demonstrations

→ pilot project

→ operational use

Task of the Concurrent Workshops

- To review the specific project steps proposed by the Coordinator
- Recommend improvements
- Develop a plan to carry out the work needed to ensure success early in the RADARSAT I era

[1] This model applies to the use of RADARSAT data.

Two Touchstones

Competitiveness[2]

- A principal thrust of the Canadian Government is to assist Canadian industry to be competitive.

- This is now a prime objective for EMR.

- It will be difficult to justify new activities for the public good.

Revenue

- RADARSAT operations are funded from revenue returned to CSA by RSI.

- Revenue is returned from station licences and royalties on data sales.

- No licence fees from Canadian or US government ground stations.

- No royalty on data used by the Canadian Government, or the US Government.[3]

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[2] The issue of competitiveness is a hotly debated one and ought to be seen from the point of view of competitiveness in the international arena.

[3] This presents a situation where the biggest users of RADARSAT do NOT generate revenue.

The Marketplace

Steps in Use of RADARSAT Data

- Request acquisition (signal data goes into archive)
- Extract signal data from archive
- Convert SAR signal data to imagery (*e.g.* CDPF at Gatineau)
- Deliver to value added company or end user (communications)
- Perform radiometric and geometric corrections
- Integrate with other data sets (data and/or information systems)
- Carry out analysis to extract information
- Generate decision support products
- The user pays
  (investment of money, staff, systems, training) ...
  ice remains only established operational application

Marketplace (continued)

Data Utilization (General)

- Main clients will be government sponsored programs.

- Little understanding of the commercial markets for RADARSAT data and associated services.

Data Utilization (Canada)

- RADARSAT applications compete with sophisticated existing infrastructure.

- Early Canadian Government requirement seems to be rather small with exception of Ice Centre

Data Utilization (US)

- Huge ice research program (NASA), operational requirement for global ice data (NOAA), operational requirement for global coastal data

- NASA/NOAA could provide data to other users linked to US government programs *e.g.* sponsorship of global monitoring/global change programs by NASA/NOAA could make RADARSAT data widely available in US research community through EOSDIS.

Data Utilization (International)

- RADARSAT data can be very attractive where there is little infrastructure

- RADARSAT data policy demands that data be purchased ... difficult to raise funds for developing countries.

- Significant potential in national ice monitoring programs

- Interest in Europe for research

Marketpace (continued)

Technology (hardware and software)

- Canada is developing some interesting products.

- Data integration/fusion is still clumsy and difficult

- Canadians are no longer alone in the market, very sophisticated products are available from US and European suppliers, international competition is becoming ferocious.

- Still have lead in ground systems

Derived Products and Services[4]

- May be market for sophisticated services if client is willing to pay premium for the products

- Uncertain of opportunities for private sector to provide services to US government

- Little likelihood of access to R&D funds offshore unless an international development agency is the source

- Foreign governments and trading blocks (*e.g.* EC, NAFTA) will prefer indigenous suppliers for operational requirements.

---

4 It has been perhaps too early to expect the private sector to make an investment in pusuing commercial markets for products and services derived from RADARSAT data. From now to launch, in two years time, one can expect to see increasing interest and activity.

The Canadian Remote Sensing Community

- Lots of talent and good ideas, substantial effort has been applied to scientific foundations, understand the principles of the potential applications

- Some expertise has not been tapped (*e.g.* Sherbrooke and Laval are delivering information solutions to desert regions)

- Limited resources to develop products and services that continue to meet international competition

- Most Canadian companies are small, serving very specialized or regional markets without resources to market products and services internationally[5].

How to Proceed?

- Evaluate clients' requirement rigorously, assess likelihood of being able to meet requirement and establish clients' ability to pay for adequate solution in near term

- Move to demonstration projects and pilot projects with true, real user participation

- Develop capability of private sector to offer appropriate products and services

- Ensure that products and services can be sold directly or carried into market by prime contractors as components of larger projects

[5] Three or four organizations are remarkably different from the majority of organizations in the Canadian community: Macdonald Dettwiler and Associates, the Intera group of companies, the Ice Centre (Atmospheric Environment Service) and SPAR Aerospace. Clearly the three companies mentioned operate internationally. In discussions it is important to know whether these are included or not in a generalization. In the oceans discipline, small companies have been able to find a non-Canadian market for their services. Some small companies serving a research market have been successful internationally.

Magnitude of the RDDP

$5M.

plus:

- CCRS resources (PYs, $, facilities)
- Resources of collaborators and participants
- External funding (*e.g.* IRAP, WED, ACOA, DIPP, provincial, international, *etc.*)
- Support from RSI and RPO/CSA
- Complementary programs (*e.g.* Canadian ERS-1 and J-ERS-1 AOs, RADARSAT Data Evaluation Program[6], GLOBESAR)

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[6] In the current proposal there are three components to this: an international scientific component to be run along the lines of a familiar NASA AO, a component sponsored by RSI to support the development of commercial applications, and a component sponsored by CSA and CCRS to provide Canadians with limited amounts of data (from anywhere on the globe) for scientific research, applications development, products development, marketing etc..

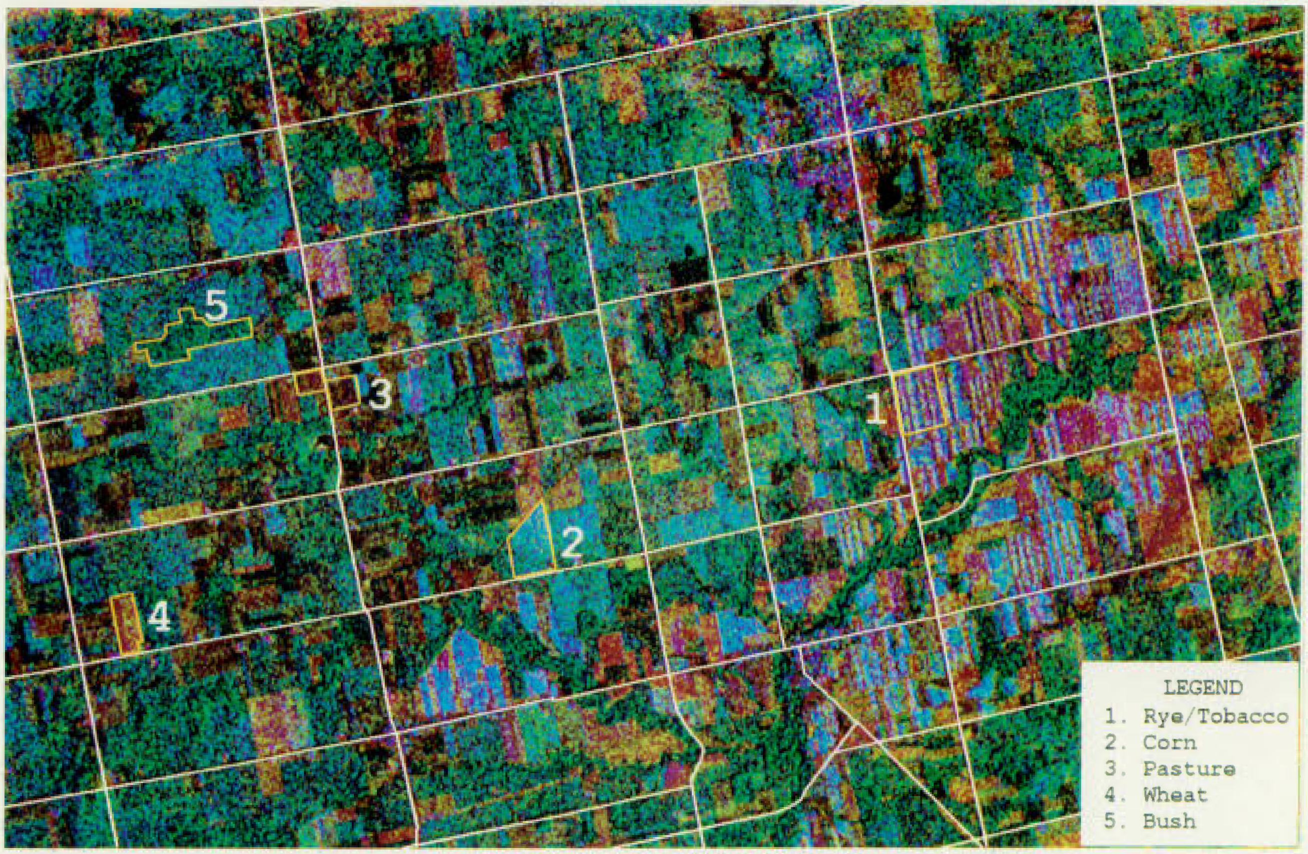
RDDP: Applications Development

and

Agriculture - An Overview

by

Ronald J. Brown
RDDP Coordinator / Agriculture
Canada Centre for Remote Sensing



Colour image of area near Norwich in Oxford County, Ontario with Landsat TM band 3 (August 1992) displayed as red, ERS-1 (August 1992) displayed as green, and ERS-1 (July 1992) displayed as blue. Considerable variation is seen across the agricultural area between the land cover types. ERS-1 has shown that the multitemporal aspect of SAR imagery is very valuable for vegetation-related applications. (Copyright ESA 1992).

RDDP: Applications Development

Overall Goal

- Develop and demonstrate the uses of remotely sensed data
- Assist in the implementation of remotely sensed data in an operational environment

Short Term Goal

- Develop applications for RADARSAT data
- Develop capabilities to supply information products[1]
- Data integration / synergy[2]

1 Joint effort of CCRS and industry.

2 It should be recognized that SAR data can only fulfil certain information requirements; other remote sensing and GIS data sources need to be considered as well.

- User driven[3]
- National / cooperative effort
  - Other federal departments
  - Provinces
  - Universities[4]
  - Industry
- Good applications development model
  - Development of national objectives
  - Strong in-house CCRS program[5]
  - Joint projects with users
  - Applications Working Groups
  - Access to imagery[6]
- Elements
  - SIR-A, SIR-B, SEASAT
  - Airborne SAR and scatterometer
  - Ground based scatterometer
  - Satellite SAR simulation
  - ERS-1 / JERS-1
  - SIR-C
  - RADARSAT
- Complex problem
  - Must build upon a solid scientific base
- International development
  - Tropical Forestry Initiative (TFI)
  - GlobeSAR
  - ESA / JERS / SIR-C AO
  - RADARSAT AO
  - Contacts

---

[3] Project work proceeds only after thorough requirement definition.

[4] Universities fulfil an important role because their work broadens the scientic base of applications development work.

[5] In conjunction with users.

[6] Prime example: CCRS's own Airborne C/X SAR system which can be used for SAR applications development work across Canada and, in future, for missions overseas.

Agricultural Applications

Requirements

- Land use
- Crop type and area
- Crop condition
- Documentation of events
  - Tornadoes
  - Crop lodging
  - Effect of frost
- Information is part of an overall larger program

User Agencies

- Crop Insurance Agencies
- Local agricultural representatives
- Companies
  - Intera Information Technologies Corp.
  - Terrain Resources Ltd.
  - Terrestrial and Aquatic Environmental Managers, Ltd.
  - Devel-Tech Incorporation
- Agriculture Canada
- Canadian Wheat Board
- Statistics Canada
- Commodity industry
- Ministère de l'energie et des ressources du Québec
- Ministère de l'agriculture, des pêcherie et de l'alimentation du Québec

Participating Agencies

- Ontario Provincial Remote Sensing Office
- Ontario Ministry of Food and Agriculture
- Universities of Guelph, Sherbrooke, Waterloo, Laval, Alberta
- Agriculture Canada
- Manitoba Remote Sensing Centre
- Saskatchewan Research Council

Thrusts

- Soil conservation practice monitoring and implementation of remedial action
- Crop area estimation
  - Field
  - Region
- Vegetation condition[7]
  - Region
  - Local (ERS-1)
- National / international component

---

7 The development of methodologies to improve the measurement of soil moisture by means of SAR will be an important part of the R&D program over the next five years.

Soil Conservation

- Major concern nationally and internationally
- Wind and water erosion models
- Inputs
  - Land cover[8]
  - Permanent / agricultural
  - Grains
  - Oil seeds
  - Residue
  - Cultivation
  - Topography
  - Soil type
- Significant progress: RDDP

  Relationship between surface roughness and soil conservation classes

  - 1988 scatterometer (Saskatchewan)
  - 1990/1992 : airborne SAR (Alberta)
  - 1991 : airborne SAR (Ontario)
  - 1991 : airborne SAR (Quebec)
  - SAR/VIR synergy needed for cultivation/residue class discrimination (SAR uniquely gives information on cultivation)

  Landcover classes

  - Grains, oilseeds easily distinguished (VIR and a/c SAR)
  - Verified with ERS-1
- Future development
  - Satellite SAR resolution[9]
  - Time of data acquisition (season)[10]
  - Effect of moisture

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[8] For example, SAR is able to provide a clear separation earlier in the growing season than with VIR between oil seeds, grains and fallow.

[9] Also, the effect of incidence angle variation for the RADARSAT ScanSAR mode (500 km swath width) needs to be studied.

[10] For example, effect of snowfall on the backscatter due to roughness needs to be studies.

Crop Area

- Region
  - Statistics Canada
  - Agriculture Canada
  - Marketing Boards
  - Commodity community

- Field
  - Manitoba Crop Insurance Corporation
  - Saskatchewan Research Council
  - Manitoba Remote Sensing Corporation
  - Agriculture Canada

Crop Area - Region

- Approach adopted from VIR work
- Significant progress: RDDP

Synergy between VIR/SAR

- 1988 (Saskatoon)

Multitemporal SAR

- 1983 (Melfort)
- 1988 (Melfort/Oxford)
- 1990 (PEI)

Environmental effects

- 1989 (Melfort)
- 1990 (Oxford)
- 1992 (Oxford/ERS-1)
- Satellite SAR
- 1992 (Altona)[11]

Diurnal effects

- 1989 (Melfort)
- MIMICS
- Scatterometer

Incidence angle

- Scatterometer
- 1992 (Altona)

Expert systems

- Crop rotation probability

Classification

- pixel/field
- segmentation
- preprocessing

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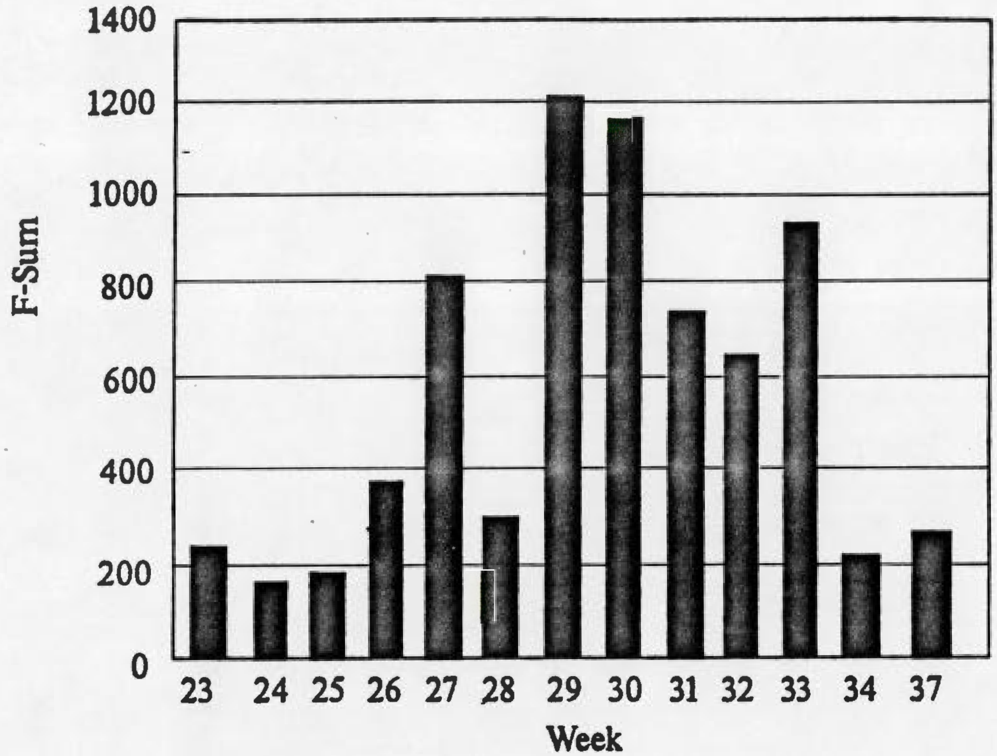
11 Recent results from the Altona test site suggest that ERS-1 SAR data (small incidence angle) may be suitable for assessing conditions on a field-by-field basis (knowing the crop type).

SEPARABILITY

CROPS	DIVERGENCE	TRANSFORMED DIVERGENCE
FLAX-WHEAT	0.55	0.13
FLAX-SUGAR BEETS	18.57	1.80
FLAX-CANOLA	8.86	1.34
FLAX-SUNFLOWERS	40.87	1.99
FLAX-CORN	7.09	1.18
WHEAT-SUGAR BEETS	28.57	1.94
WHEAT-CANOLA	15.08	1.70
WHEAT-SUNFLOWERS	58.58	2.00
WHEAT-CORN	12.56	1.58
SUGAR BEETS-CANOLA	1.15	0.27
SUGAR BEETS-SUNFLOWERS	2.17	0.48
SUGAR BEETS-CORN	1.96	0.44
CANOLA-SUNFLOWERS	6.86	1.15
CANOLA-CORN	0.09	0.02
CORN-SUNFLOWERS	9.07	1.36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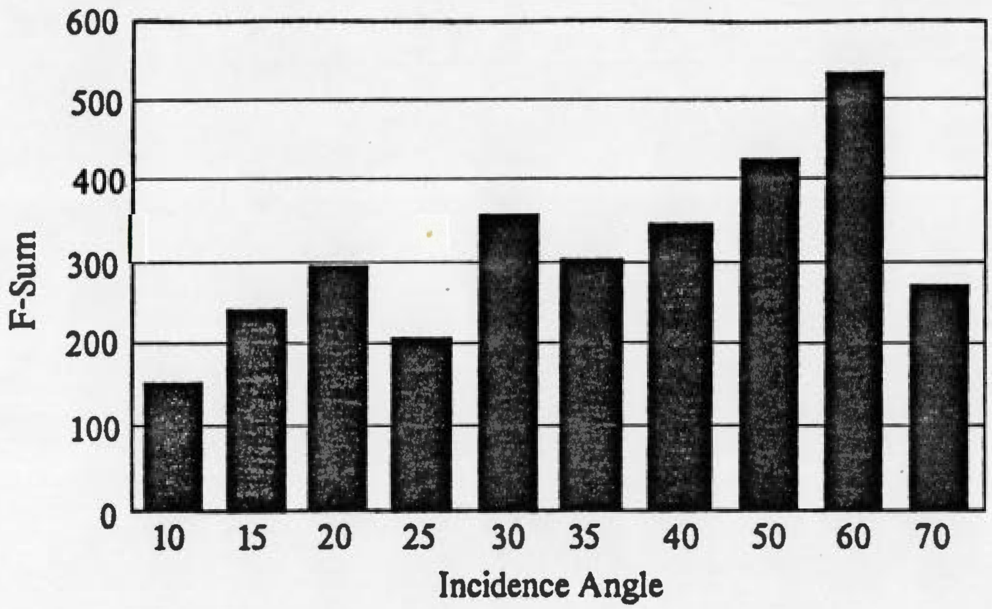
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70
Incidence Angle

- Future development
  - Incidence angle (SIR-C)
  - Pilot project (national)
  - International expansion
  - Multitemporal / single date

Crop Area - Field

- Normally know crop type
  - Area to 5%
  - Condition relative
- Development from start of RDDP
  - Regression
  - Pixel division
  - Maybe restricted to specific crop types
- Future development
  - RADARSAT modes / resolutions
  - RADARSAT incidence angles
  - Damaged areas

Vegetation Condition

- Direct observation of vegetation
- Soil moisture
  - 1983 (Outlook)
  - 1988 (Outlook)
  - 1988-92 (scatterometer)
  - 1990 (Oxford)
  - 1992 (Oxford)
- Significant progress RDDP
  - Quantitative soil moisture / roughness levels
  - Models to relate to root zone
  - Relate backscatter to depth
- Further development
  - Model roughness / soil moisture
  - Assess region of validity

Other Applications / Developments

- Duck habitat / land use
- Data compression
- Rangeland
- Salinity

RECOMMENDATIONS - AGRICULTURE WORKSHOP

Presented by

Ronald J. Brown
RDDP Coordinator / Agriculture
Canada Centre for Remote Sensing

International

- Strongly support the expansion into the international market
  - Soil conservation
  - Disaster mitigation
- Feel that the GLOBESAR approach to promoting Canadian technology and expertise is a good one[12]
- Look at expansion of existing contracts to use SAR (universities): use of other Canadian expertise[13]
- Support the suggestion of generation of a compendium of SAR "signatures"[14]

Soil Conservation

- Significant application development area
- Information required nationally and internationally
- Significant SAR role: unique information content
- Interest in New Brunswick, Quebec, Ontario, Manitoba, Alberta
- Need to organize a national workshop on the topic
  - Identify the requirements by region and internationally
  - Coordinate the activities throughout the country[15]

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12 Support is not only required for SAR data acquisition, but also for follow-on processing and analysis work.

13 For example universities, other government departments, and industry

14 This compendium would contain SAR image data of different land cover types, information on plant phenology, as well as appropriate on-site information, for example photographs of ground conditions.

15 The emphasis should be on the entire program and should not be restricted to remote sensing issues.

Area/Cover Type Determination

- Important (especially at local level)

- Needs to be supported

Soil Moisture

- There should be more emphasis upon soil moisture

  - Important market
  - Other applications (irrigation scheduling/water use monitoring)
  - Phased approach to the development allows for RADARSAT data use early in the program
  - Pilot project to use SAR imagery to update\revise maps based upon precipitation in 1994
  - RADARSAT data (multi-incidence) to remove roughness

Other

- Non-civilian applications have similar requirements to many agricultural applications[16]

Data Products

- Need to establish the price of data

- Geocoding costs (VAI) must be kept to acceptable levels[17]

- Calibration is important particularly for ScanSAR mode

- Need for a continuing calibration plan and activity (calibration must be reversible to make use of updated calibration coefficients)

- Need user friendly software to

  - relate modes to dates of data takes
  - review planned and acquired data

- Data turn around is important (24 hours acceptable)

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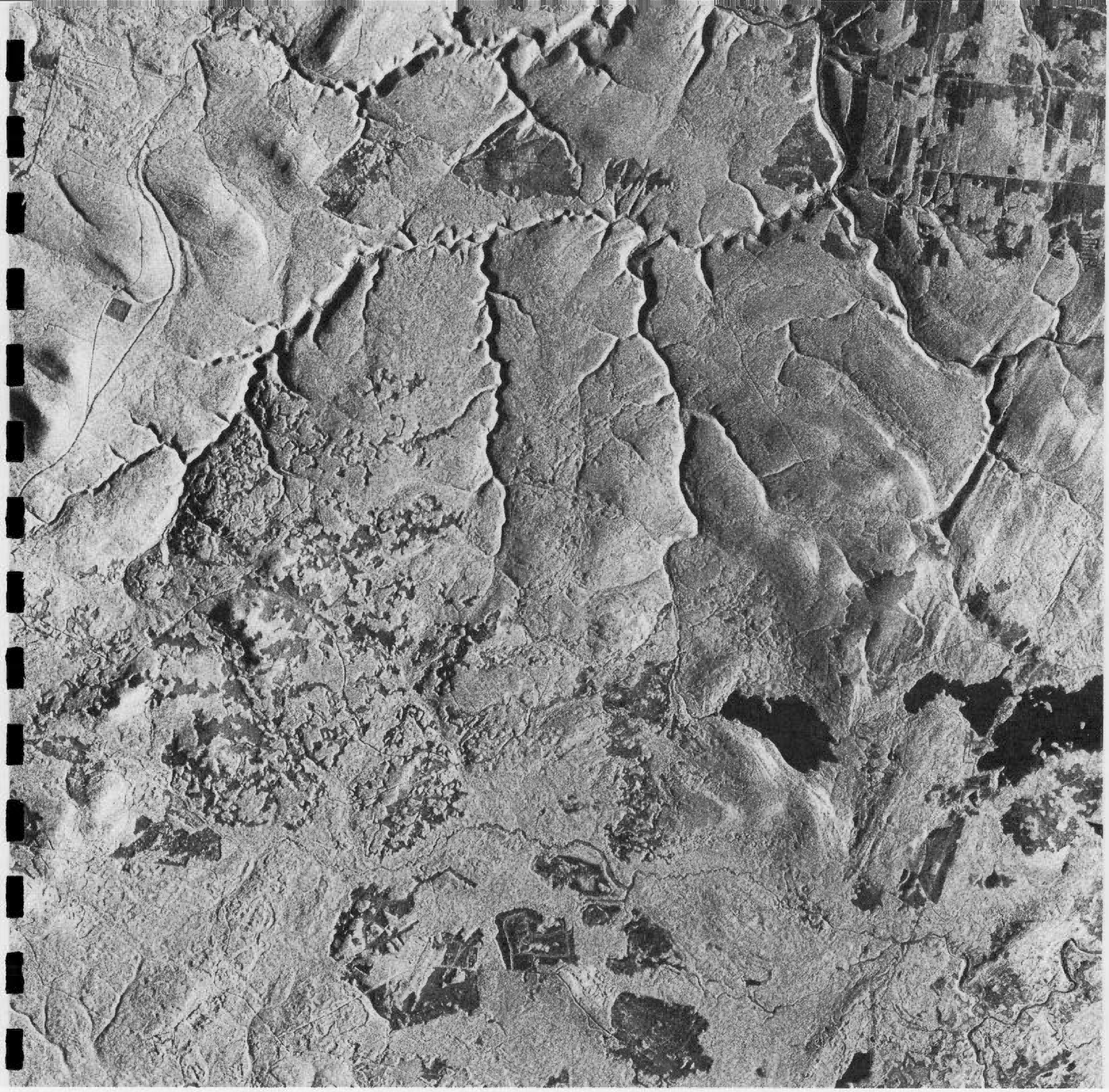
16 For example, there is a requirement for land use and land cover information.

17 Price policy and value-added costs might negate or slow down applications development.

Forestry - An Overview

by

Francis J. Ahern
RDDP Coordinator / Forestry
Canada Centre for Remote Sensing



LAC CASAULT, QUEBEC

This is a CCRS C-band HH SAR narrow mode image, in ground range representation. The look direction is from right to left across the image. The data was acquired on March 21, 1991, in the Notre Dame Mountains area of South-Eastern Quebec (Gaspe).

The general ground conditions at the time of data acquisition would have consisted of dry snow in sheltered areas, and wet snow in exposed sites, with some possible surface water on the lake ice. This would explain the lack of SAR return from the lakes. Further indication of the snow conditions can be seen in the road patterns throughout the large cut blocks. The two parallel bands of bright backscatter are a result of snow clearing activity on these roads. As well, the tonal contrast between the recent cut blocks and the surrounding forest is very distinct. The snow pack provides a much smoother and more consistent target than the slash and scrub vegetation, left from cutting operations. Older cutting areas are more difficult to detect, due to regeneration. However, there is still a significant height difference between the two types of vegetation cover, so the edges of the old cuts are discernable.

The forest types in this area are primarily spruce and balsam fir with a mix of hardwoods (maple and birch). There are two distinct cutting patterns, indicated in this image. These patterns are consistent with selective cutting practices, within a mixed-forest type, for softwood extraction. Courtesy of (Centre de télédétection du Québec)

Overall Goal

The goal of the forestry applications portion of the RDDP is to improve the management of forests through the application of microwave remote sensing technology.

A secondary goal is to strengthen the Canadian private sector in its ability to offer hardware and software products, and natural resource management services, in a growing world market.

Potential RADARSAT Contribution (at the beginning of the RDDP)

Forest depletion mapping was identified as the most promising operational application of RADARSAT in 1985 (Cihlar *et al.*). Monitoring of tropical deforestation was indicated as one of RADARSAT's most important potential contributions. Timber volume and regeneration were identified as potential applications with lower probability of success.

RADARSAT Applications

After five years of RDDP sponsored investigation into many potential forestry applications of microwave data, it appears that the primary operational applications for RADARSAT-1 will be clearcut and burn mapping. Broad cover type mapping is feasible with multi-season data, and this application may be important in poorly mapped areas.

Principal Users

The provincial forest ministries are the ultimate clients of nearly all of the operational forestry remote sensing applications in Canada to date. The principal reason is that the information content of satellite data and the areas to be managed make satellite data most suitable for their requirements. This situation will also hold true for RADARSAT. The information required by the private forest companies is generally too detailed to be obtained from either optical or microwave satellites.

Information Required

The information requirements of the Canadian forest sector have been the subject of many studies during the life of CCRS, and are well summarized by *Ahern and Leckie (1987)*. Of the desired information, timely mapping of forest depletions by fire and logging appear the most suited to operational use of RADARSAT-1 data. Additional information on stand species composition, mean tree diameter, and stand biomass appear feasible with a dual-frequency polarimetric SAR such as proposed for RADARSAT-3.

Unknowns at the Beginning of the RDDP

Knowledge about the utility of microwave remote sensing for forestry applications was very scanty indeed at the beginning of the RDDP, particularly with respect to C-band data. Some of the unanswered questions included:

- Optimum and acceptable wavelengths, incidence angles, and spatial resolutions for clearcut and burn mapping.
- Sensitivity of microwave backscatter, especially at C-band, to forest tree species of interest in Canada.
- Sensitivity of microwave backscatter, especially at C-band, to forest biomass and other stand parameters of interest in Canada.
- The influence of seasonal effects: Do seasonal changes provide useful information, or are they just a source of noise?[1]
- Suitable methodologies for operational clearcut and burn mapping.
- The information content, in a broad sense, of radar data, and in what ways it complements and/or duplicates the information available from optical sensors.
- The potential uses of RADARSAT data in tropical forest environments.

---

1 It should be noted that forestry applications may require multiple data sets in order to provide useful information, e.g. change detection; this has serious cost implications.

Progress Made To-date

Operation	Research	Demo.	Pilot
Broad cover type mapping			
Hardwood/Softwood		*	
Softwood species		*	
Depletion monitoring			
Clearcut mapping			*
Burn mapping			*
Regeneration monitoring		-	
Forest stand characteristics			
Forest biomass			*
Diameter / density		*	
Tropical forest applications		*	

Summary

In summary, tremendous progress has been made in answering many of the questions which existed at the beginning of the RDDP. Certain applications, particularly clearcut and burn mapping, were found to be more difficult than originally expected. We now have a much better idea which applications will be feasible with RADARSAT-1, which applications will have to wait for more advanced spaceborne radars, and which might be feasible with specialized airborne radars. We also have a much clearer picture of the work which remains to make RADARSAT-1 a success in forestry.

Work To Be Done

Use the *Archibald-Ahern technique* to evaluate the clearcut mapping accuracy of several data sources including the C-SAR, simulated RADARSAT (high resolution and standard modes), and JERS-1.

Develop operational GIS software for digital forest inventory updating using RADARSAT data (Dendron initiative with strong support from CCRS).

Carry out a RADARSAT "dry-run" demonstration using JERS-1, or simulated RADARSAT data.

Use combined observational and modelling studies to define optimum frequency/polarization combinations for timber volume and tree size determination.

Determine the information content of multifrequency polarimetric SAR data of Canadian forests.

RECOMMENDATIONS - FORESTRY WORKSHOP

Presented by

Francis J. Ahern
RDDP Coordinator / Forestry
Canada Centre for Remote Sensing

RADARSAT-1 Readiness / Forestry

- Most promising applications
  - Domestic[2]
- What has to be done
  - Applications R&D
  - Systems
  - User readiness
    Forestry Working Group
  - Operational requirements (*e.g.* satellite scheduling)
  - Price

RADARSAT-2

- HH vs VV (and HV?)

RADARSAT-3

- Schedule
- Envelope (technical feasibility)
- R&D necessary

Workshop Presentations

J. Drieman - C-SAR and ERS-1 results in Newfoundland

G. Edwards - Clearcut mapping with airborne SAR using segmentation for semi-automated boundary placement.

Ester Boulianne - ERS-1 information content;
Forêt Montmorency

Diane Thompson - Review of some Intera operational projects in tropical forests

Ian McKirdy - Principal Components Analysis of Multitemporal, Multipolarization Radar Data Set

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2 There are also opportunities in the international arena.

Recommendations

1. It is important to determine how long it takes for a burn to become visible on C-SAR imagery, and under what circumstances[3]. Our group should be prepared to respond to the next big fire anywhere in Canada. Need coordination and preparation. Establish plans and a CCRS hotline with someone ready to respond.

2. In international applications we should be exporting value added products, not raw data.

3. Need to check on resampling kernel for geometric correction; Joji claims it needs research since traditional kernel can introduce artifacts such as ghost speckle.

4. Forestry users require terrain corrections for geometry, and, in mountainous areas, radiometry as well.

5. SMRSS should aid RSI in its survey of current and projected DEM availability.

6. The planned world stereo data set should be considered as a valuable opportunity to acquire a consistent, medium quality DEM. (Nations are protective of their topographic information). While not satisfying all traditional mapping requirements, this would provide a worldwide DEM for subsequent terrain correction of RADARSAT data. It would also be a valuable geophysical data set as well valuable ancillary data for a wide variety of applications.

   Suitable technology[4] has been developed for Magellan mission, as well as much StarMap technology.

   This data set should be provided nonrestrictively, under the same open skies rules which govern satellite data distribution.

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[3] The potential of using ERS-1 SAR data for this application needs to be explored.

[4] For example 'shape-from-shading' techniques

7. A forestry working group aimed at preparing for RADARSAT should be affiliated with the Canadian Forest Inventory Remote Sensing subgroup. Membership should include M. Gillis (chair of CFIC RS subgroup), one or two provincial members of CFIC, a private sector member with international links, someone from a domestic forestry consulting company, someone from a forest products company (preferably with overseas operations; Fletcher Challenge was suggested), and someone from PROGERT, as well as the CCRS forestry coordinator. Consideration should be given to the tight travel restrictions on provincial foresters.

8. A post-launch demonstration/evaluation program should be planned[5]. The A/O approach is too loose. The ideal would be for CCRS to supply two-date terrain corrected data to one project in each province. RDDP funding equivalent to 3 p-m should be provided to carry out the evaluation. The best studies should be packaged as case studies to convince more users to try RADARSAT. Several international test cases should be carried out as well.

9. International development funding agencies should be prepared for RADARSAT (e.g. World Bank). RSI should prepare promotional material aimed at this community.

10. CCRS should consider sponsoring the development of a low-cost SAR workstation to stimulate RADARSAT usage around the world.

11. Operational recommendations for clearcut mapping:

    - Large incidence angle
    - Thick snowpack (poor timing for Quebec[6])
    - One month delivery
    - Geometric accuracy: 20 m
    - Two images (before/after) from same look direction

12. A price range of $500 to $1200 per scene (100kmx100km) of terrain corrected data was considered competitive. Anything higher would have difficulty competing with Landsat.

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5 Strictly for users in Canada

6 Reporting period in Quebec is November/December.

13. Provision of HH / VV choice for RADARSAT-2 was considered valuable, in light of results presented by Linda Dion. Cross-pol has been found to have higher contrast for clearcut mapping, roads, and other human disturbances. However, SNR will be lower with RADARSAT-2. Someone should simulate an expected RADARSAT-2 cross-pol image.

14. A clear statement on plans for RADARSAT-2 is needed if users are to be persuaded to adopt RADARSAT-1 data[7].

15. The RADARSAT-3 timeframe was expected to be 2005-2010. The design should not be frozen more than 5 years before launch to allow it to make use of technology and applications development. If that is not possible, the SmallSat route should be considered as an alternative.

16. The following was proposed as strawman specs for a sensor of greatest value for forestry applications:

    - Two fully-polarimetric bands
    - Low and high frequencies, well-separated[8]
    - 100 km swath at finest resolution
    - Decreased resolution/increased swath modes as in RADARSAT-1
    - 5 m - 1 look spatial resolution one band, 10 m in the other, interchangeable and user-selectable.

---

[7] Data continuity is important for the forestry user community.

[8] Preferably by a factor of 5 to 10, rather thana factor of 2.

17. The following R&D areas should be pursued to provide better advice regarding RADARSAT-3 and prepare for its introduction:

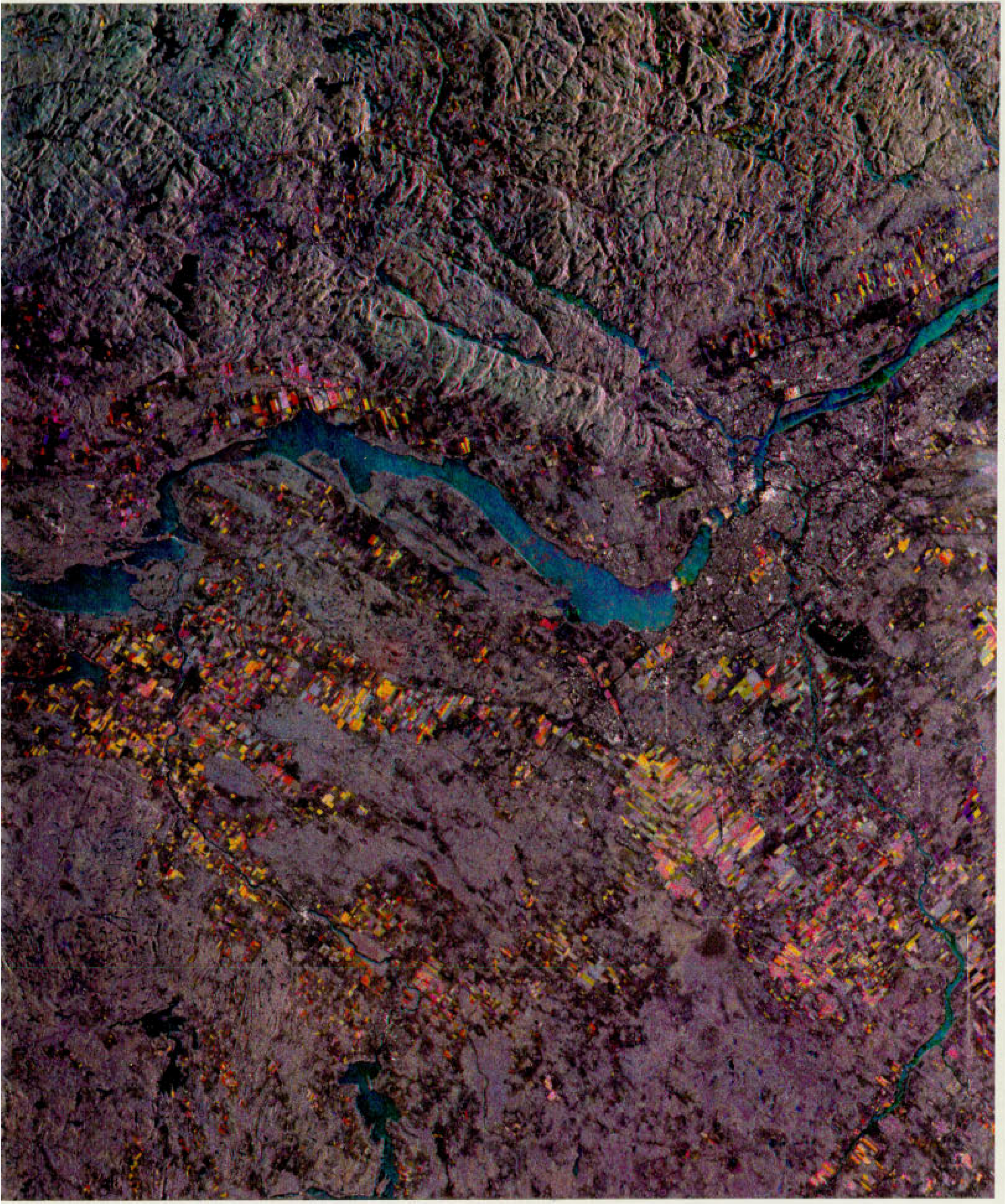
    - Forest biomass, particularly P vs L bands
    - Sensor optimization for biomass
    - Detecting partial cuts
    - Forest species
    - Image analysis research
    - Textural research
    - Extraction of tree size distribution or at least mean stand dbh
    - Research leading to fully corrected products from the data vendor
    - Principal components analysis of high-dimensionality data sets
    - Evapo-transpiration
    - Revisit/improve clearcut, burn, and road mapping
    - Made-in-Canada backscatter modelling effort.
    - Research an optical sensor specifically designed to complement RADARSAT-3. Could be on same bus or on separate free-flyer.

18. CCRS/RDDP should help stimulate NSERC or other funding source to support university researchers, in order to provided the needed basic research.

Hydrology - An Overview

by

Terry Pultz
RDDP Coordinator / Hydrology
Canada Centre for Remote Sensing



This image is a colour composite of ERS-1 data of the Ottawa River, Ontario and surrounding area. The images used to form the composite were acquired on November 28, 1992 (displayed in red), October 24, 1992 (displayed in green) and August 19, 1992 (displayed in blue). Surface water features such as rivers, lakes and wetlands are easily identifiable in the image as are different land cover types. The various colours of the agricultural fields relate to differences in surface geometry and moisture content. (Copyright ESA 1992)

Goal

- Overall

  Develop the system elements required for the successful operational use of satellite data in hydrology.

Short Term

- Evaluate the feasibility of extracting information from SAR data

  - Soil moisture
  - Areal extent of snow cover (wet and dry)
  - Snow water equivalent
  - River ice dynamics
  - Flood extent and flood damage
  - Wetland condition

- Initiate and support research and development

  - Distributed hydrological models that can effectively use spatial data as input;

  - Techniques to assimilate remotely sensed data into hydrological models for runoff forecast

- Demonstrate the use of radar and other spatial data for hydrological applications in an operational setting

Background

- Effective management of water resources depends on accurate estimations of the elements of the hydrologic cycle.
- Currently, major utilities and river forecast centres use models which use data collected at discrete points on precipitation, snowpack, temperature and streamflow (DCPs).
- Errors of 10 to 20% in stream flow are frequently obtained.
- More accurate forecasts could be obtained by combining area-wide information from remotely sensed data combined with the site-specific data from DCPs.
- Currently, very little use is made of remotely sensed data in hydrologic modelling
- Very few hydrology users have systems for ingesting and analyzing spatial data.
- Water resource managers express interest in remote sensing.

However, the benefits need to be clearly demonstrated[1].

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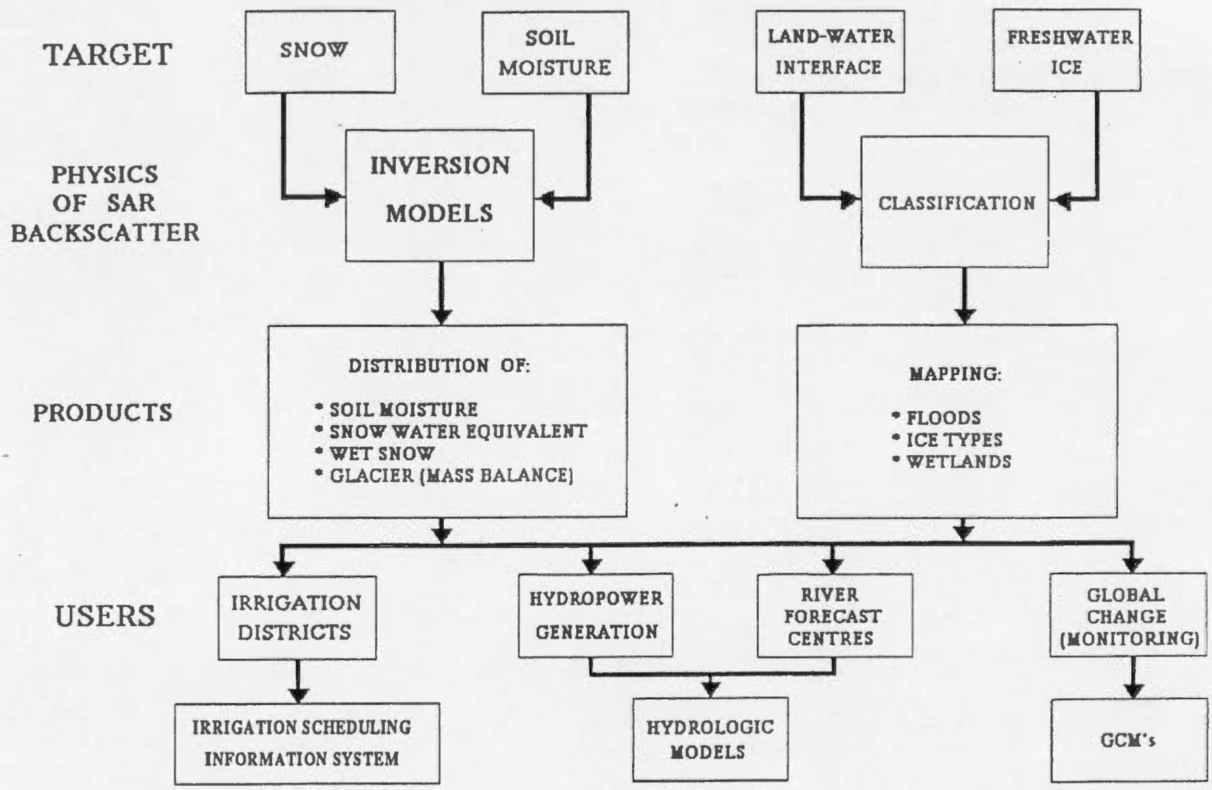
1 This requires considerable effort in developing new numerical models.

HYDROLOGY PROGRAM



Projects To-date

- Snow studies
  - Churchill Falls, Newfoundland
  - Woodstock, New Brunswick
  - Eaton River Basin, Quebec
  - Carp, Ontario
  - Upper Grand River Basin, Ontario
  - Whitecourt, Alberta
  - Peyto Glacier, Alberta
  - Sentinel Glacier, British Columbia

- Soil moisture studies
  - Woodstock, New Brunswick
  - Carp, Ontario
  - Big Otter Creek watershed (Oxford County), Ontario
  - Outlook, Saskatchewan

- Fresh water studies
  - Saint John River, New Brunswick
  - Burntwood River, Manitoba

- Flood and wetland studies
  - Saint John River, New Brunswick
  - Hudson Bay Lowlands, Ontario
  - Carp, Ontario

- Hydrological modelling
  - St. Francis River, New Brunswick
  - Eaton River, Quebec

Cooperative Research Program

Agencies, universities, and companies have been involved in joint projects.

- Agriculture Canada / soil moisture
- University of Saskatchewan / soil moisture
- New Brunswick Department of Environment / snow hydrology, fresh water ice and flood mapping
- MacPlan / river ice
- University of Waterloo / snow, soil moisture
- NHRI / evaluation of hydrologic models, snow
- DRES / snow
- CRREL / snow

CCRS Internal project work

- Soil moisture project with CCRS Agriculture Group
- Snow hydrology project with CCRS Forestry Group
- Snow hydrology project with TEP / Memorial University

Support (financial and technical) has been provided to agencies, universities, and companies

- INRS-Eau / development of a distributed hydrological model GIS/Image analysis package for flood runoff simulation and forecasting
- Horler Information System / development of software to automatically delineate watershed boundaries and calculate soil erosion parameters from DEMs
- University of Ottawa / evaluation of HYDROTEL
- University of Waterloo / snow and soil moisture research
- Terrain Resources / scatterometer data collection and analysis on snowpacks
- Intera Information Technologies / research assistance on internal projects

Status Report

Soil Moisture

- Quantitative relationship between soil moisture and radar backscatter demonstrated[2].
- Surface roughness can have a significant effect on backscatter and is a function of incidence angle.
- SAR penetration characteristics are not well understood.
- No universal model relating backscatter to soil moisture.

Snow

- Dry Snow (SWE)
  - Scattering in the snowpack is not well understood
  - Nature of the underlying surface has a significant effect
- Wet Snow
  - Acts as a "lossy" material, signature significantly different than dry snow
  - SAR will be useful in mapping the areal extent of wet snow.

[2] It should be noted that there is no universal model to quantify this relationship; most modelling efforts to-date rely on site-specific models.

Land-Water Interfaces

- Flooding
  - Mapping of flood extent demonstrated with airborne SAR and simulated RADARSAT data
  - Incidence angle is important[3].

- Wetlands
  - Open water wetlands can be identified and changes in water levels can be monitored.
  - Wetlands with standing water can be identified using a change detection approach using summer and winter (wet snow) data.

Fresh Water Ice

- Variety of ice conditions can be identified on SAR imagery

Hydrological Modelling

- Distributed hydrological models are required to make use of spatial data.
- Benefits of using distributed models must be demonstrated to the user community[4].

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3 Relatively large incidence angles (> 40 degrees) are most suitable for flood detection by means of SAR.

4 This community deals primarily with point source data and is less acquainted with the operational use of spatial data sets.

Current Plan

- To acquire an understanding of the mechanisms driving the behaviour of microwave energy in snowpacks for different snowpack conditions; to develop and test algorithms for converting radar data into snow water equivalent; to evaluate the effectiveness of using radar-derived snow parameters (airborne and satellite) into hydrological models[5].

- To develop and test algorithms for extracting soil moisture information from airborne and satellite SAR; to evaluate the effectiveness of using soil moisture distribution derived from SAR data (airborne and satellite) into hydrological models.

- To develop and document a procedure for extracting information on ice conditions and potentially flooded areas from airborne and satellite data.

- To evaluate the accuracy and usefulness of mapping wetlands from satellite SAR data.

- To determine the best mechanism for introducing remotely sensed data into the management of Canada's water resources.

- To develop an operational distributed hydrological model optimized for radar and other remotely sensed data inputs; to demonstrate the methodology for, and the value of, using SAR and other remotely sensed data as inputs into GIS-based hydrological models; and, in the process, to develop a product with export market potential.

---

[5] At this point in time it appears that the provision of wetness indices (and not necessarily absolute values) is sufficient.

Summary

The principle objective of the program will be to implement a pilot project(s) to develop and evaluate distributed hydrological models which are capable of incorporating spatial data on watersheds representative of the various hydrological regimes in Canada.

This pilot project will involve the development and evaluation of the use of radar and other remotely sensed and spatial data for extracting information on wetlands, fresh water ice, flooding, soil moisture and snow characteristics as input to the distributed hydrological models.

The mechanisms for acquiring and processing remotely sensed data and disseminating the end products (e.g. snow water equivalent maps) will be evaluated.

To develop an irrigation scheduling system which makes use of remotely sensed data in a GIS environment. Initial development to take place in the Canadian Prairies.

RECOMMENDATIONS - HYDROLOGY WORKSHOP

Presented by

Terry Pultz
RDDP Coordinator / Hydrology
Canada Centre for Remote Sensing

Thrust

- Implement pilot project on test basin(s)

Primary Objective

- Evaluate contribution of remotely sensed data to distributed models

Tentative Site(s)

- Grand River, Ontario
  - User: Grand River Conservation Authority (GRCA)
  - Well-instrumented
  - Historical data sets

- Tributary of St. John River - Flood Forecast
  - User: St. John River Forecast Centre, N.B. Power Commission

- Future project(s)
  - Northern environment - low density sample sites[6]
  - Require northern partners
  - Provincial agencies
  - Utility companies
  - Forested environment

---

6 It appears that the benefits of using remote sensing as a tool for hydrological modelling in Canada's North are particularly high.

Data

- Multiple data sets required[7]
  - Landcover (TM/SPOT)
  - DEM/mapping
  - Ground-based radar[8]
  - SWE (Passive Microwave)[9]
  - Snow cover area (SAR)[10]
  - Soil moisture/API (SAR)

Snow

- Snow cover area mapping is feasible (particularly wet snow)
- Exploit synergism between passive and active systems (*i.e.*, SWE)
- Demonstrate improvement over AVHRR data

However...

- It is important to continue research on the estimation of SWE from SAR
- Further the understanding of the natural variations within snow packs

Therefore ...

- Research on various test sites to investigate different snow/environmental conditions should continue
- One needs to look beyond RADARSAT-I, *i.e.* multifrequency/multipolarization radars[11]

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[7] for use in distributed models

[8] for measuring distribution of precipitation

[9] used already in a quasi-operational mode

[10] particularly for wet snow

[11] better suited for determining SWE

Soil Moisture

- Demonstrate SAR-derived API superior to traditional method
- Continue research into the development of quantitative relationships from a variety of targets (*i.e.*, pasture)
- Coordinate with Agriculture Group

Flood Mapping / Fresh Water Ice / Wetlands

- Continue support of TEP
- In-house demonstrations

Data Requirements

- Snow
  - Approx. one observation per week during Winter
  - Approx. two observations per week during Spring[12]
  - Fast delivery required < 1 day
  - Data on subscription terms
- Soil Moisture
  - Regular Monitoring - TBD by geographical location
  - Severe Weather Warning - subscription term data delivered in < 12 hrs. of forecast[13]
- User: Stream Forecast Centres
- Flooding/Ice Conditions
  - Target of Opportunity
- Data Products
  - Calibration - essential (SCANSAR)
  - Geocoding - desirable, but related to cost
  - Fast turn-around time required
  - Lower the cost = greater probability of use
- International
  - Water supply - high elevation snow pack
  - Flood mapping
  - Historical focus on temperate climates
  - Need to demonstrate applications in Canada first

---

12 more dynamic events during melting periods

13 e.g. for better prediction of river flow rates

Summary

- Pilot project will concentrate on demonstration of snow cover area mapping, estimation of API and synergism with other data sources to improve streamflow forecasts from distributed hydrological models

- Continue to look beyond RADARSAT- I

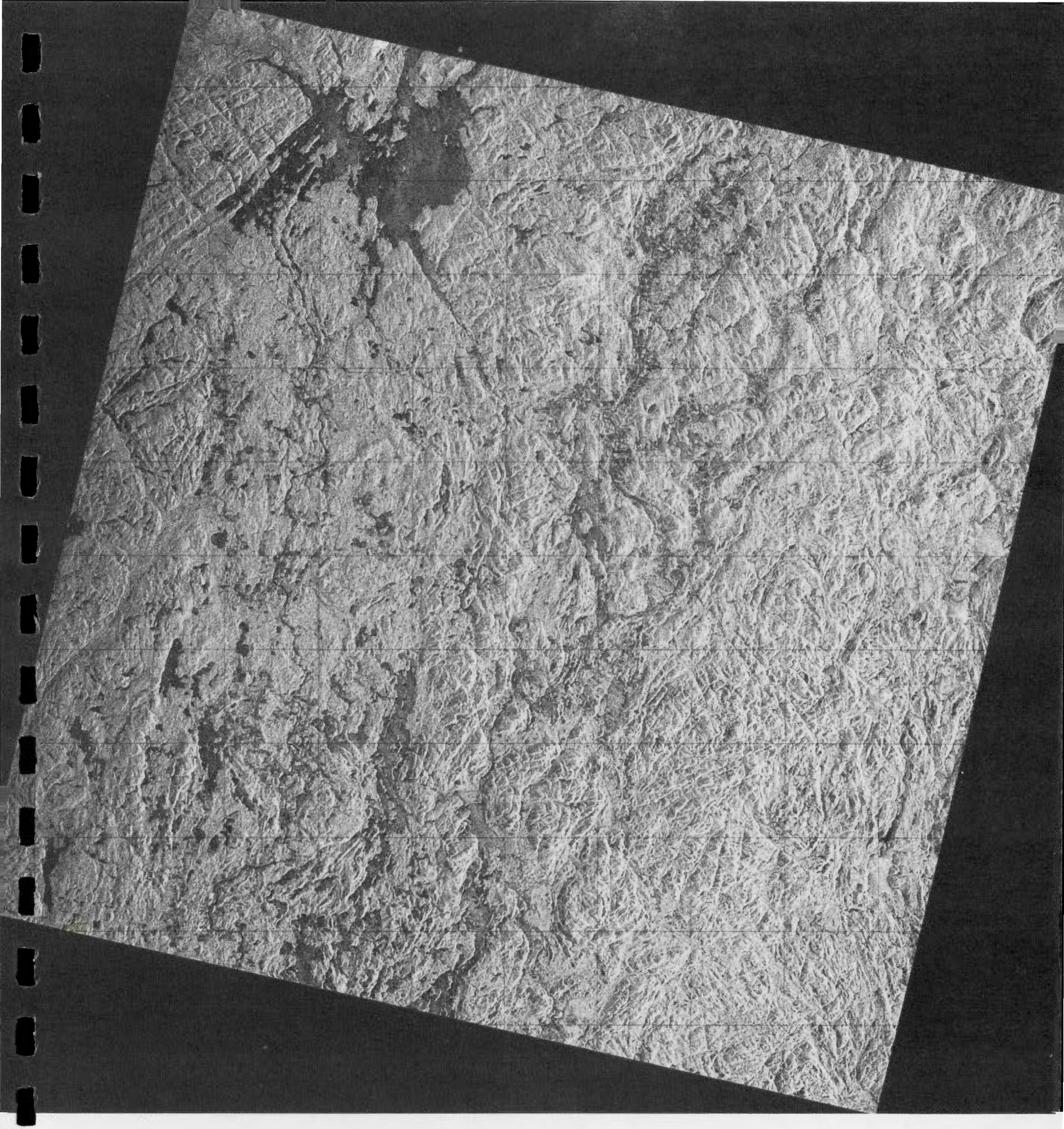
- Cultivate user community

- Develop required system elements for operational user of remotely sensed data in hydrological applications

Geology - An Overview

by

Vern Singhroy
RDDP Coordinator / Geology
Canada Centre for Remote Sensing



BASKATONG RESERVOIR, QUEBEC

This ERS-1 image, acquired july 11 1992, was geometrically corrected to a UTM map projection system. Two filters were applied on the image, median filter 3X3 and high-pass 9X9. The first filter was used to remove the speckle effects and the later was applied to enhance the lineaments present on the left side of the image. This procedure allows for a study of the geologic structure in this area. (Copyright ESA 1992)

Goal

The geology RDDP program develops methods to use SAR imagery in support of geological applications.

- Determining what kinds of geological information can be extracted from SAR images and other geological or geophysical datasets in support of geological mapping and exploration and hazards studies.
- Encouraging geologists and geological agencies to use airborne and satellite radar.
- Developing cooperative programs with national and international geological agencies; e.g., the Geological Survey of Canada and exploration companies.
- Participating in ERS-1 evaluation.

Activities

- Coordinate airborne SAR program for geologists (numerous sites involving 70 geologists, 10 universities, 11 agencies, 6 companies)
- Produce SAR enhanced images, and integrated products for geological mapping and exploration (6 sites, produce SAR/geophysics/lithology maps)
- Investigate radar science for the Sudbury basin impact structure: ERS-1 and airborne SAR for terrestrial geology (agencies OGS, GSC, PRSO, NASA, University of Manitoba, CCRS)
- Collaborate with GSC in "storefront projects" (15)

Results

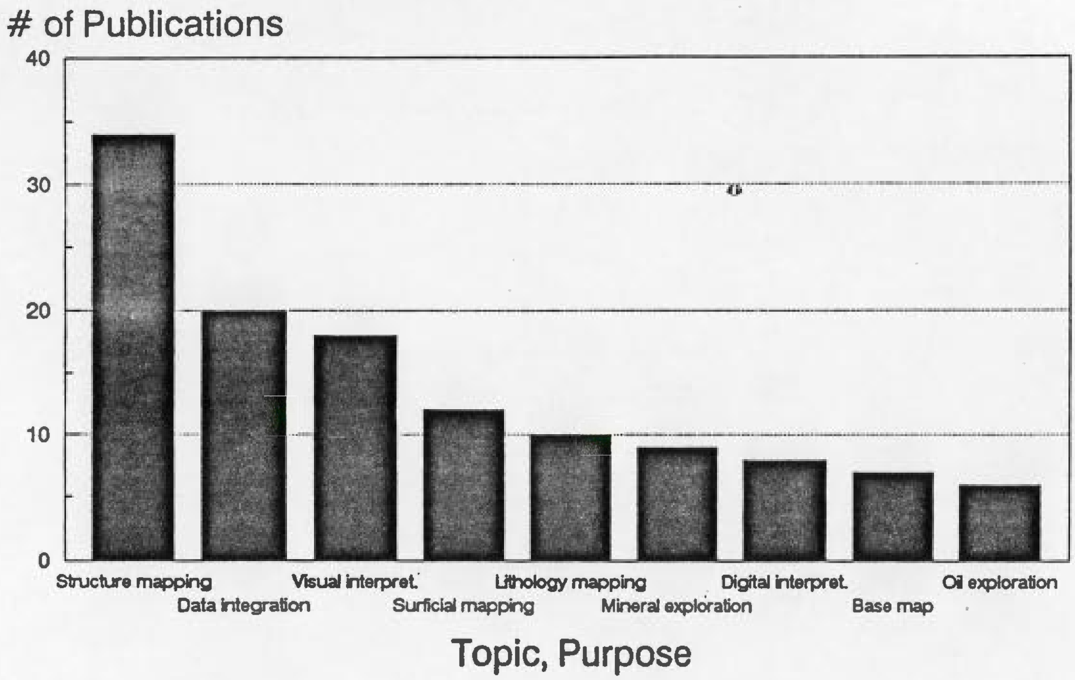
- Approx. 100 Canadian geologists have worked with radar images (consultants, exploration companies and government geologists and researchers)
- Approx. 60 papers were published (case studies, technique development, market surveys)
- SAR/integrated products are being used (GSC)
- SAR images are visually interpreted to map geological structures and geomorphic features

Technique Development

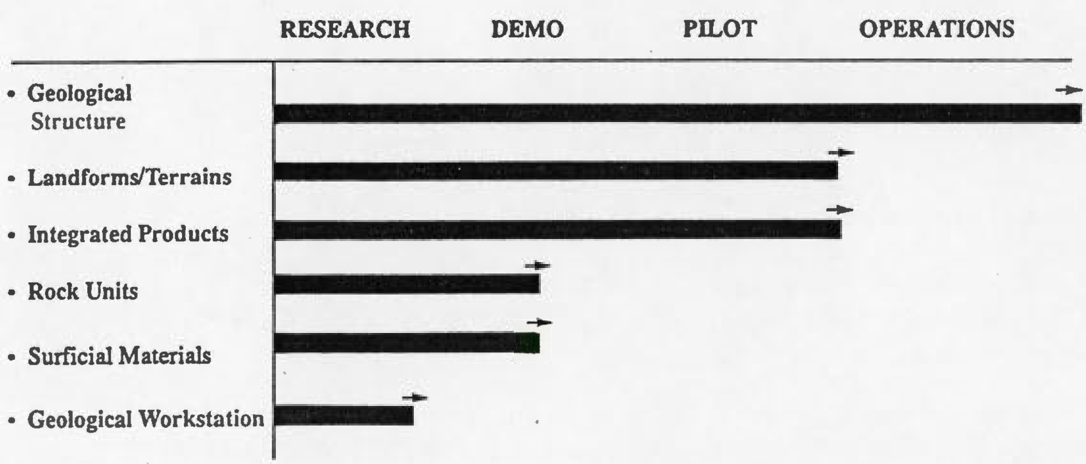
SAR data were acquired in support of technique development.

- Structural/tectonic investigations to search for mineral deposits and hydrocarbon traps, and seismic hazard assessment
- Terrain and lithologic mapping
- Integrated products - SAR, geophysics, geochemistry, lithology
- Sudbury basin ERS-1 multidisciplinary site

Canadian Geological SAR Studies:
topic summary of 42 publications



(most of the these publications have more then one topic or purpose)



Status of Geological Remote Sensing (1992)

	Research Demo Pilot Operational
Geological Structure	Air Photo 1:5,000 - 1:50,000
	TM 1:100,000
	ERS-1 1:100,000
	C-SAR 1:50,000
Integrated Products (Cris)	SAR/TM 1:100,000
	SAR/Geophysics 1:100,000
Landforms/Terrain Geomorphology	Air Photo 1:5,000 - 1:50,000
	Airborne C-SAR/TM 1:100,000
	ERS-1 1:100,000
Integrated PRoducts (Cris)	SAR/DTM 1:50,000 (topography)
	SAR Terrain Maps
Rock Units	Air Photo 1:5,000 - 1:50,000
	CSAR/Geochemistry
	SAR/Lithology
Surficial Materials	Air Photo 1:5,000 - 1:50,000
	C-SAR-TM 1:100,000
	ERS-1 1:000,000
Geological Workstations	

What information can be obtained from SAR

Mineral Exploration

- Eastern Nova Scotia (CCRS, GSC, Intera) — Integrated SAR images (SAR/magnetics using IHS) produced mineral potential maps (gold)
- Sudbury (CCRS, GSC, INCO, OGS, MIR) — SAR and magnetics image product mapped a number of dykes and faults that are correlated to ore bodies

What Information can be obtained from SAR? (continued)

Category	*Technique and Results*
Neotectonics	
• North Shore, Lake Ontario	- SAR-TM for regional tectonic interpretation. Air photo superior to SAR and TM images to detect large scale low relief structures.
Seismic Hazards	
• Charlevoix, Quebec	- Digital mosaic image produces a seismotectonic map of Charlevoix seismic zone
• Nahanni, N.W.T.	- Integrated C-SAR and SPOT image products produce a seisomotectonic interpretation of Nahanni earthquake belt
Hydrocarbon Exploration	
• Western Sedimentary Basin • Peace River District	- SAR/TM reflect basement faults which control hydrocarbon traps - Lineament density maps show good correlation in the oil and gas fields
Rocktypes	
• Sudbury, Wawa, Thunder Bay • Cape Breton • Bathurst Inlet, N.W.T. • Baskaton, Quebec	- Co-registered geoscience and R/S data and produced enhanced products to facilitate lithological and structural mapping - SAR/DTM show poor correlation with lithology and geophysical units (C. Breton) - Visual interpretation of SAR; redefine the geological boundary in the Grenville front
Quaternary	
• Southern Ontario • Central Nfld. • The Pas, Manitoba	- Visual interpretation of glacial landforms and coarse textures fill from SAR images - SAR/TM composite facilitate mapping of surficial materials in vegetated areas

ERS-1

Current Problems

- The 23° incidence angle is too steep to map low relief structures and geomorphic features.
- The registration of ERS-1 to 1:50,000 topographic map produces inaccuracies of about 50 m. This is a severe limitation for data registration.
- Look direction is a severe problem for imaging radar both orbital and airborne in low relief and shield terrain. Geological structures parallel to ERS-1 looks are not visible.
- Multiple look directions are essential for topographically-expressed structures.

Geology Workstation

- Contract awarded to Photosur-Geomat and MIR TEC to look into the feasibility for a workstation to integrate geoscience/remote sensing data sets
- Currently: oil and mining companies starting to use GIS and remote sensing data. This trend increasing
- Large diversity of existing radar data
- Multiple distribution agencies
- Time consuming for co-registration
- Numerous PC platforms within the mining and oil industry

Some Market Concerns

- There is a need for precision geocoded data for data integration products.
- STMs are not available to produce SAR precision geocoded imagery (in Ontario, OBMs for southern Ontario exist).
- Geologists require ready made enhancements as standard products (enhancements to SAR imagery are site-specific).
- A major constraint of the use of SAR by mining companies is the fact that their GIS databases are not fully in place.

Summary of Suggested Principal RADARSAT Products for Geology (after: Horler 1992)

	PRODUCT	PHYSICAL FORM	APPLICATION EXAMPLE
Standard Radarsat Products	Georeferenced(SGF, SGC) or system geocoded(SSG)	Film print or transparency	Regional photo-interpretation
	Precision geocoded(SPG)	Film and digital	Photo-interpretation for regional studies or preliminary exploration; digital analysis and data integration
Combination Products	SPG image maps	Paper	Regional interpretation; logistical planning
	SPG + aeromagnetic data	Paper	Regional and preliminary exploration
	SPG + airborne gamma radiometry	Paper	Regional and preliminary exploration
	SPG + aeromagnetic + gamma radiometry	Paper	Regional and preliminary exploration
	SPG + TM	Film and paper	Regional and preliminary exploration; logistical planning

International Activities

Opportunities:

Geological hazards/mapping/exploration

SAREX

- Coastal Guyana
  - SAR images are used to update quaternary maps and to map the extent of marine ridges in coastal Guyana
  - Recent coastal erosion, breaks of dykes, depletion of mangrove forest, have caused serious flooding in coastal populated areas
- Brazil (INPE, Petrobras)
  - Develop integrated products for:

    Geological mapping in the Carajas mining district, and oil exploration in the Amazonas Basin, Trapajos test site
- Costa Rica
  - Identification of volcanic cones and geological
- Venezuela
  - Geological mapping (1:100,000 scale)
- **GlobeSAR** (Greece and China)
  - Proposal under consideration to use SAR to map seismically active faults for earthquake prediction

Future Directions

- Technology transfer with Canadian companies

  Sudbury Basin: mapping/exploration

  - Work closely with the major mining companies Inco, Falconbridge in integrating the SAR products in their mining operations
  - Evaluation of ERS-1 for the Sudbury impact structure
  - RADARSAT simulation RSI (look direction and incidence angle)

  Williston Basin: Saskatchewan (Petro Canada)

  - Development of integrated products with Petro Canada for hydrocarbon exploration

- Technology transfer to develop and promote SAR products internationally
  - International focus on SAREX and GlobeSAR
  - Promote geology products and results: PDA, mining convention, IUGS, Geotechnia, ASTM

- Research
  - Effect of look direction and incidence on terrain morphology
  - Further development of integrated products (topography, DTM)
  - Geology workstation

- Further support to the GSC remote sensing programs

- Other - after workshop

Technical Presentations

- Sudbury Basin Study. *P. Lowman*, NASA-Goddard
- Sudbury Integration Techniques and ERS-1 Evaluation.
  C. Morasse and V. Singhroy, CCRS
- SAR Mosaics, Sudbury. *C. Bowie*, PCI
- SAR Integration and Cost Benefits Studies.
  R. Mussakowski, PRSO and *N. Trowell*, OGS
- SAR Geochemistry and Enhancements. *M. Rheault*, MIR TEL.
- SAR Integration Techniques. *J. Harris*, GSC
- SAR Surficial Mapping. *D. Grant*, GSC and *D. Graham*, CCRS
- SAR Integration Techniques - Marathon Area, Coldwell Complex, Ontario. *D. Graham*, CCRS and *D. Grant*, GSC
- ERS-1 for Mineral Exploration. *S. Carboni*, DOZ
- SAR Geology Mapping, Baskatong, Quebec.
  K. Sharma, Geological Survey of Quebec and *C. Morasee*, *V. Singhroy*, CCRS
- SAR Geomorphologie. *R. Desjardins*, Université du Québec, Montreal
- ERS-1 Evaluation, Ottawa. *M. Akhavi*, COGS
- Geological Workstation Feasibility Study. *Photosur and MIR TEL*
- Trends in Radar Geology - Market Survey. *Horler Information Inc.*
- SAR Exploration Tools. *Touburg Consultants*
- SAR/Geophysics. *W. Moon*, University of Manitoba

RECOMMENDATIONS - GEOLOGY WORKSHOP

Presented by

Vern Singhroy

RDDP Coordinator / Geology

Canada Centre for Remote Sensing

Action Items

Short Term

- Major problems related to geometric correction on SAR

- Urgent need for high precision DEM for data integration

- Look direction/ascending and descending orbits

- Seasonality/target characteristics changes

- Integrated products:

  - SAR + Geophysics / Better Interpretation
  - SAR + Geochemistry / Potential

- Sudbury Basin

  - RADARSAT Airborne Simulation
  - Detailed Multi-ring analysis
  - Closer cooperation with Inco and other companies

Technology Transfer / Communication / Marketing

- CCRS should do a better job[1]
- Good case studies and techniques
- Working with GSC is essential
- More workshops and courses targeted to geological community using GSC and Provincial Geological Surveys
- Set up formal working group with users: i.e. terms of reference, etc.
- Canadian Journal of Remote Sensing January 1994 Special Issue (8 committed papers)

Operational Successes

- Geological structure[2]
- SAR / geological maps[3]
- International applications
- High potential for GlobeSAR
- SAR & drift thickness

Research Questions

- Physical properties of rocks[4]
- Backscatter & surficial materials
- Capabilities of stereo SAR for structure mapping

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[1] Although CCRS is highly recognized for its technical expertise, the workshop participants noted that there is little in the way of developing appropriate marketing skills.

[2] The market for this type of information is limited.

[3] There appears to be a good market for 'integrated map' products. Registration of data sets remains an ongoing problem.

[4] Dielectric properties, particularly in arid regions

Ice - An Overview

by

Michael Manore
RDDP Coordinator / Ice
Canada Centre for Remote Sensing

This image presents a comparison of winter-time Intera STAR-2 (left) and ERS-1 SAR (right) in the Canadian high arctic (swath width = 100km). Both images were used for operational ice navigation during a voyage of the M.V. Arctic to the Bent Horn Oil facility on Cameron Island (top centre). Multi-year ice appears bright toned in both image types, compared to the dark returns from smoother, first-year ice. (Copyright ESA 1992)

Users

- Ice Centre Environment Canada (ICEC)[1]
- Canadian Coast Guard (CCG)
- Commercial shipping/fisheries/offshore
- Other misc. (science, etc.)

Information Requirements

- Ice edge[2]
- Concentration/leads
- Type (thickness, age, properties)
- Ridging
- Motion/pressure
- Historic ice regime (from archive)
- Icebergs

- Global, strategic, and tactical scales[3]
- Forecasts[4]

Regions of Interest (seasonal)

- East Coast
- Gulf of St. Lawrence
- Eastern/Central Arctic
- Beaufort Sea

---

1 The Ice Centre is currently the major player in this group of users.

2 SAR is used operationally for obtaining the first seven information requirements listed here.

3 Science driven, e.g. for ice/climatology, energy flux studies

4 Fast data turn-around time is required; particular interest for RADARSAT ScanSAR mode data

Status

- Radar is the *best* sensor for ice type discrimination (X-, C-band, HH polarization)
- Radar is the *only* sensor capable of providing all weather ice information (cloud, fog, darkness)
- As a result, airborne SAR and SLAR now used operationally for[5]:
    - Ice forecasting (ICEC)
    - Navigation support (e.g., CCG, Canarctic, Canmar)
- Communications and analysis infrastructure for operational ice forecasting already in place (to/from ICEC)
- Operational use relies on *visual interpretation* (in combination with other information sources)
- Current volume of data can be handled (just!)

Outstanding Issues

- High volume of RADARSAT will be unmanageable (ICEC)
- Questions remain about:
    - Seasonal transitions[6]
    - Range/incidence angle effects (C-HH)
    - ScanSAR image quality
- RADARSAT 'products'
    - Specification of products
    - Delivery of data/products to VAI/end users

---

5 ERS-1 SAR data is currently used in an operational mode in the Gulf of St. Lawrence.

6 Snow pack conditions are of particular concern.

RDDP Ice Applications Program

Goal

- To carry out the research, development and demonstrations necessary to prepare for the optimum use of remotely sensed data, in particular RADARSAT, to provide reliable information about the distribution and condition of sea ice in Canadian waters.

Thrust

- To assist in the development of operational uses of RADARSAT data to support Canadian shipping and offshore activities

- Focus on support to ICEC

Working Objectives

- Algorithm development
  - Ice motion
  - Ice/no-ice classifier

- Ice properties and SAR signatures (C-band)
  - Participation in field validation experiments (PIPOR, SIMMS, etc.)
  - Micro surface roughness measurements (CCRS Surface Roughness Meter)

- Data synergism
  - Passive microwave, optical, non-image data integration

Approach

- Balance of algorithm development, research, and ice/remote sensing community coordination

- Development of a strongly cooperative program with ICEC, other gov't. labs, contracts to private industry and universities

- Joint projects for algorithm development and field experiments

- Contribution of data sets (SAR, optical, ground truth, ice surface roughness) to R+D community, teaching institutions

Major Activities

1987-89	LIMEX'87 and LIMEX'89 field experiments (ice structure, dynamics, growth/decay, SAR signatures in the marginal ice zone on the Labrador Shelf)
1990	Beaufort'90 field experiment (ice motion, SAR calibration, C-band SAR signatures of Arctic ice -led by CCRS/DAD)
1990	Development and implementation of operational Ice Motion Algorithm initiated (joint CCRS/ICEC contract to industry)
1990-92	Participation in Sea Ice Monitoring and Modelling Site (SIMMS) field experiments (lead by U. of Waterloo)
1992	Commencement of ice classification algorithm development (joint contract CCRS/ICEC to industry)
1992	ERS-1 field validation campaigns for PIPOR, Canadian AO investigators
1992	Operational demonstration of Ice Motion Algorithm with ICEC

Working Groups[7]

- Canadian Ice Working Group (CIWG)
  - Membership open
  - Annual workshops
  - Opportunity for information exchange
  - Shared government, university, industry chair
  - Likely to become CMOS Floating Ice SIG

- RADARSAT Ice Working Group
  - Goal of preparation for RADARSAT
  - Focus on operational use
  - Identify/act on barriers
  - Initiate demonstration projects

  Two-tiered structure

  - Executive (ICEC, CSA, CCRS, RSI, CCG)
  - Consultative Group
    (shipping, offshore, research, VAI (approx. 20))

  Example actions

  - Addition of far range SCN mode
  - Gulf Demonstration Project (CCG, industry)
  - SPECAN processing of ERS-1 ice imagery (ScanSAR algorithm)
  - Data flow/product definitions

---

[7] There are currently a number of Working Groups; their main purpose is the exchange of information and determination of information requirements for future sea ice information systems.

Future Directions

- Data/product demonstrations for VAI/end users
  - Image transmission to ships (Gulf Demo, Canarctic)
  - RADARSAT product definitions
  - RADARSAT simulation products
  - ScanSAR image quality

- Algorithm development
  - Operational motion and ice/no-ice classifier for IDIAS-2

- SAR signatures
  - C-HH vs. C-VV
  - RADARSAT incidence angles

- International RADARSAT Applications
  - Scandinavia

RECOMMENDATIONS - ICE WORKSHOP [8]

Presented by

Michael Manore
RDDP Coordinator / Ice
Canada Centre for Remote Sensing

[8] Note: The afternoon session was jointly held with the participants of the Oceans Workshop (see also 'Recommendations - Oceans Workshop' in the following section.

Presentations / Morning Session

Tom Hirose Noetix Research Inc.	Operational Demonstration of Ice Tracking Algorithm
David Barber University of Waterloo	Ice/Snow Backscatter Modelling
Mohammed Shokr AES/Downsview	Ice Centre Experience with ERS-1
Bob Gorman Canarctic Shipping	ERS-1 for Tactical Navigation
John Falkingham AES/Ice Centre	RADARSAT in the Ice Centre's Operations Gulf Demonstration
Mike Manore CCRS/RDDP	Review of RDDP Directions

Presentations / Afternoon Session (Combined Ice-Oceans Session)

David Lapp RADARSAT International	Potential RADARSAT Image and Value-added Products
John Falkingham AES/Ice Centre	ICEC Plans for RADARSAT (data flow, VAP)
Richard Olsen Satlantic	ACEOS

Discussion

- Ready to make use of RADARSAT data through ICEC, however ...

Technical[9]

- Delivery time
  - Acquisition - ICEC (< 3hrs)
  - Acquisition - end user (< 6hrs)

- Communication of high volume of image data
  - ICEC --> ships vs. aircraft --> ships

- RADARSAT image quality vs. airborne data
  - New ice - open water (-18dB noise floor)[10]
  - Ice topography (incidence angle)

- High data volume will require automated interpretation algorithms (motion, ice-no ice)[11]

- CDPF-ICEC communications link not finalized

- Relationship between SAR signatures and physical properties[12]

- Ready to make use of RADARSAT data through ICEC, however...

[9] Main concerns and barriers are considered in this context.

[10] Good success was noted using shallow incidence angle airborne SAR data; steep incidence angle viewing geometry of ERS-1 SAR is less suitable for this application.

[11] It is expected that these algorithms will be fully implemented for the RADARSAT era.

[12] There is a definite need to continue basic R&D on these topics.

Policy

- Roles of ICEC and Value-Added Industry[13]

Future Directions

- Data/product demonstrations for VAI/end users
  - Image transmission to ships (Gulf Demo, Canarctic)
  - RADARSAT product definitions
  - RADARSAT simulation products
  - ScanSAR image quality

- Algorithm development
  - Operational motion and ice/no ice classifier for IDIAS-2

- SAR signatures
  - C-HH vs. C-VV
  - RADARSAT incidence angles

- International RADARSAT Applications
  - Scandinavia

13 This concerns the delivery of good and affordable products to the user.

Oceans - An Overview

by

Cathryn Bjerkelund
RDDP Coordinator / Oceans
Canada Centre for Remote Sensing

The "dimpling" is a series of von Karman vortices being shed as the incoming tide flows past Quaco Ledge, about 2m below the surface. The interesting current features are tide rips around Cap d'Or, Isle Haute, Cape Chignecto and Cap Enrage (in order bottom to top). Clear wind streaks off NS indicate a S wind with the lee under North Mountain, valley winds visible as enhanced backscatter. Increased backscatter further in the Bay as the tidal currents get stronger, also due to increased bottom roughness there. The long linear feature just off Cape Chignecto is probably caused by roughened surface water as the current flows over a gravel bar known to be there. Note the two well-defined eddies downstream from Cap d'Or (large cape on bottom side of Cape Chignecto). On the land, the NS side clearly shows the airport at Greenwood, the Annapolis valley, and between it and the Bay the crest of the North Mountain. The slicks in the outer Bay are probably biological in origin; the wind was very light and and so they have stayed together quite well. (Copyright ESA 1992).

Goals

- Operational and research tool for ocean features, coastal regions and fishery activities

- Advise and assist remote sensing initiatives

- Preparation for RADARSAT through implementation specific applications of satellite (ERS-1) and airborne SAR

- Links to international community and promotion of Canadian expertise

Strategies

- Cooperative activities with other agencies, centres and industrial organizations

- Demonstration projects of ERS-1 SAR under CCRS ERS-1 AO activities

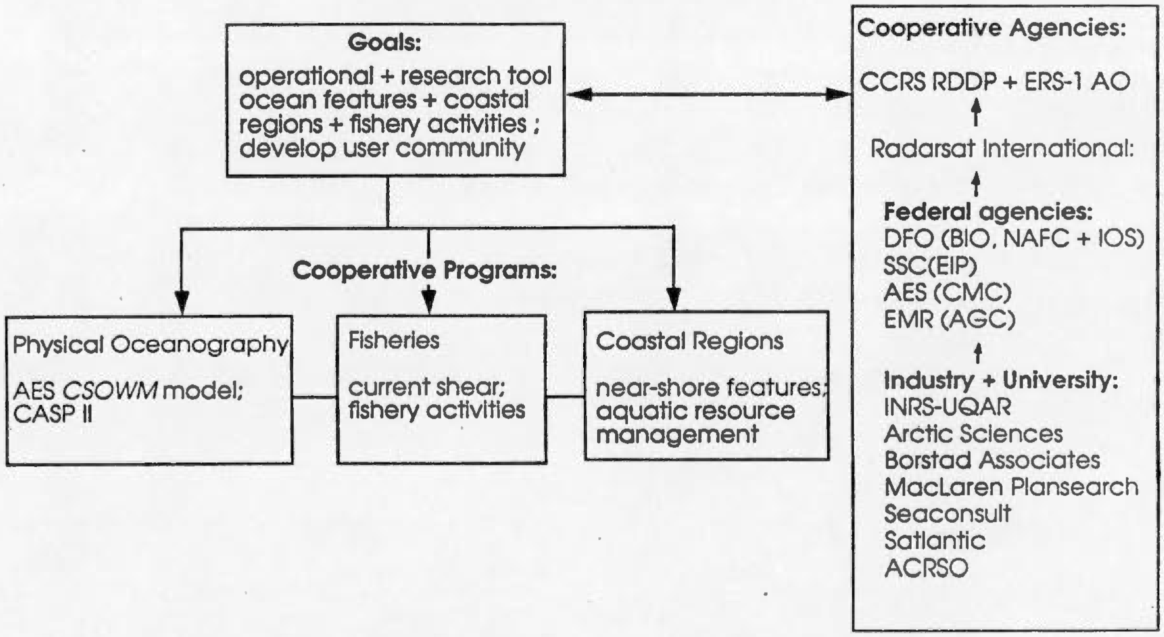
- Participation in technology transfer programs, workshops and promotion of value added products

Milestones Accomplished

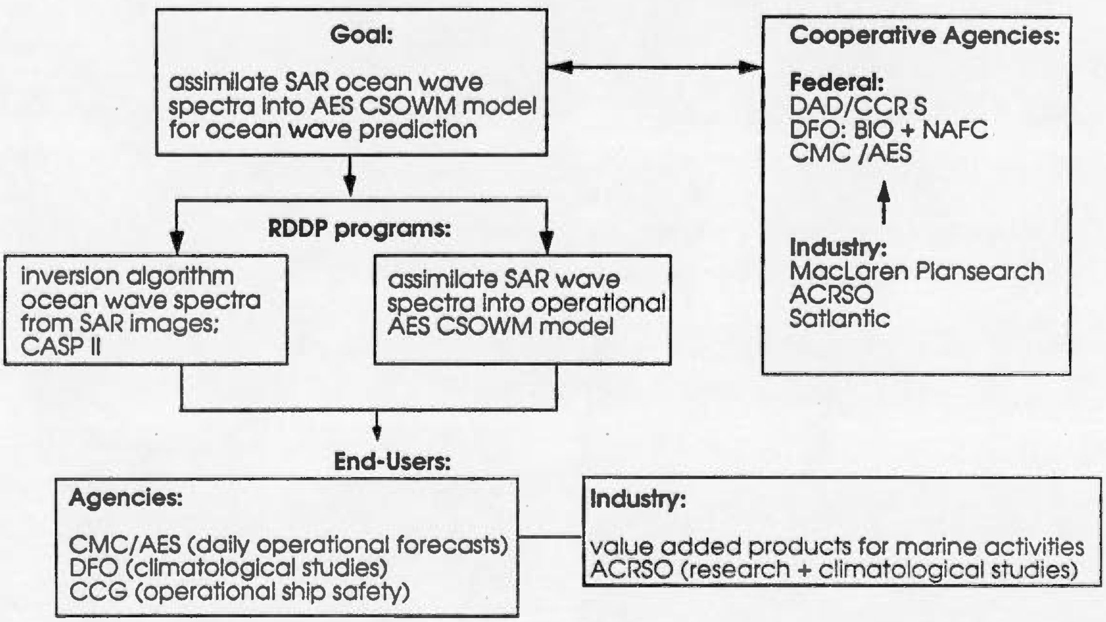
- Inversion algorithm for ocean wave spectra with BIO and MacLaren Plansearch Ltd.

- Assimilation of SAR wave spectra into the operational AES CSOWM model for ocean wave prediction

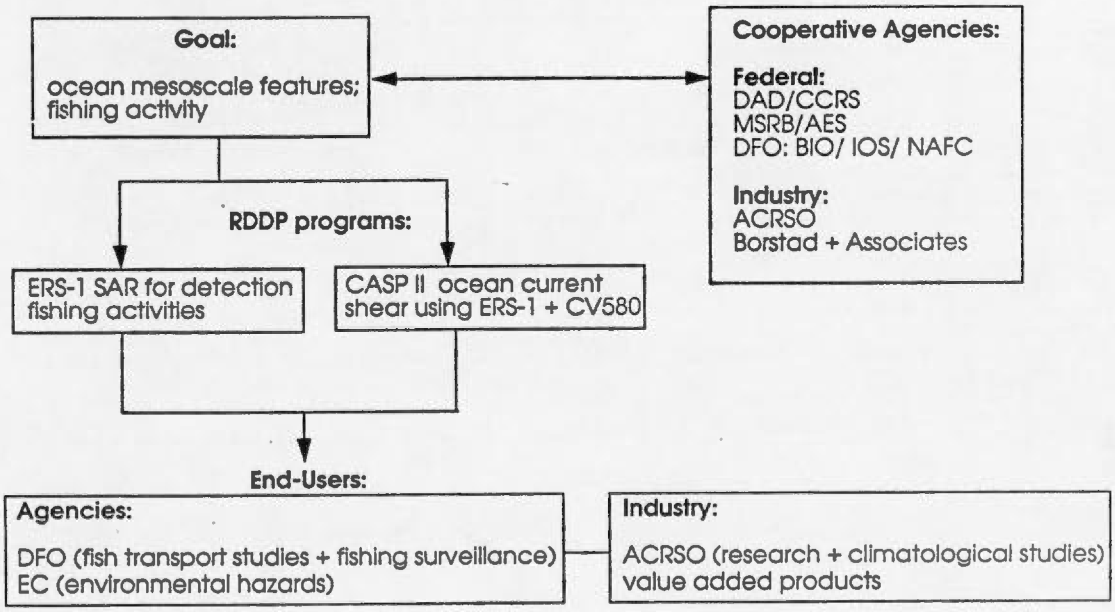
Program Structure



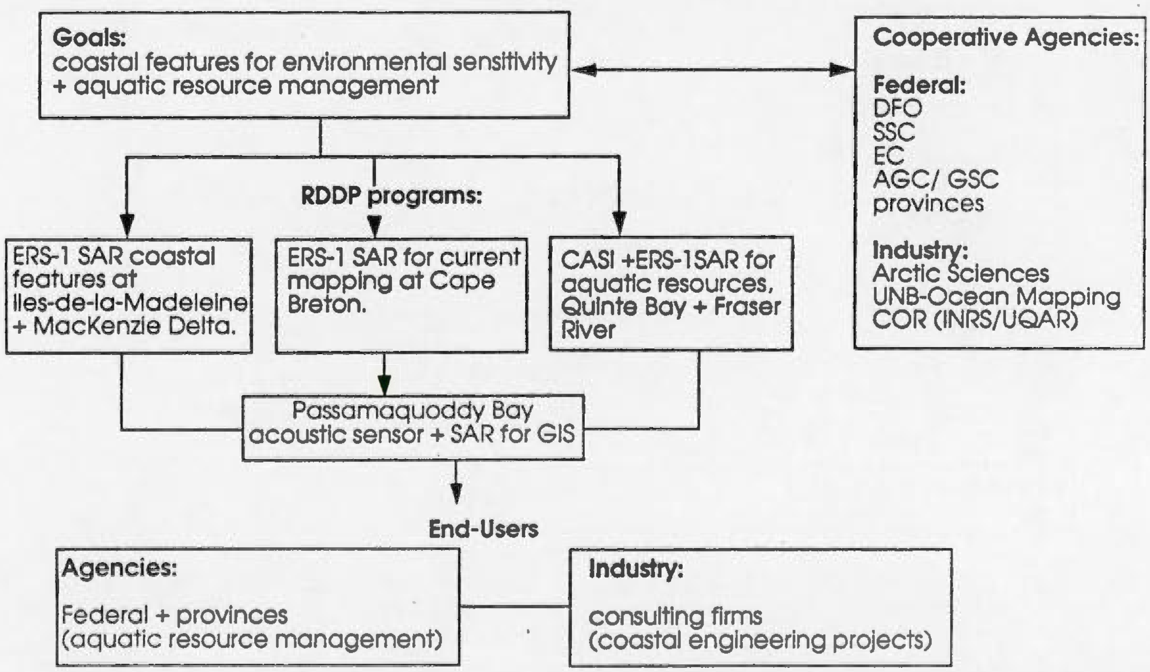
Physical Oceanography



Fisheries



Coastal Zones



assimilation SAR wave spectra into AES CSOWM model

Goal:

assimilation SAR wave spectra into operational AES *CSOWM* model

Cooperative Agencies:

BIO/DFO
AES
DAD/CCRS
MacLaren Plansearch
industrial contractor

RDDP programs:

(1) BIO/MacLaren Plansearch (1989-93)

(2) AES (1993-96)

History:

(CCRS/DFO):
- LEWEX, LIMEX, SWADE, ERS-1 cal/val
- code for inversion algorithm
- validation algorithm with ERS-1 SAR + comparison in-situ + marine radar spectra
- production of high quality marine wind field
- validation against AES CSOWM model predictions

(CCRS/AES):
- verification of CSOWM model + SAR algorithm
- analysis spectral wave data from numerous points
- compare CSOWM model's analysis made without SAR
- assimilate SAR data into CSOWM models
- implement model operationally

Concern:
- readiness Radarsat to provide operational ocean products in a timely manner
- sensitivity ScanSAR wide mode for ocean features
- relationship between wind speed + cross section for HH polarization not well understood
- influence wind speed + direction masks wind speeds > 8m/sec

coastal surveillance

Goals:
assess SAR for environmental sensitivity + resource management

Cooperative Agencies:

Federal:
DFO
EC (Green Plan)
provincial agencies

Industry/University:
Seaconsult
Arctic Sciences
COR (INRS-UQAR)
COGS
AERDE
Acadia Univ

RDDP programs:

airborne CV580:
- 1988+90 Nfld: nearshore currents
- 1989 Passamaquoddy Bay: aquaculture
- 1989 Minas Basin: intertidal
- 1990+92 IDM: nearshore currents + coastal erosion
- 1990 NB: coastal sensitivity
- 1990 Vancouver Island: coastal currents

Results:
- aquaculture sites + nearshore circulation features
- intertidal features + sedimentation/erosion processes
- wetlands
- nearshore bathymetry

Concern:
Potential satellite SAR to coastal zone engineering and environmental monitoring considerable, but not yet proven

Future Initiatives

- Goals
  - Develop the application of RADARSAT
- Domestic programs
  - Aquatic resource monitoring using CASI, MEIS + SAR
  - HF radar + ERS-1 for currents
  - SeaWifs + ERS-1 SAR for oceans productivity + fishstock assessment
- International programs
  - ERS-1 + airborne SAR for mangroves
  - Oilspill detection with Norwegians

RECOMMENDATIONS - OCEANS WORKSHOP [1]

Presented by

Cathryn Bjerkelund
RDDP Coordinator / Oceans
Canada Centre for Remote Sensing

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[1] Note: The afternoon session was jointly held with the participants of the sea ice workshop.

Program / Morning Session

- Participant introduction and their area of interest

- Presentations

  - *Cathryn Bjerkelund:* ERS-1 and RDDP activities at CCRS
  - *Scott Akenhead:* Activities at Borstad and Associates
  - *David Fissel:* Activities at Arctic Sciences
  - *Daniel DeLisle:* Activites at COR (INRS-UQAR)
  - *Pierre Larouche:* Activities at IML/DFO
  - *Fred Dobson:* Activities at BIO/DFO
  - *Howard Edel:* Activities at DFO

Areas to pursue/continue support

1. Ocean features

   - Ocean circulation
   - Currents / eddies
   - Internal waves
   - Water mass boundaries / convergence

   End-users:

   - Fishing / Shipping
   - Defence
   - Science

2. Ocean wave modelling

- Wave climatology
- Storm generated waves
- Regional wave forecasts

End-users:

- Offshore engineering
- Shipping / Fishing

3. Coastal regions[2]

- Waves and currents
- Tidal mixing
- Near-shore regimes

End-users:

- Coastal engineering
- Aquaculture
- Environmental emergency response

Issues

1. Cannot use SAR in isolation; requires assimilation with other products to provide comprehensive analysis; requires more development

2. Multi-sensor mission for RADARSAT-'N' to better meet oceans requirements (altimeter, scatterometer)

[2] A frequent question with regard to ERS-1 SAR image analysis is whether or not ocean or atmospheric phenomena are actually observed. More experience needs to be gained in analyzing SAR imagery in coastal regions.

Program / Afternoon Session:

Joint ice / ocean session on RADARSAT requirements

- Presentations
  - *David Lapp:* Activities at RSI
  - *John Falkingham:* Activities at the Ice Centre
  - *Richard Olsen:* ACEOS Activities

Discussion

- Data delivery (format, timeliness)
- Value-added products (government/industry)
- Operational scenarios for fast delivery products (conflicts?)
- Current processor configuration (how will it handle our needs?)

Joint topics - Ice and Oceans group

- Viable marine remote sensing industry requires ice and oceans business; ice now dominated by ICEC
  - Issue: Government / VAI competition
- ICEC not prepared to leave delivery of value added services to industry alone: three models proposed for ICEC/industry interaction
  - need fair mechanism for opening discussion (e.g., non disclosure)
  - industry invited to propose innovative mechanisms for cooperation
- ACRSO disagrees that only big companies can compete; niche market best served by small flexible companies or consortia
- Largest single customer is government; VAI should not only replace government functions, but develop new markets (e.g., international)

Action items - Ice and Oceans Group

1. Consideration to combining ice and oceans working groups into a single working group
2. VAI invited to approach ICEC with proposals for cooperative services (VAI)
3. Sponsor forum to define value added domestic and international opportunities (*RDDP*, RSI, CSA, VAI)
   - Clarification of respective roles of RSI and industry regarding data distribution and value added products
4. Oceans group to propose priority products and value added processor at CDPF to overcome telecommunications costs (oceans working group)

Airborne SAR Program - Status and New Developments

by

Laurence Gray
Data Acquisition Division
Canada Centre for Remote Sensing

<table>
<tr><th colspan="7">Image Recording, Edo (dry silver paper) and VCR Product Table</th></tr>
<tr><th>Image Mode</th><th>Freq. Band</th><th>Tr. Pol</th><th>Processed Image Swath</th><th>HDDT Image Recording</th><th>Edo note (2) (Dry Silver)</th><th>VCR note (2)</th></tr>
<tr><td rowspan="4">Normal</td><td rowspan="4">X
and/o
r
C</td><td rowspan="2">H</td><td>Full</td><td>HH
or
HV</td><td>HH
or
HV
note (1)</td><td>HH
or
HV</td></tr>
<tr><td>Near Half-Swath
or
Far Half-Swath</td><td>HH
and
HV</td><td>HH
and
HV</td><td>HH
and
HV</td></tr>
<tr><td rowspan="2">V</td><td>Full</td><td>VV
or
VH</td><td>VV
or
VH
note(1)</td><td>VV
or
VH</td></tr>
<tr><td>Near Half-Swath
or
Far Half-Swath</td><td>VV
and
VH</td><td>VV
and
VH</td><td>VV
and
VH</td></tr>
</table>

<table>
<tr><th>Image Mode</th><th>Freq. Band</th><th>Tr. Pol</th><th>Processed Image Swath</th><th>HDDT Image Recording</th><th>Edo note (2) (Dry Silver)</th><th>VCR note (2)</th></tr>
<tr><td rowspan="2">Quad Pol</td><td rowspan="2">C only</td><td rowspan="2">H
and
V</td><td>Full</td><td>any one of..

HH and VH
HH and VV
HV and VH
HV and VV</td><td>only one of..
HH, VH,
HV or VV
note (1)</td><td>one of
HH, VH,
VV or HV</td></tr>
<tr><td>Near Half-Swath
or
Far Half-Swath</td><td>all four of

HH, HV,
VV and VH</td><td>only one of..
HH and HV
or
VH and VV</td><td>one of
HH and HV
or
VH and VV</td></tr>
</table>

(1) User may choose 1/2 swath enlargement of RTP pixels 1:2048 or 2049:4096.

(2) There is only one Edo recorder and one VCR recorder on-board the aircraft.

Airborne SAR Program: Status and New Developments

- Role of the Airborne SAR
- Status and new developments
    - Improvements since the '90 RDDP meeting
    - What we can/can't do now
    - What we can offer in the future

Role of the Airborne SAR

The CCRS C/X SAR is a world-class R&D facility useful for...

- Provision of data
    - Developments in existing applications
    - R&D into new applications of SAR data
- R&D into SAR technology
- Making money for Canadian industry and offsetting CCRS/SMRSS expenses
- Support initial RADARSAT marketing through demonstration projects like GlobeSAR
- Support future RADARSATs by providing the necessary R&D facility for optimization of the spaceborne SAR.

New Developments Since 1990

- Dual-channel azimuth processor (1/2 swath)
- Real-time motion-compensation upgrade
- Quad-pol C-band imagery using 2 APU's
- Radiometric corrections for all geometries
- Exabyte image data recording (almost ready)
- UNS and GPS navigation equipment

SAR Configuration Choices

New Choice: "Normal" and "Quad-pol" Modes...

Normal Mode	Quad-pol Mode
C and X-bands	C-band only
Usual polarizations	HH and VV full swath
Usual geometries	or
etc.......	HH, HV, VV, VH
	half swath

New Developments (not operational)

- Calibration software and hardware
- Polarimetric C-band data
  (with inter-channel phase)
- Interferometry
  (repeat-track, across-track and, soon, along-track)

Future Developments

- Along-track Interferometry
- Helical scan tape-recorders (signal data)
- Radar altimeter
- Improved azimuth drive

  (Old equipment replacement/upgrade)
  (Low frequency channel?

Can Do / Can't Do Summary

- Can do......
  - Provide high quality C- and X-band data with flexible geometry, polarizations, high resolution, good turn-around, etc.
  - Can be acquired at your site when required
- Can't do.....
  - Provide calibrated products routinely
  - Provide ortho-images or DEMs operationally
  - Provide full polarimetric C-band data
- Solution.....
  - Technology transfer

The CCRS Airborne SAR– More Advances in Remote Sensing Capabilities*

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Abstract

Since their commissioning in 1986 and 1988, the CCRS C- and X-band SARs have logged several thousand imaging hours in Canada, USA, South America, and Europe. The instruments have undergone a series of upgrades including; polarimetric and interferometric capabilities at C-band, multichannel real-time processing, more flexible geometries, improved navigation, motion-compensation, and recording systems, as well as system changes required to support the new operational modes. This paper reviews these upgrades and presents a user perspective on these new capabilities.

*For circulation at the RDDP Workshop held at Ganonoque, Ontario, Jan 26–28, 1993. Based on a paper originally presented at the Canadian Symposium for Remote Sensing June 1–4, 1992.

INTRODUCTION

CCRS operates[1] a Convair-580 aircraft equipped with X- and C-band Synthetic Aperture Radars (SARs). The system was described generally in [7] after the commissioning of the C-band hardware and later when X-band [8] was added. The original systems allowed multi-polarization (HH and HV or VV and VH) simultaneously at X and C-band over a wide range of geometries at two range resolutions and has been the mainstay of radar remote sensing research in Canada for a number of years. The system has provided:

- Data for SAR applications development for example [16, 17, 10, 1];
- Data for R/D in SAR processor development [12];
- Data for development of new SAR modes and technology [3];
- A means for Canadian companies to market advanced airborne SAR data worldwide; and,
- High performance data for assessment in applications of spaceborne and airborne SAR.

Continued international use of the CV-580 is expected to help attract attention and users to RADARSAT, for example through the Globe-SAR project.

This paper provides an update from a user perspective to new system facilities and upgrades since the earlier reviews [7, 8]. The upgrades include: polarimetric and interferometric C-band capabilities; multichannel real-time processing; more flexible geometries; improved navigation, motion-compensation and recording systems; as well as system changes required to support the new operational modes. Also, CCRS DAD has invested in hardware and in the development of software to help calibrate, process, and analyze the new SAR data products.

[1] Through contracts with *Innotech Aviation* and *Intera*.

MOTION-COMPENSATION AND PHASE-INTEGRITY UPGRADES

From 1990-1992, a major upgrade to the SAR motion-compensation system was designed and implemented under a contract to *MacDonald Dettwiler and Associates* (MDA) of Richmond, B.C. The overall objective of this work was end-to-end phase integrity through the airborne sensor and associated G-SAR ground processor. The motion-compensation system controls two important functions: one related to antenna steering (mainly radiometric in nature); and the other, to data phase corrections (mainly focus and geometric related[2]). Both functions relate to compensation for excursions from the reference track. Together they have profound effects on the overall image quality including radiometry, phase, and geometry. The improved system features incorporate:

- A great circle reference track model, instead of the damped version of the actual track previously used;
- Adaptive, decreasing memory filters after switch on, instead of the long time constant ones;
- Use of body accelerations to derive excursions from the reference track, as opposed to horizontal frame accelerations;
- Continuous phase projections across the swath, instead of the block projections; and,
- Three-axis (pitch over azimuth over elevation) antenna steering, instead of the two-axis (azimuth over elevation) system.

The resulting system has been shown in flight trials to exceed design limits and significantly outperform the previous implementations.

[2] Here too, there is secondary coupling to radiometry and of course to the phase of the signal data and down-stream complex data products.

INTERFEROMETRIC MODE

Based on SAR data collected on July 20, 1990, it was shown that interference could be observed by coherently combining pairs of either X- or C-band airborne SAR images from separate passes over the same test site [4]. Repeat-pass interferometry with airborne SAR opens the possibility for temporal coherence studies and differential interferometric SAR experiments with the flexibility afforded by the airborne platform. In this work, a loss of coherence was observed at both C- and X-band for forested areas under light to moderate winds; the height of a building was estimated; and the movement of a radar reflector was measured to an accuracy on the order of one millimetre. The latter experiment reinforced the expectation that differential SAR interferometry, based on data from three or more satellite passes, will, under some conditions, be able to detect and measure changes on the surface of the earth to a fractional radar wavelength scale.

In July 1991, the first dual-antenna interferometric experiment [3] was performed with the Convair 580. Cross-track interferometry for derivation of terrain elevation depends on measurement of the phase difference in the data from a remote target as seen from two receive antennas displaced in the across-track plane. This phase difference can be related to the *incidence angle* at which that target is imaged. This, coupled with the range information implicit in radar measurements, allows a measurement of the height of the target. In the initial assessment of height uncertainty, height noise of 1.5 to 5 m rms was obtained for high resolution (6 m slant range, 0.8 m azimuth) pixels. With more averaging, height noise could be reduced. There is also a possibility of height bias errors which can be reduced or eliminated by using terrain control points.

A second cross-track InSAR flight was flown on February 7, 1992, over the *Kananaskis* and *Three Hills* test sites. In this case, aircraft position was subsequently determined through the use of differential GPS[3]. Through the use of differential GPS, we hope to be able ultimately to do radar mapping without the benefit of control points. Initial results from the Kananaskis test site; contour plots, perspective views *etc.* are quite encouraging and rival surveys done by traditional methods. It should also be stressed that the synergy that exists with the radar data implicitly registered with a DTM through interferometry, through geocoding and radiometric calibration, is yet to be exploited and represents an important new avenue for applications research.

This mode of imaging is to be regarded as experimental rather than operational due to the complex data analysis required. CCRS expects that the interferometric capability will be transferred to Canadian industry once the proof of concept to operational mapping is achieved.

Later in 1993 we expect to take delivery of a new double antenna structure designed to allow *along-track interferometry*. By comparing the phase of images produced from the two antennas displaced in the along-track direction, it is possible to accurately measure the velocity of targets moving towards or away from the radar. The applications to be investigated initially include measurement of sea ice drift velocities, ocean currents, and some ocean wave parameters.

POLARIMETRIC MODE

The first polarimetric measurements [9] with the CCRS SAR were completed in 1989 when a collaboration with DND/DREO allowed a demonstration/proof of concept implementation at X-band. In polarimetry, the object is to *simultaneously*[4] collect coherent signal returns, both amplitude and phase, from the same target in all orthogonal polarization combinations: HH, HV, VV, and VH. The idea behind polarimetric measurements is that the complex polarization matrix derived from a target provides a further handle on its classification.

Installation and initial testing of polarimetric capability at C-band was completed in March, 1992. The implementation is similar to the original X-band sys-

[3] Global Positioning System, by using an aircraft GPS receiver and three ground receivers at surveyed points, it is possible to refine aircraft position to an accuracy normally less than 10 metres.

[4] Before polarimetry, data collection was possible only when more than one pass was taken. In this case, it is likely that phase coherence between data sets is lost and the required simultaneity is not achieved.

tem with the SAR operated at double PRF and successive transmit pulses interleaved between H and V polarizations. Both like- and cross-polarization signals are simultaneously received for each pulse[5]. A new robust switching network was designed and built by *COMDEV* for the C-band installation. Calibration studies [14] have shown that reliable calibration could be obtained for the early X-band data using special techniques. Preliminary calibration studies using the C-band polarimeter have shown that the system distortion matrix is diagonal prior to any calibration work demonstrating that the switch and antenna isolation characteristics are indeed very good.

Prototype software for full polarimetric SAR processing exists at CCRS and is under test. Plans to move this capability to a production environment are in an embryonic state at present.

The new switch and interface capability, shown in Fig. 2 also has two interesting side benefits which are not necessarily related to the complex data analysis. These involve double PRF and properties of the RF switch:

1. Simultaneous HH and VV full swath real-time processing at C-band. This involves switching polarization on successive pulses in the normal polarimetric mode, but processing two channels in real time.

2. Double PRF recording with no polarization switching to increase azimuth bandwidth. This will be of interest to users who may be limited by the now almost critical sampling in azimuth, for example in imaging moving targets such as the ocean.

In general, polarimetric and interferometric processing, involve a complex set of post flight data manipulations that cannot be regarded as operational at CCRS. Investigators interested in either capability are therefore encouraged to approach CCRS using a collaborative rather than customer stance.

[5] In the CCRS implementation, four receivers separate the data streams but in principle only two are required.

RECORDING, REAL-TIME PROCESSING, AND CONFIGURATION UPGRADES

In response to requirements for more real-time processing diversity, more versatile data recording and more flexible geometry; three basic changes were made to the system. Figure 1 gives an overview of the new recording and other system architecture features now available.

Dual-channel Processing

CCRS has always had the real-time (7-look[6]) capability to process either receive channel (like- or cross-polarization) from each radar band (X or C). In 1991, we offered for the first time the capability to process simultaneously in real time half-swath data from both receive channels. When polarimetric switching is added, the possibilities increase as given in Table 1.

EXABYTE Recording

To accommodate the need for real-time processed data recording on computer compatible media and cash in on advances in new technology, CCRS contracted *Knudsen Engineering* to complement the existing HDDT recording and formatting to a CEOS compatible [11] exabyte format. Four exabyte tapes are simultaneously produced: one for each of the two real-time processors, and two backups.

The new tape format also includes important ancillary data previously keyed in during transcription: ground speed, mode, polarizations, *etc*. This system is now being used in parallel with the HDDT recording and when fully commissioned, will replace the image HDDTs.

[6] The real-time formatter originally developed by *Knudsen Engineering*, the Alice Formatter in Fig. 1, also provides a 28-look, half-resolution product by averaging 4 of the original RTD pixels. This product is not available on exabyte.

Flexible Geometry

The initial configuration of the CCRS SARs called for 3 basic imaging geometry modes: *nadir*, *narrow swath* and *wide swath*. Nadir and narrow swath modes had 6 m slant range resolution and wide swath, 20 m resolution with geometries beginning at incidence angles of 45, 0, and 45° respectively. In 1991, CCRS introduced the concept of *variable* range gate delay for these modes so that the near edge of the swath could be arbitrarily placed (and the far edge moved accordingly). This feature allows users to concentrate their data acquisitions as their experiment requires, without straining the radar to meet unrealistic imaging geometries.

NAV SYSTEM UPGRADES

Near the heart of a successful SAR system is its motion detection system. CCRS uses a Litton-92 INS[7]. In 1988, CCRS introduced a universal navigation system (UNS) which Kalman filters the many diverse navigation inputs available to the system: INS, DMEs, Omega, barometric altimeter *etc.* The UNS provides a suite of more accurate parameters which in turn help in both navigating the aircraft and in providing post flight data recovery. The advantages of GPS and differential GPS are being incorporated into the system and the benefit of using these enhanced capabilities in providing input to the SAR motion-compensation system is also being investigated.

Since knowledge of operating altitude is key to SAR geometry; an in-house project to develop an accurate radar altimeter to operate at normal SAR acquisition altitudes was initiated in 1992. This altimeter averages and filters over 256 instances of the nadir return from the SAR compressed pulse to provide an estimate of the true flying height above terrain with an accuracy of 2 m. Noise power is continuously estimated to set realistic thresholds for the nadir return detection process. All altimeter data is recorded on PC-MAID. The altimeter will be integrated into the overall SAR system.

[7] During the mo-comp upgrade, errors in several output parameters of this system were detected and measures were taken to circumvent these.

CALIBRATION

The utility of a sensor for applications development is usually[8] enhanced by precise calibration. For SAR this involves characterization in terms of phase, geometry, and radiometry.

Radiometry has been stressed at CCRS through *in-situ* measurements of the antenna pattern through a contract to *MPB Technologies* using the NRC radar range facilities in Ottawa and through empirical testing [5]; systematic analysis of the calibration methodology [2, 15]; and in careful tracking of system upgrades. Stabilities to the order of 1 dB are routinely possible; however, work with point targets for precision calibration is recommended. Commercialization of research code developed at CCRS is being planned for 1993; so that users may have access to routinely calibrated products.

Phase [13] and geometric calibration [3] are also being pursued but mainly under the auspices of polarimetry and interferometry.

CONCLUSIONS

The CCRS airborne SAR continues to offer a suite of operational and experimental data collection modes to support the research community in development of radar remote sensing applications. Its wide range of geometry, polarization diversity, phase coherence, interferometric channel, resolution, and site specific coverage capabilities ensure that Canadian researchers can acquire the very best possible data for applications development. In this way, the airborne facility is invaluable for RADARSAT 'readiness', and as a tool to complement experiments and demonstration missions with ERS-1 and RADARSAT data. In many ways, satellites and aircraft are complementary platforms and we would encourage the remote sensing community to access this unique facility through collaboration, technology transfer, and data requests.

[8] There are of course exceptions, such as certain mapping applications.

Table 1: Real-time Processor/Signal Recording Options.

Polarization Mode	Band	Transmit Pol	Processed Subswath	RTP Processed Pols/ Signal Recorded Pols
Normal	X and/or C	H	Full Near half or Far half	HH or HV HH and HV
		V	Full Near half or Far half	VV or VH VV and VH
Quad-pol	C only	H and V	Full Near half or Far half	(HH or HV) and/or (VV or VH) (HH and HV) and/or (VV and VH)

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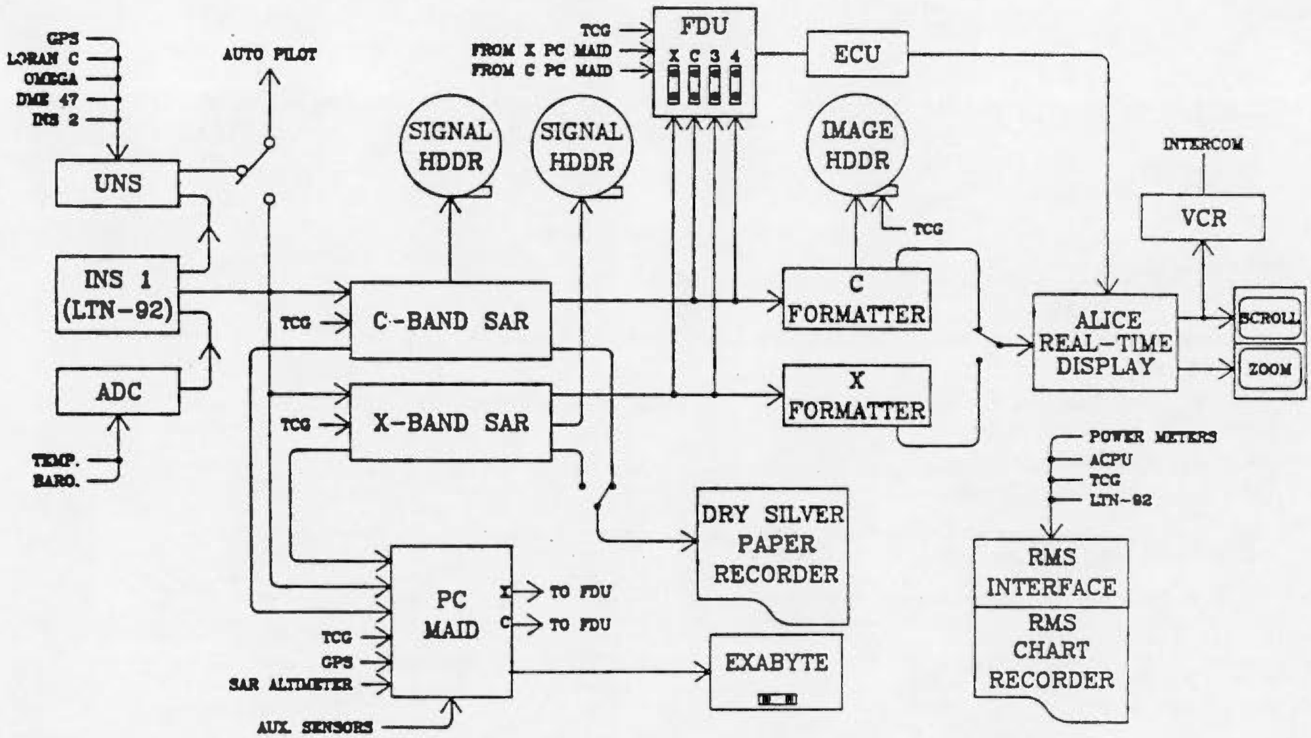

CV 580 SAR DATA ACQUISITION SYSTEM

Figure 1: SAR System Configuration.
This figure shows the new system features of the upgraded SAR including the UNS and the recording of RTP data on HDDR and/or Exabyte.

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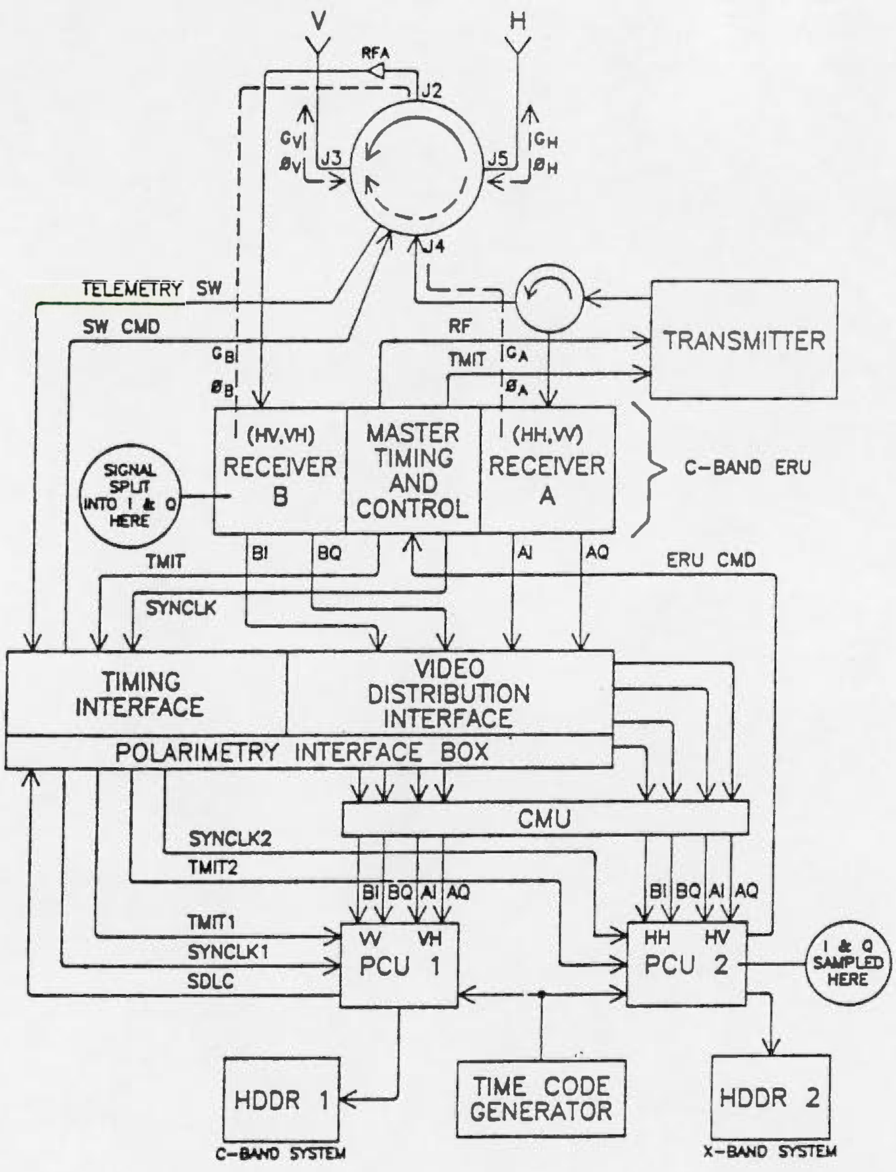


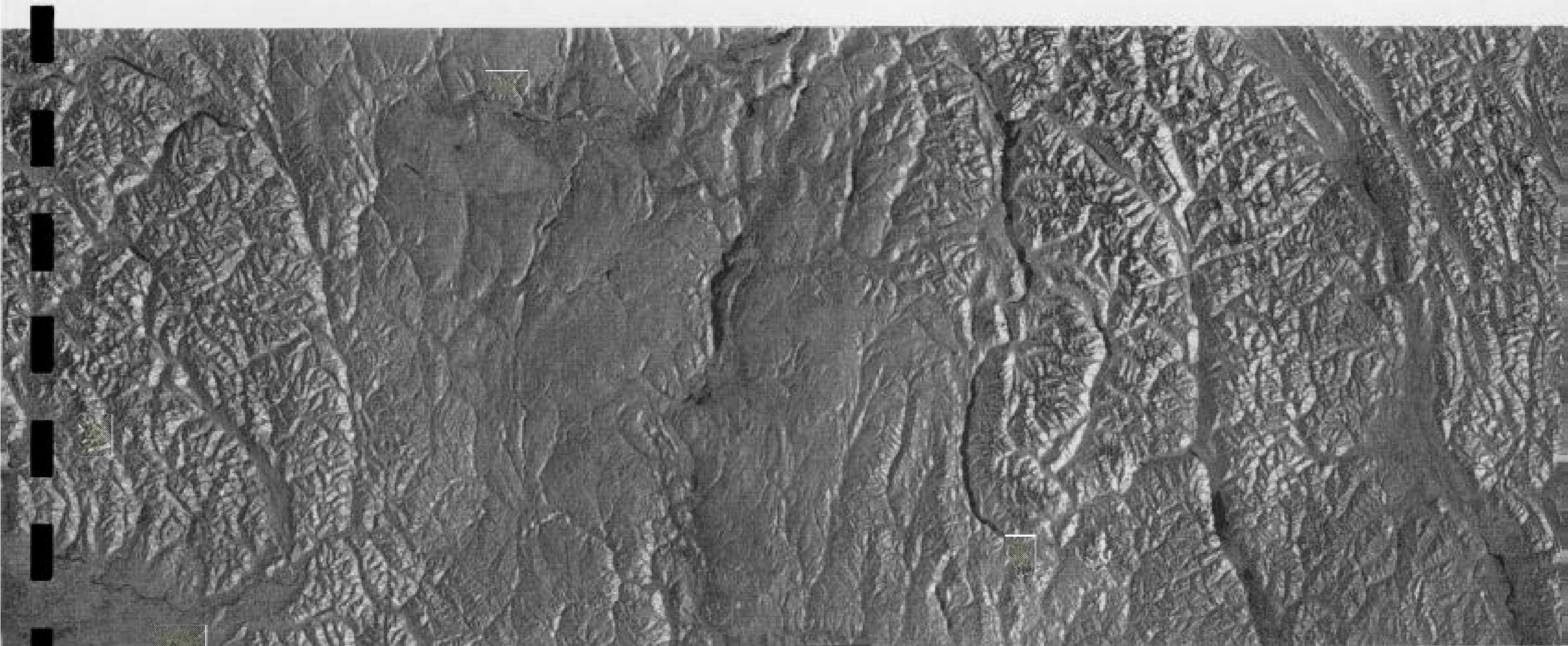
Figure 2: Polarimetry Switch.
This figure shows the signal path for the new C-band polarimetry switch. The switch is activated by a controller for each PRI, and directs the transmitter pulse to one of the antennas for transmission and the received signals from both antennas to the appropriate receivers. In polarimetric mode, the PRF is doubled and the transmit polarization is alternated between H and V.

Geometric Calibration of Spaceborne SAR Images

by

Bert Guindon

Canada Centre for Remote Sensing



SOUTHERN BRITISH COLUMBIA

This mosaic was created by merging data from 53 descending pass ERS-1 scenes acquired between April 17 and August 25, 1992. Each scene was geometrically corrected with the aid of Level 1 Digital Terrain Elevation Data (DTED). The area, bounded by latitude 49 to 51 degrees North and longitudes 114 to 124 degrees West includes the city of Vancouver (lower left) and a variety of topographic regions including the Rocky Mountains, the Okanagan Valley and the Coastal Ranges. The city of Calgary is in the upper right, where the transition from the foothills to flatter prairie is evident. (Copyright ESA 1992)

Geometric Calibration

Complete process to the production of orthoview imagery sampled regularly on a cartographic projection[1]

Major Sources of Geometric Error in Satellite Imagery[2]

- Spacecraft ephemeris ~ 1 km
- Spacecraft attitude ~ 100 m
- Accuracy of ground control - 10 to 50 m
- Terrain-related parallax / sensor-dependent

Comparative Importance of Terrain-Related Parallax

- Topographic scaling factor (TSF)
  - Apparent horizontal displacement per unit vertical error[3]

SENSOR	CONFIGURATION	TSF
LANDSAT TM		0.075
SPOT HRV	2 DEGREE LK	0.041
	15 DEGREE LK	0.307
	27 DEGREE LK	0.599
RADARSAT	STANDARD (N)	2.32
	STANDARD (F)	0.96
	SCANSAR (N)	1.80
	SCANSAR (W)	1.50

[1] Historically, CCRS has been involved in operational image correction work for a long time.

[2] The development of operational and user-friendly products for RADARSAT presents an opportunity for the private sector companies and their clients.

[3] Note the relatively large error for the spaceborne SAR case (>1).

Major Sources of Large Area Digital Elevation Data

- ETOPO-5
  - Global
  - 5 arc minute sampling
- Digital chart of the world
  - Global
  - 1:1,000,000 scale
  - 0.5 to 1.0 km sampling
- Digital terrain elevation data (DTED)
  - Selected regions (15-20 % of Canada, all of U.S.)
  - 1:250,000 scale[4]

Geocoding Errors Associated with Inherent DTED Errors[5]

RADARSAT MODE	ERROR IN RESOLUTION ELEMENTS	
	AZIMUTH	RANGE
STANDARD (N)	1.59	2.23
STANDARD (F)	1.59	1.87
SCANSAR (N)	0.89	1.03
SCANSAR (W)	0.44	0.50

4 Note that DEMs are not available at coarse resolutions on a global basis.

5 Errors are on the order of 50 m in each dimension, given good ground control point data; however, the actual elevation error is large.

Issues Related to the Interpretation of Geometrically Calibrated Scenes

- Nature of the coupling between radiometric and geometric calibration
- Inhomogeneity of the spatial characteristics of geometrically corrected imagery
- Limitations imposed on the calibrated imagery by auxiliary data employed in the calibration process[6]

[6] The main reason for this limitation is the lack of detailed DEMs.

ERS-1 SAR
Image Calibration Tutorial

by

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Data Aquisition Division
Canada Centre for Remote Sensing

Requirements for SAR Image Calibration

- Measure physical properties of terrain cover from SAR images
- Compare land cover signatures at different times/places
- Combine measurements from SAR images with other spatial information in master data bases (GIS)
- Mapping
- Automatic information extraction algorithms

SAR Image Calibration

- What is it?
- Why bother?
- How?
- Limitations and problems

  (In engineering there is no free lunch)

Calibration Elements

1. Correct the image data for instrument effects

    - Sensor and imaging geometry compensations

        - SAR antenna pattern correction
        - Range spreading loss correction

    - Image presentation compensations

        - Two image presentation planes
            - slant range (natural radar coordinates)
            - "ground range" (projected onto an elipsoid)

    - Sensor system gain compensation

        - Composite correction for:
            - Transmitter power
            - Receiver gain
            - Processor gain

2. Correct the image data for terrain relief effects

    - Requires a DTM

    - Radiometric compensation

        - Terrain slope correction

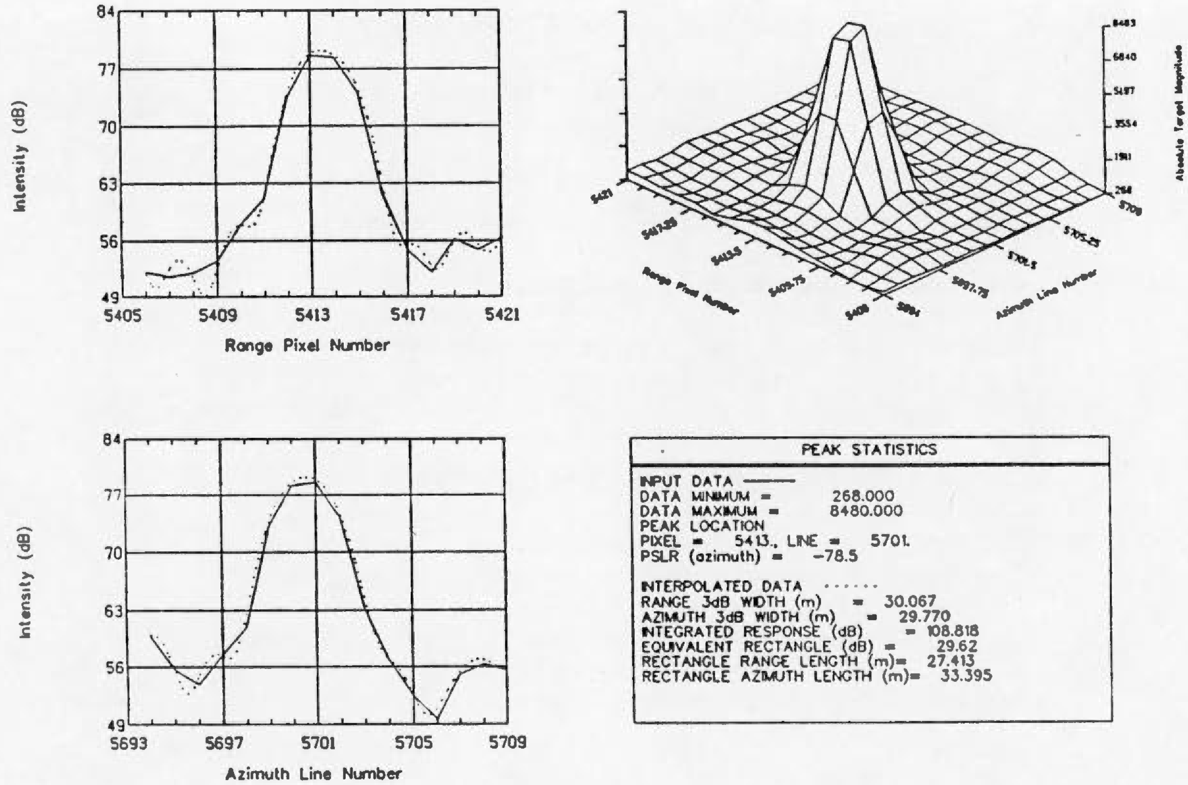
    - Geometric compensation

        - Planimetric position from slant range and terrain height

SAR Images: Background Information

- Radars measure the distance between the radar and the target (slant range).
  - The natural coordinate system for radar images is the slant range plane
- Radar range resolution = the range impulse response width
  - Determined by the radar bandwidth and the processor
  - Fundamental to the information content of an image
- SAR azimuth resolution = the azimuth impulse response width
  - Determined by the azimuth (doppler) bandwidth and the processor
  - Minimum value is 1/2 antenna length at 1 look
  - Fundamental to the information content of an image
- A digital SAR image is an array of samples of the output of a SAR processor.
  - The number of samples is not simply related to the information content of the image.
  - Range sample interval < range resolution
  - Azimuth sample interval < azimuth resolution
  - The sample intervals are called "pixel spacing".
- A SAR image combines physical properties of the terrain, the radar and the imaging geometry

UNIDISK PEAK ANALYSIS OF DU13:[POLAR.ERS1XCAL.ERS1]L13030.UNI
22-JUL-1992 09:53:33.44



November 1 Stirlingville

Compensation for the ERS-1 SAR, SAR Processor, Imaging Geometry

Calibrated data output: normalized radar cross section, σ^0 image

- Physical parameter dependent on terrain cover, environmental conditions, incidence angle

$$\sigma^0(x,y)=(D_{N_{x,y}}{}^2-D_{N_n}{}^2)\sin(\theta(x,y))(\frac{R_{x,y}}{R_0^3})\frac{1}{K}$$

- Image coordinate:	y range x azimuth
- Image magnetude digital number	D_N
- Image noise floor digital number	D_{Nn}
- Local incidence angle (at terrain element mapped to (x,y))	$\theta(x,y)$
- Slant range of image point (x,y)	$R(x,y)$
- Reference slant range	R_0
- Calibration constant containing radar equation terms and processor gain (image product specific)	K

Image Products from the Gatineau SAR Processor

- SGF SAR Georeferenced Fine Resolution
  - Multi-Look (3.3), Detected
  - Ground range projected (onto geoid at sea level)
    - Range resolution 30m
    - Azimuth resolution 30m
    - Range sample spacing 12.5m
    - Azimuth sample spacing 12.5m
    - Range cells across swath 8000

- MLD Multi-Look Detected
  - Ground range or slant range projection

- Range resolution	ground:	30m
	slant:	13m
- Azimuth resolution	30m	
- Range sample spacing	ground:	12.5m
	slant:	7.9m
- Azimuth sample spacing	ground:	12.5m
	slant:	4*v/PRF[1]
- Range cells across swath	ground:	8000
	slant:	6250

[1] Data from the SAR work order report - must be requested.

Gatineau SAR Processor

Processed SAR images are defined on an elipsoidal geoid model at mean sea level.

- GEM-6 (Goddard Elipsoid Model) geoid

$$R_e = R_{ee}\sqrt{\frac{\cos(\lambda)^2 + \left(\frac{R_{ep}}{R_{ee}}\right)^4 \sin(\lambda)^2}{\cos(\lambda)^2 + \left(\frac{R_{ep}}{R_{ee}}\right)^2 \sin(\lambda)^2}}$$

R_e earth "radius" at latitude λ in m

R_{ee} equatorial earth radius 6,378,144 m

R_{ep} polar earth radius 6,356,759 m

Near and far swath slant ranges in the CCT header are defined from the satellite to the geoid.

Near, mid, and far swath lattitude and longitude, in the CCT header, for each range line are defined on the geoid.

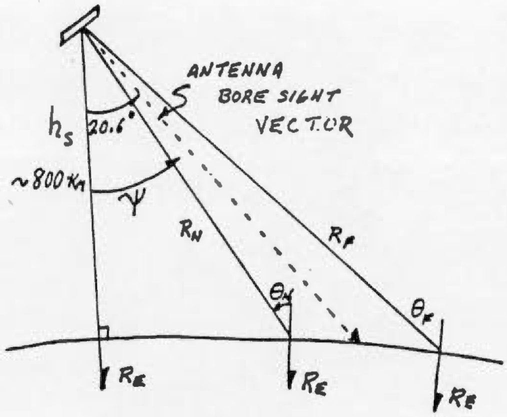
The ground range sample spacing is defined on the geoid.

Ground range projections are calculated on the geoid from slant range images by a $(\sin(\theta_g))^{-1}$ transformation (θ_g is the incidence angle of the slant range sample points at the geoid) and are resampled to 25 m using a curve fitting interpolator.

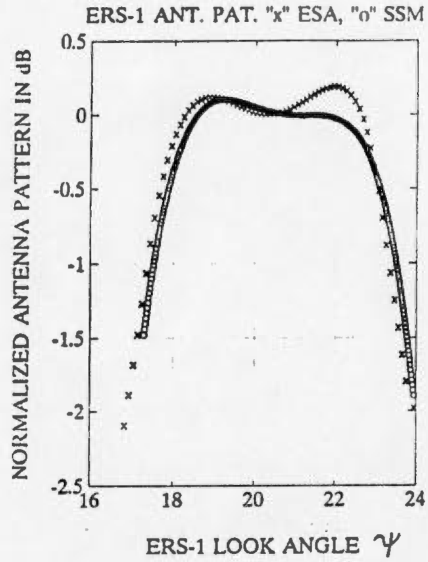
Image point displacement with terrain height $h_t/\cos(\theta_g)$

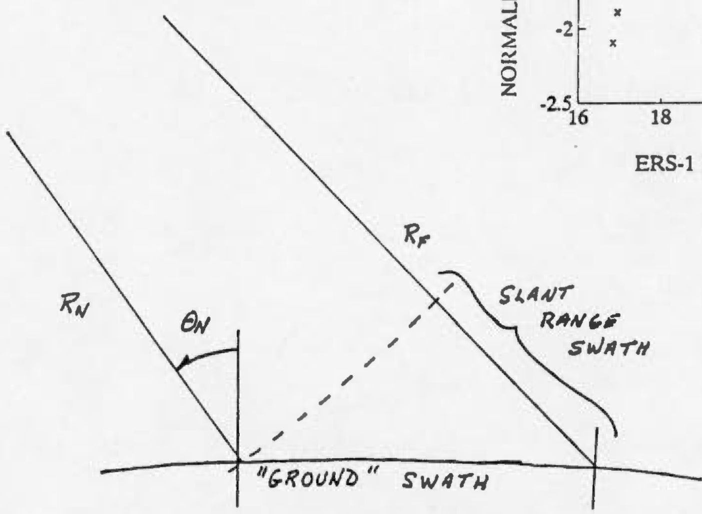
SAR calibration is the transformation of digital number values of processed image samples in the slant range plane of the radar (or in a geoid projection) to a planimetric array of geophysical parameter

ERS-1 SAR Imaging Geometry

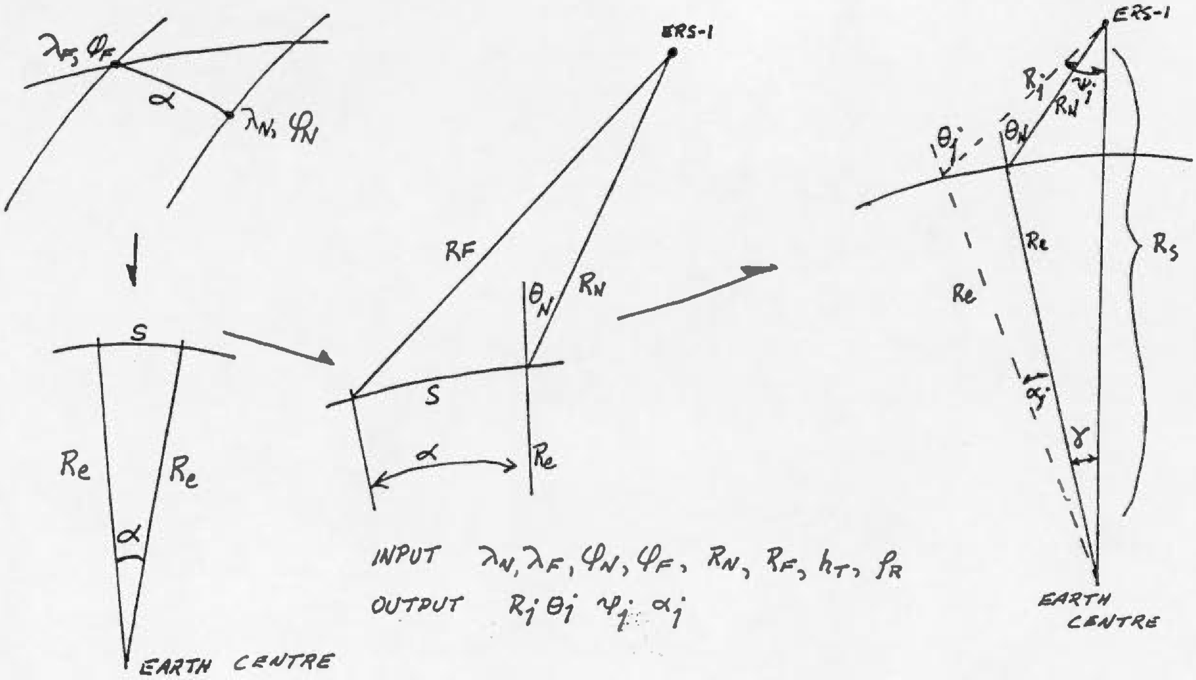


EXPANDED VIEW

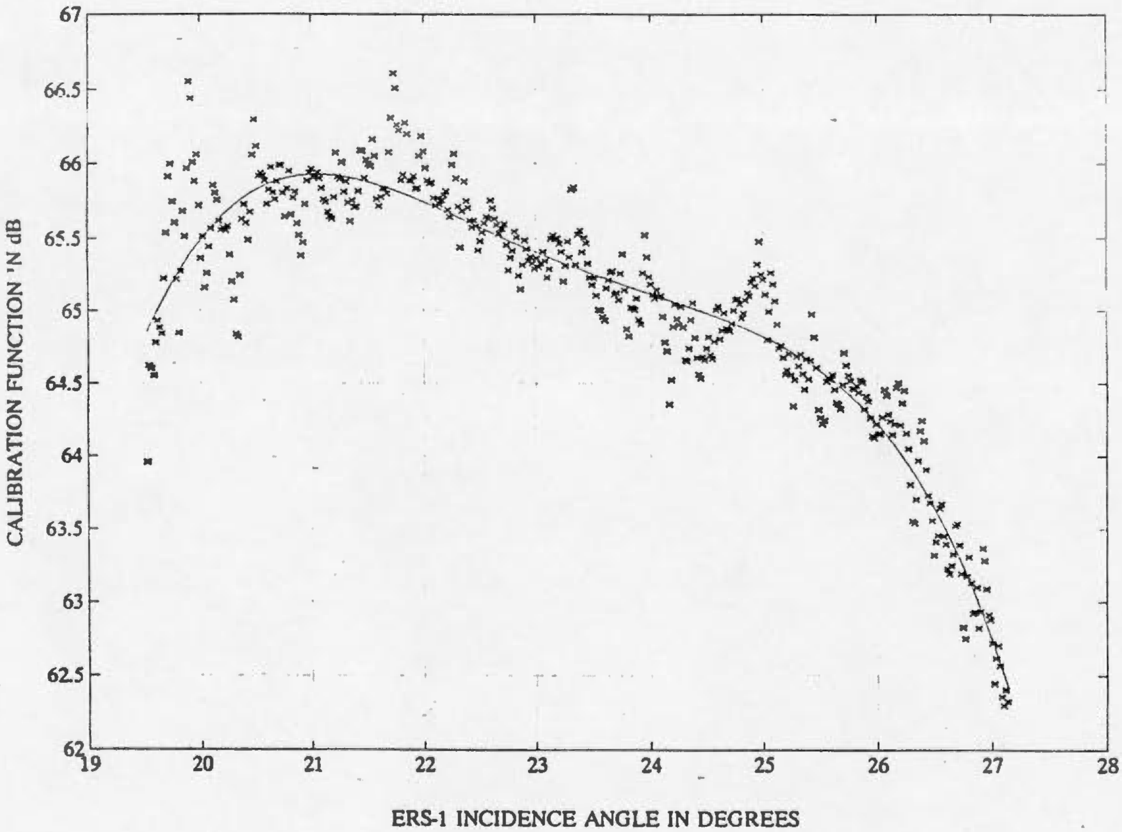




Calibration Geometry Calculation Geometries



LPF Calibration Function with Polynomial Fit



RADARSAT -
Canadian Data Processing Facility and Proposed Products

by

David Lapp
Manager, Application Development
RADARSAT International Inc.

Organization and Staffing

- Relocation of RSI Headquarters to Richmond, B.C.
    - Consolidation of RSI Data Centre with RSI HQ into old MDA building
    - Relocation of 7 staff members from Ottawa to Richmond
    - Operational starting January 18, 1993

- RSI Ottawa office remains
    - CCRS/CSA liaison and consultation
    - AES Ice Centre and OGD liaison and contract development
    - ERS-1 order desk and data sales
    - Eastern Canada LANDSAT and SPOT data sales and service
    - Contract negotiations and implementation
    - RADARSAT Applications Working Groups
    - GlobeSAR
    - Education programming and materials development with CCRS/CSA

Applications and Product Development

- National Demonstration Projects and Product Development
  - RADARSAT Applications Working Groups
  - CCRS RDDP Programs

- CCRS TEP and Provincial Programs
  - Cost-effective case studies
  - RADARSAT simulations
  - Data integration and fusion
  - Development of image products and derived products
  - Data delivery and communication
  - Value-added industry

- International Demonstration Projects and Product Development
  - RADARSAT Working Groups
  - GlobeSAR '93
  - GOSAP Project (U.S.)
  - Norwegian Oil Spill Experiment
  - ERS-1 and J-ERS-1 P.I.'s
  - International value-added industry

- Value-added Industry Relationships
  - Non-disclosure agreements with Intera, Noetix, Terrain Resources, AERDE and Norland Science and Engineering Ltd.
  - Other NDA's under discussion
  - Working with Geomatics International and PCI on ERS-1 projects
  - Industry call for proposals for GlobeSAR
  - Training and education seminars in SAR ice interpretation

Market Development and Assessment

- ISTC market study of opportunities for Canadian value-added industry
    - Phase I report nearing completion
    - Preliminary findings presented here for the first time

- Nordic market study of near real-time markets for RADARSAT
    - Cooperative study with Norway and Sweden
    - Study of Nordic countries including Norway, Sweden, Finland and Denmark

Market Feasibility Study (for ISTC)

Background

- 1995-1999 projected RADARSAT data sales = $187 million

- Data sales by region (expected)

Asia-Pacific	25%
Europe	25%
North America	20%
Latin America	15%
Middle East	10%
Africa	5%

- Ratio of Value-added to Data Sales is 7 : 1

  Therefore, large international opportunity for Canadian value-added companies.

- Specifically, where/what are the opportunities?

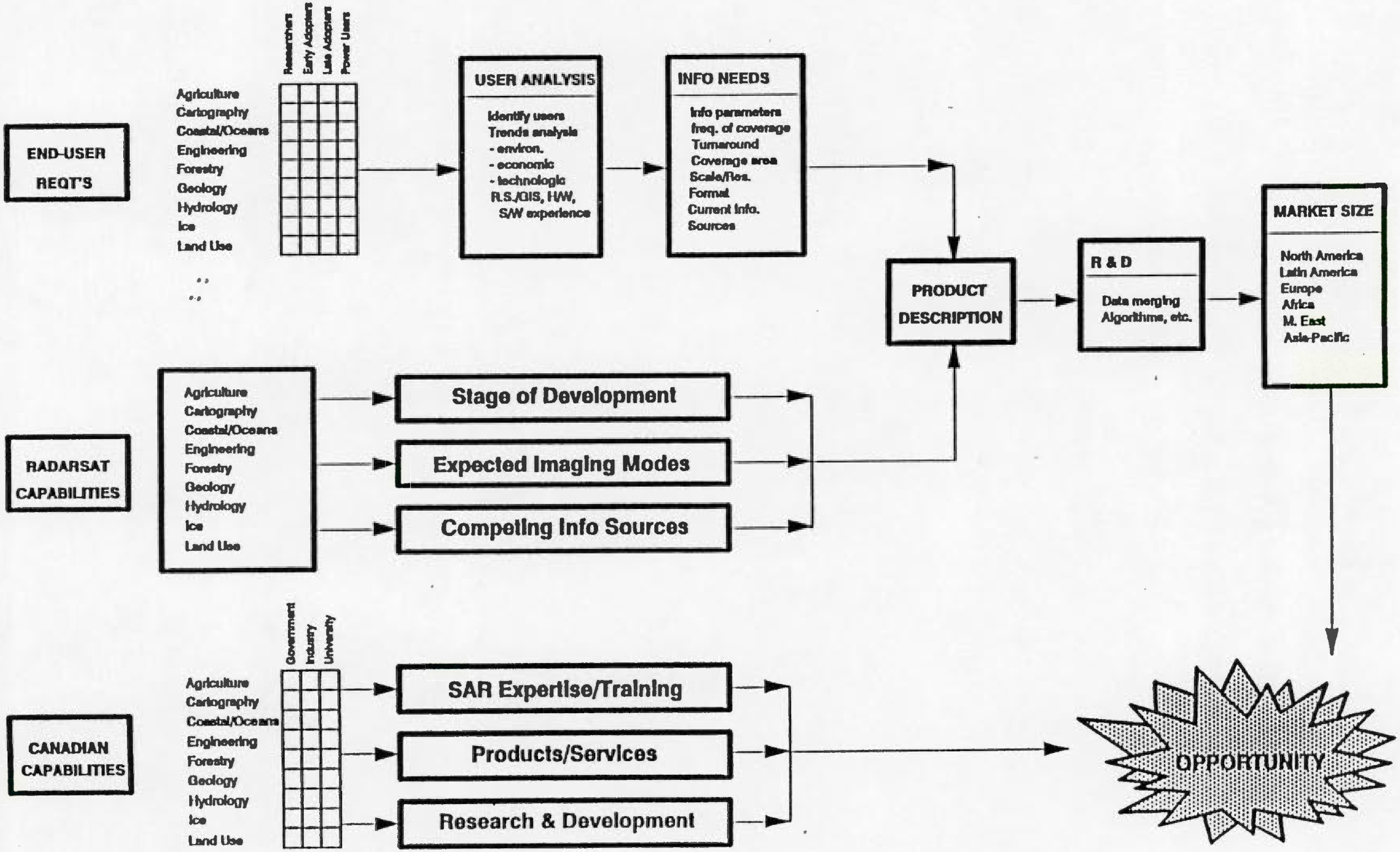
Objectives of Study

- Phase 1
  - Define the characteristics of products required in support of operations and decision making.
  - Identify the capabilities within the Canadian value-added industry that could be utilized to meet the requirements.
  - Summarize applications product requirements and the ability to meet the demands.

- Phase 2
  - Define product specifications in order to identify business opportunities.
  - Develop strategy to foster the production of goods and services necessary to meet the demand.

Methodology

- Assess end user requirements in different market segments and applications.
- Identify RADARSAT capabilities in different applications.
- Define products, and R&D required to develop these products.
- Assess market trends, size and competition that will affect demand for these products.
- Analyze Canadian capabilities against these requirements to define opportunities.


END-USER REQT'S
Researchers
Early Adopters
Late Adopters
Power Users
Agriculture
Cartography
Coastal/Oceans
Engineering
Forestry
Geology
Hydrology
Ice
Land Use
USER ANALYSIS
Identify users
Trends analysis
- environ.
- economic
- technologic
R.S./GIS, H/W, S/W experience
INFO NEEDS
Info parameters
freq. of coverage
Turnaround
Coverage area
Scale/Res.
Format
Current info.
Sources
PRODUCT DESCRIPTION
R & D
Data merging
Algorithms, etc.
MARKET SIZE
North America
Latin America
Europe
Africa
M. East
Asia-Pacific
RADARSAT CAPABILITIES
Agriculture
Cartography
Coastal/Oceans
Engineering
Forestry
Geology
Hydrology
Ice
Land Use
Stage of Development
Expected Imaging Modes
Competing Info Sources
CANADIAN CAPABILITIES
Government
Industry
University
Agriculture
Cartography
Coastal/Oceans
Engineering
Forestry
Geology
Hydrology
Ice
Land Use
SAR Expertise/Training
Products/Services
Research & Development
OPPORTUNITY

Preliminary Findings

- "Late adopters" are large segment providing large opportunity. They:
  - Use data for operational decisions
  - Have limited capability to process, analyze, interpret data
  - Require value-added, user-friendly products.

- Few operational RADARSAT applications outside of Ice, Geology
  - Therefore, high priority to develop radar applications.

- Radar data is complex, market is un-educated with respect to radar.
  - Require automated feature extraction algorithms, simplified interfaces to make data accessible to majority of market.

- Real-time requirements of some applications (Ice, Oceans, Hydrology)
  - Fast SAR processor, data delivery requirements, end-to-end systems.

- Many late adopters are using/evaluating GIS technology. GIS trend towards application specific solutions, and merging of image processing and GIS technologies.
  - Market is for GIS-based application solutions that use RADARSAT data for monitoring.

System Requirements

- Functional Requirements
    - General
    - Control and reporting
    - Ingest and processing
    - Calibration
    - Products (RAW, SGF, SSG, SPG, SCW, SCN, SLC)
    - Archiving

System Design

CDPF PRODUCT SUMMARY (INCL. VOLUMES)

LAN output (not shown) applies to RAW, SLC, SGF, SGC, SCN, SCW.
Volumes shown as (no. of products in initial system/no. of products in upgrade), and [no. of mins of real-time data processed in initial system/no. of mins in upgrade].

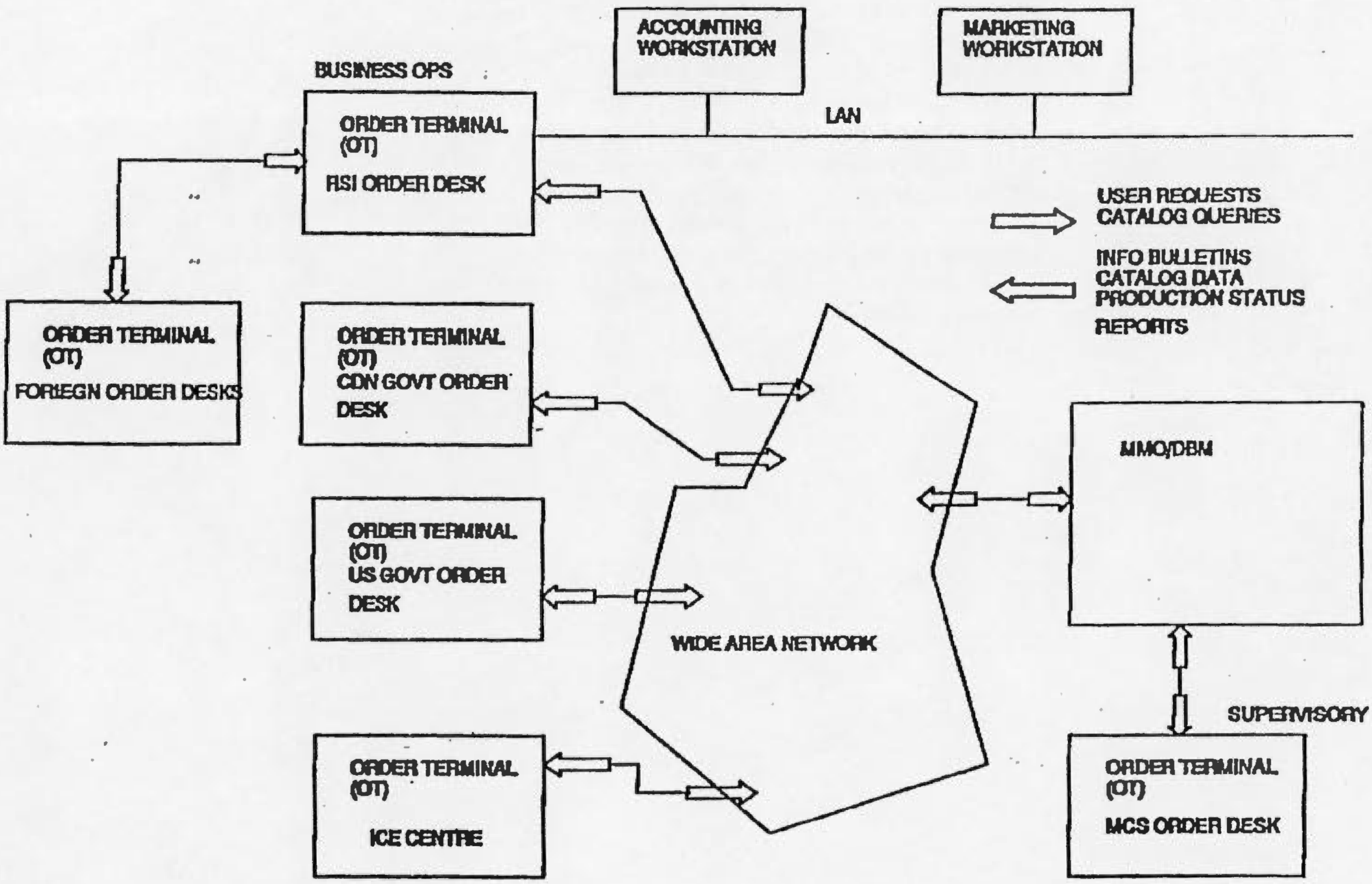
PRODUCT		SINGLE BEAM					ScanSAR		MEDIA		
Sq. Scene	SWATH	Std.	Wide	Fine	High	Low	Wide	Narrow	CCT	EXA	ITN
	RAW (1/2)	✓	(1/2)	✓	✓	✓	✓	✓	✓	(1/2)	
SLC		✓	✓	✓	✓	✓			✓	✓	
SGF (18/36)		(11/22)	(2/4)	(4/8)	✓	(1/2)	✓	✓	(9/18)	(9/18)	
SGC (1/2)		(1/2)	✓	✓	✓	✓			(1/2)	✓	
SSG (20)		✓	✓	✓	✓	✓			✓	✓	
SPG (4)		✓	✓	✓	✓	✓			✓	✓	
	SCW • (16/32)						(16/32)		✓	✓	(16/32)
	SCN • (8/16)							(8/16)	✓	(5/10)	(3/6)
TOTAL SCENES 44/88		(12/24)	(3/6)	(4/8)	✓	(1/2)	(16/32)	(8/16)	(10/20)	(15/30)	(19/38)
TOTAL MINUTES		[3/6]	[1.125/2.25]	[.5/1.0]	✓	[.425/.85]	[24/48]	[6/12]			
Sq. Scene	ScanSAR										
[5/10]	[30/60]										

RADARSAT Canadian Data Processing Facility (DPF) - Preliminary Design Review (PDR)[1]

- CPDF Design Meets Key Mission Requirements
  - Processes data from all operational satellite modes
  - Satisfies image quality
  - Is a commercial production system
  - Meets initial throughput and turn-around requirements
  - Support fast turn-around of data (3 hours for ICEC)
  - 1/10 real time (5 times faster than ERS-1)
  - Effectively balances complexity against long-term operational costs
  - Emphasizes design simplicity/flexibility of operation
  - Upgrade paths identified to meet increased demand
  - Designed to work as part of overall RADARSAT system
  - Re-uses SARDPF

[1] Delivery of the RADARSAT processor is scheduled for October, 1994. The processor is built by MDA. The design studies stress system flexibility with regard to data throughput and requirements for operational use.

Order Desk and MMO/DBM Configuration



Concluding Remarks

by

Robert O'Neil
Director, Major Projects Office
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Workshop on Commercial Opportunities in RADARSAT

- Understand the interface between RSI and companies providing value-added products and services
- RADARSAT data policy, RADARSAT products and prices
- Identify international opportunities for Canadian companies and determine if there are ways that could help them into the international market

The Workshop is to be held in the spring of 1993.

Regional Briefings

- Sponsored by CSA with participation of CCRS and RSI
- Presentations on applications, opportunities *etc.* in the RADARSAT Program
- Tailored to regional requirements

The Regional Briefings are to be held in spring of 1993.

Applications Tutorials

- Sponsored by RDDP/CCRS
- Similar to earlier workshops (~20) organized by TEP/RDDP/CCRS
- Organized in various centres in Canada, possibly combined with regional briefings at some locations

The tutorials are scheduled to begin in the Spring of 1993.

Discipline Workshops

- Organized by CCRS discipline coordinators
- Similar to meetings held already on a regular basis by some of the disciplines

CCRS Working Groups

- Formerly the CACRS Technical Working Groups
- Will address the entire discipline including technology and application
- Involvement of user community, CSA and RSI
- In near term, will focus on RADARSAT but not to the exclusion of other remotely sensed data sources

RDDP Unsolicited Proposal (UP) Fund

- See end-note[1] for details
- Key elements
  - Development of commercial products and services
  - Short technical proposal emphasizing outputs
  - Commitment of end user ... contribution of $'s to contract
- Budget for FY93/94 is expected to exceed $500k[1]

Long Term Space Plan

- RADARSAT Data User Program (RDUP)
  - Extension of the RDDP to encourage increased activity in the user community
- Specific initiatives to develop information systems in various federal government departments
- Expect plan to be submitted in Spring 1993

[1] A total of $700k was available this in FY92/93 but because it takes time to work up a proposal, most of the money was committed to other commercially oriented activities. In future, the total available will approach $1M/yr (recognizing, of course, that there will be projects carried from one year to the next).

GlobeSAR

- Follow on from SAREX '92 ... take CV-580 around the world
- 4-year program to provide visibility for RADARSAT Program and RSI
- Generate data for "simulations[2]" and applications development
- Conduct seminars and training sessions in client countries
- Great deal of effort by CCRS in generating support
  - International development agencies (CIDA, IRDC, UN, *etc.*)
  - Client countries
- RSI has prepared international announcement to private sector
  - Foreign companies can participate only in cooperation with Canadian companies

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[2] The word simulation must be used with care. In Canada software exists to simulate the pixels size and speckle of RADARSAT by transforming an image from an existing SAR with known characteristics. A separate program can simulate the effects of elevation changes using DEMs. The two programs are not combined. There is no software which simulates the effects of different angles of incidence (requires the scattering function) polarization, frequency, land cover *etc.* Thus the ability to simulate RADARSAT data is very limited and viewers of simulated imagery should be warned not to draw too many conclusions from it. Using CV-580 imagery (with 6m pixels) to simulate RADARSAT may create unrealizable expectations for RADARSAT imagery.

RADARSAT Data Evaluation Program (RDVP)

- Three components
  - Opportunities for international scientific community[3] managed along the lines of a familiar NASA AO; sponsored by CSA and NASA
  - Opportunities for a limited number of international commercial demonstrations; sponsored by RSI
  - Opportunities for Canadians to get small amounts of data (from anywhere) to develop and demonstrate applications, products and services; sponsored by CSA and CCRS

- Funding to support the RDVP infrastructure (documentation, regional conferences, final conference, user support team) and Canadian participants is being requested through the Long Term Space Plan

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[3] NASA and NOAA have rights to data from RADARSAT in exchange for the launch. As part of the MOU putting this in place, NASA identified that it would use some of its data for an AO. An international AO is a very large and complex undertaking. CCRS and CSA had been working to ensure that Canadian research groups would have adequate opportunity to participate in this segment. At the RDDP Workshop a number of participants expressed concern that, by permitting NASA to have the lead on this component, Canada was not controlling and exploiting all the advantages (prestige) of its own satellite. There was also some concern that if NASA provided a great deal of data and money for the US (and allied) research community, some applications and industrial capability would be developed that would be in competition with Canadian companies. CCRS and CSA will look into this further; however, a great deal is expected of the Canadian community in the early RADARSAT era. The capacity of the community to respond is limited and it is not clear that additional funding will address this effectively.

Terrain Correction for RADARSAT Imagery

- CSA, CCRS and RSI seeking means to provide some level of terrain correction in standard RADARSAT products

- Some image analysis systems have ability to handle DEMs (*e.g.* DTED for parts of Canada and all of USA) and to correct SAR imagery (*i.e.* remove the parallax displacement due to differing elevations of pixels)

Other Sources of SAR Data

- Through associate membership in ESA, Canada has/will make substantial financial contributions to:

  - ERS-1
  - ERS-2
  - ASAR/POEM

- CCRS has agreement with NASDA/Japan for research using J-ERS-1 imagery (resulting in the Canadian J-ERS-1 AO)

- Need to accept (or exploit) the complementarity (or competition) of these data sets to those of RADARSAT I, II and III

Acknowledgements

I would like to express my sincere appreciation to all who participated at the RDDP Workshop in Gananoque. Collectively we discussed the requirements and surrounding issues for the effective utilization of RADARSAT imagery and we will be better able to focus our limited resources between now and the launch of the satellite. In my view, a great deal was accomplished; and though the challenge is great, I am confident that we will make RADARSAT a success in Canada and internationally.

Ron Brown, Terry Pultz, Frank Ahern, Vern Singhroy, Cathryn Bjerkelund and Mike Manore (the RDDP Coordinators) did an excellent job of setting the stage for the discipline workshops, guiding the deliberations and reporting the conclusions. What we gained from the each workshop is result of their preparation, competence and hard work. I am grateful for their cooperation.

I would also like to thank Chuck Livingstone, Lawrence Gray, Bert Guindon, and David Lapp who made special presentations on topics of general interest. The topics were important, and interest was high, as evidenced in all the discussions that followed.

Dirk Werle assembled and reviewed these pages prior to printing to ensure that there is some coherence between the presentations and that details and explanations occur where appropriate. We depend on his knowledge of the RDDP and the user perspective.

The notion of beer and posters provided a novel perspective to the technical/scientific side of the Workshop. The evenings were, in my opinion, most worthwhile and enjoyable. The breadth and quality of work exhibited was truly impressive. The Workshop owes a great deal to all those who prepared posters and demonstrations, probably not knowing quite what to expect.

Finally, I would like to acknowledge Louise Dorval who organized the entire Workshop, and Marion Normoyle who assisted her. Organizing a workshop for 150 participants from across the country is a big task composed of minute details. That the Workshop went extremely smoothly is credit to their competence and diligence. I am very fortunate to work with Ms. Dorval and Ms. Normoyle.

January 31, 1993 *R. O'Neil*

Endnote 1.

Radar Data Development Program (RDDP) Unsolicited Proposals (UPs)

In order to encourage the development of commercially viable products and services based on the utilization of standard RADARSAT Synthetic Aperture Radar (SAR) data products, the RDDP will accept Unsolicited Proposals. Few proposals will be truly unsolicited: most will have been developed by the service industry, the clients, the responsible federal and provincial government agencies and CCRS. The criteria for selection of a UP are still being developed but will be flexible. The following are guidelines:

- The project should develop and/or demonstrate a capability in the private sector to provide user products and services based on or exploiting standard RADARSAT data.

- Projects might include the development of the necessary algorithms, analysis and product generation software, or the demonstration of a operational concept using ERS-1, J-ERS-1, ALMAZ to simulate RADARSAT. Given the limitations of the current RDDP budget, it is unlikely that the UP fund will be able to contribute significantly to the development of the infrastructure that will be needed to set up large information systems to do routine monitoring. (The development, implementation, and operation of such systems are properly in the domain of the agency responsible for the operational monitoring.)

- The end user of the product or service may be the private sector, the educational community (as in a teaching aid or manual), a provincial or federal agency. CCRS is not an end user.

- As in all RDDP funded activity, the proposal must be oriented to meet a real Canadian requirement. It may be possible to conduct the project such that the results, products and services could also be marketed abroad.

- The end user must demonstrate a commitment to purchase the product or service from the private sector on a continuing basis. An alternative commercially viable scenario might exist when there are a large number of end users who will each buy an occasional product.

- There should be other contributors to the project besides the RDDP. These might include clients, the agencies responsible for the targeted economic sector and a variety of funding programs (*e.g.* IRAP). The contributions should be in terms of real money that can be spent by the private sector in meeting the objectives of their proposal. Obviously, many projects will need contributions in kind: data, access to data bases *etc.*

- The resulting technology shall belong to the private sector contractor; CCRS shall expect the contractor to pay royalties (based on revenues) in recognition of its contribution to the project. It may be that other contributors will expect the same.

- The project should be proposed, managed and executed by the private sector.

- The proposal need not be lengthy but should address the usual topics: objectives/outputs, method, schedule, other participants, markets addressed, funding sources, funding requested from the RDDP. The proposal should be directed to:

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The proposal will be evaluated by a panel composed of the RDDP coordinators, the responsible federal or provincial agency (e.g. if it is a geology project, then the Geological survey of Canada would be asked to comment) the intended end user, and other funding agencies that may be involved.

APPENDIX 1

Poster Presentations

National Capital Region, IHS Transform / ERS-1 SAR / Landsat TM Bands, courtesy of Dr. M. Akhavi, College of Geographic Sciences (Copyright ESA 1992)

Airborne SAR for Surficial Geology Mapping (David Graham, Doug Grant)

An Airborne C-Band SAR Image of the Schefferville Digital Transect (Hardy Granberg *et al.*)

Clearcut Mapping Accuracy Using Multidate Winter Airborne SAR Imagery (Al Banner, Frank J. Ahern)

Crop Discrimination in Western Canada with ERS-1 Imagery (Ron Brown, Roy Dixon, Dave Bedard)

Dynamique Côtière aux Iles-de-la-Madeleine, Télédétection par Radar CV-580 et ERS-1 (Daniel DeLisle, Georges Drapeau)

ERS-1 Radiometric Calibration (Tom Lukowski, Bob Hawkins, K.J. Draper, P.L. Hamm)

ERS-1 Canadian Images/Images canadiennes *CD-ROM demonstrations* (Steve d'Apollonia)

Inventory Applications Development at the Newfoundland Forest Service (John Drieman)

Modelisation du signal radar en fonction de la profondeur de pénétration (Johanne Boisvert)

PC SAR: A PC-Based Airborne/Spaceborne SAR Processor (Bernard Armour)

Preliminary Evaluation of ERS-1 Data for the Marathon Area, Ontario (David Graham, Andy Rencz)

Seasonality of 6° Over Snow Covered Sea Ice: Implications for Operational Use of SAR Data (David Barber, Ellsworth LeDrew)

Texture Measures for the Classification of Agricultural Crops in Southwestern Ontario (Paul Treitz, Philip Howarth, Otto Rotunno, Eric Soulis, Nicholas Kouwen)

The Radarsat Tutor / demonstration (Ron Saper)

The Observations of Surface Soil Moisture from SAR Data (Huaibin Geng)

The Integration of Airborne Radar and Geophysical Data for Reconnaissance Geological Mapping in the Marathon-Schreiber Area, Northeastern Ontario (David Graham)

Automated Ice Tracking (Mike Manore)

Comparison Between ERS-1 and VIR Digital Satellite Imagery for Potato Crop

Monitoring in Prince Edward Island
(Richard Dobbins, Paul Nixon, Ken Korporal)

Computer Demonstration of PCI's Radarsoft Software (Cameron Bowie)

Data Integration Techniques Using Radar Data (Jeff Harris)

Development of Techniques for the Use of Synthetic Aperture Radar Satellite Data in Imaging Ocean Waves for Coastal Zone Applications
(David Fissel)

Digital Image Processing and Interpretation of ERS-1 SAR Data (Manou Akhavi)

EarthView: A Geocoding Application Using DTED and SAR Data / demonstration (Jim Ehrismann)

ERS-1 User's Guide *demonstration* (French/English) (Ron Saper)

ERS1 / CV-580 Images (Mike Manore)

Evaluation of SPOT, C Band SAR and DEM for Detection and Classification of Chignecto Bay Wetlands, N.S. (John Weston, Manou Akhavi)

Mapping with SAR Interferometry (Laurence Gray)

Radar Remote Sensing Imagery of Coastal Regions on CD-ROM
(Dirk Werle)

Remote Sensing for Soil Conservation in Canada
(John Naunheimer, Ron Brown, Brian Brisco, Dave Bedard)

SAR Simulation of Boreal Forest (Black Spruce) (George Xu)

Soil Moisture Estimation with SAR
(Brian Brisco, Dave Bedard, John Nauheimer, Ron Brown)

Structural Interpretation of the Baskatong Area from SAR Images
(K. Sharma, Vern Singhroy)

The Effects of Changes in Soil Moisture and Rainfall on SAR Data Crop Classification (John Fischer)

Use of Satellite Data for Short Term Stream Flow Forecasting with the Hydrotel Model (Monique Bernier, Jean-Pierre Fortin)

Géomorphologie Structurale. Analyse de l'Astroblème de Charlevoix par Télédétection (Robert Desjardins)

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