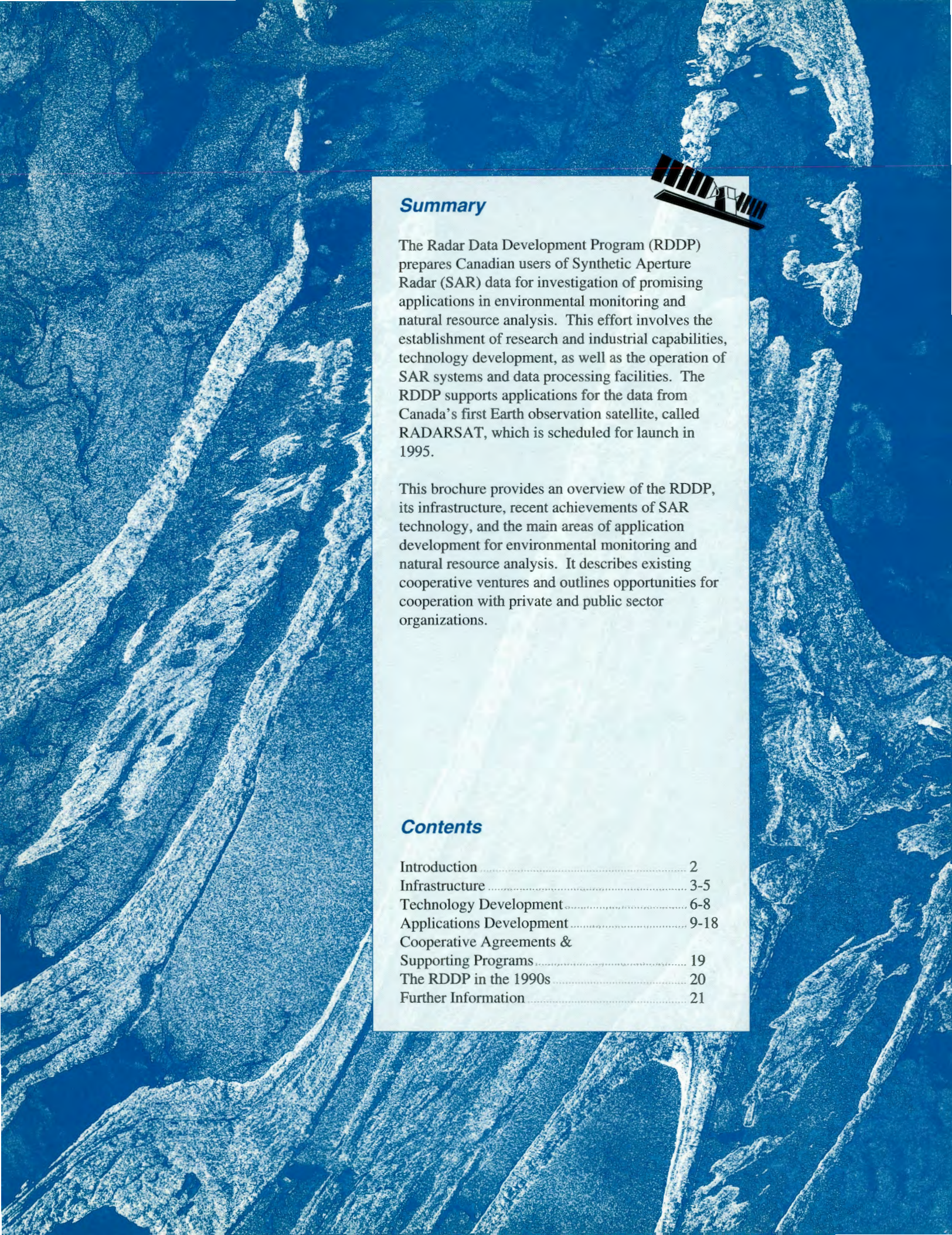
CANADA CENTRE FOR REMOTE SENSING
Surveys, Mapping and
Remote Sensing Sector

RADAR DATA DEVELOPMENT PROGRAM

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

THE ENERGY OF OUR RESOURCES

THE POWER OF OUR IDEAS



Summary

The Radar Data Development Program (RDDP) prepares Canadian users of Synthetic Aperture Radar (SAR) data for investigation of promising applications in environmental monitoring and natural resource analysis. This effort involves the establishment of research and industrial capabilities, technology development, as well as the operation of SAR systems and data processing facilities. The RDDP supports applications for the data from Canada's first Earth observation satellite, called RADARSAT, which is scheduled for launch in 1995.

This brochure provides an overview of the RDDP, its infrastructure, recent achievements of SAR technology, and the main areas of application development for environmental monitoring and natural resource analysis. It describes existing cooperative ventures and outlines opportunities for cooperation with private and public sector organizations.

Contents

INTRODUCTION

Historical Background

In Canada, radar remote sensing began in earnest during the mid 1970s with the SURSAT Program. Analysis of the airborne and SEASAT radar imagery was directed toward assessing the need and capability of SAR technology for Canadian applications. The results confirmed the importance of these data for imaging the enormous northern landmass and territorial waters, where frequent cloud cover and darkness during the winter months preclude data acquisition by means of conventional sensors that rely on sun illumination and cloud-free weather conditions.

RADARSAT

In 1995 Canada will launch its first Earth observation satellite, RADARSAT. The RADARSAT Project, which is led by the Canadian Space Agency, has several partners: The Canadian Government, the United States of America, Canadian provinces and a private sector consortium, RADARSAT International (RSI). The RADARSAT system, the orbit chosen, the SAR specifications and the data processing throughput and products have been designed to deliver data reliably and on time to clients with operational requirements for SAR imagery. RADARSAT will have a five year design life; RADARSAT II and III are now being planned to ensure a continuous source of data to users.

RADARSAT International Inc., a consortium of Canadian companies, is assessing the commercial applications of satellite radar data, educating the potential user community, and creating an effective marketing and distribution network. RSI, as a partner in the RADARSAT Program, is responsible for the global commercial marketing, processing and distribution of RADARSAT data.

Main Goal of the RDDP

The Radar Data Development Program (RDDP) is a federal government program led by the Department of Energy, Mines and Resources at the Canada Centre for Remote Sensing (CCRS). The main goal of the RDDP is to ensure that Canadians are able to use synthetic aperture radar (SAR) effectively for resource management and environmental monitoring. This is being addressed by a balanced program of applications and technology development involving universities, other government departments, user agencies, and industry.

Scope

The RDDP coordinates and supports the development of appropriate methodologies for the use of SAR data. In addition to data from airborne imaging radars such as the CCRS Airborne C/X SAR, Canadian users can rely on a continuous stream of SAR data from several satellite sensor systems, including the European ERS-1 SAR, the Japanese JERS-1 SAR, the American SIR-C mission and the Canadian RADARSAT. The RDDP is now focused on activities that will encourage the utilization of information derived from RADARSAT imagery.

INFRASTRUCTURE

CCRS C/X SAR System

The Radar Data Development Program relies heavily on the CCRS Airborne C/X SAR as a data source for research and development projects. Since their commissioning in 1986 and 1988, the C- and X-band SARs have been installed in a Convair-580 aircraft. More than two thousand hours of data acquisition have been logged, not only for RDDP related projects in Canada, but also for other projects in the USA, South America and Europe.

Capabilities, Upgrades

In 1991, the instruments underwent a series of upgrades. These included adding polarimetric and interferometric capabilities; flexible radar illumination geometries for available nadir, narrow and wide swath imaging modes; improved components for navigation and motion-compensation; and dual channel real-time data recording. The suite of operational and experimental data collection modes of the CCRS Airborne C/X SAR by far exceeds current spaceborne SAR capabilities and offers the remote sensing community a versatile tool to develop radar applications, not only for RADARSAT, but also for future space missions.

Airborne SAR Data Processing

The Airborne C/X SAR data acquisition capability has been designed around the concept of end-to-end phase integrity. This involves both airborne sensor as well as associated ground processor hardware and software for a complex set of post flight data manipulations. The ground facilities at CCRS include systems for data transcription, digital SAR processing and hard copy image production.

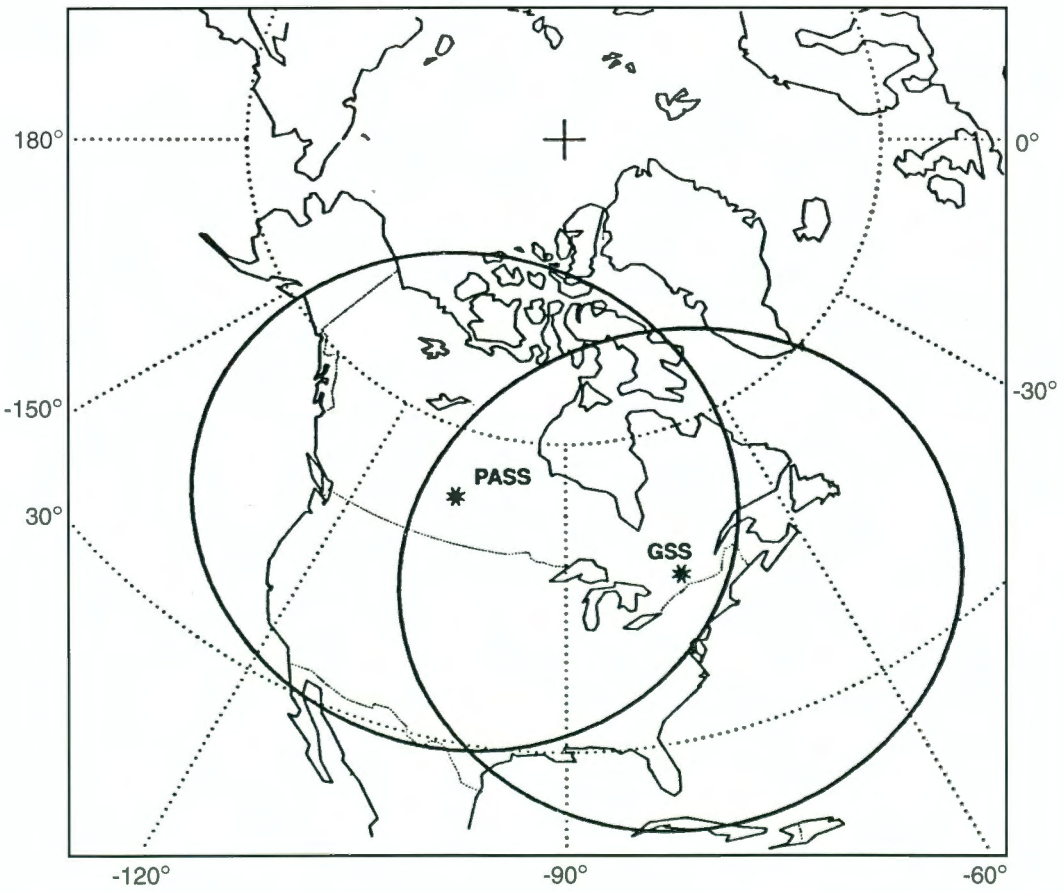
The CCRS Airborne C/X SAR is installed on board a CV-580 aircraft operated by CCRS/EMR Canada.

Satellite Stations

Canada has access to ERS-1 and JERS-1 data through the CCRS satellite stations at Gatineau and Prince Albert where SAR data acquired over all of Canada and its territorial waters (with the exception of the High Arctic north of 77 latitude) is received, recorded and processed into usable products for distribution. These stations are key to being able to offer satellite SAR data tailored to the needs of RDDP participants and other Canadian users.

ERS-1 SAR Data Processing

At the Gatineau satellite station, a newly installed SAR processor is at the core of the ERS-1 data production facility. The system is designed for rapid data delivery to the user and provides management facilities such as catalogue maintenance, order entry and processing, and product distribution. The Canadian Space Agency (CSA), RADARSAT International (RSI) and CCRS will upgrade the ERS-1 processor for the RADARSAT era.



Location map of the Prince Albert and Gatineau satellite stations with ERS-1 Station Masks. These receiving stations are key to being able to offer satellite SAR data to Canadian users.

Information Sources

Accessible, up to date information is essential to the many individuals and organizations involved in radar remote sensing research and development.

A new network system, GCNet, provides o0n-line access to CCRS databases such as the CCRS Image Inventory and RESORS. The CCRS Image Inventory permits searches of Landsat, MOS, NOAA & SPOT satellites' raw imagery and an archive of ERS-1 images will soon be available. International datasets pertinent to environmental monitoring are also accessible through GCNet, as well as the PlaNet electronic bulletin board service.

RESORS is a unique on-line database that provides rapid and precise access to bibliographic information. Over the past 20 years, RESORS staff have been indexing journal articles, books, research reports, reference documents and other remote sensing related materials. Services include assisted or unassisted on-line searching with a keyword or keyword combination.

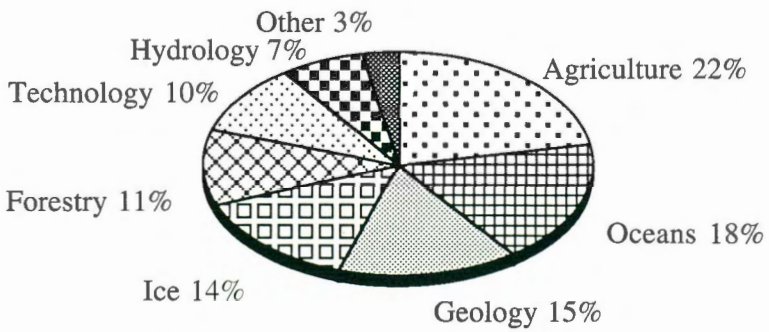
The Surveys, Mapping and Remote Sensing Sector Information Centre also provides a comprehensive, in-depth source of information for radar scientists, engineers, educators and students.

Project Management

The overall RDDP management resides within the Major Projects Office at CCRS. Various program components for SAR data acquisition, data processing, and applications development are, in turn, administered by the respective CCRS Divisions and their RDDP coordinators.

Funding Support

Funding levels over the expected lifespan of 15 years will average approximately $5M per year. Program reviews are conducted every five years. During the first five years of operation, RDDP expenditures were distributed among the various application disciplines, technology development efforts and other infrastructure related items. It is expected that this trend will continue during the second five-year phase of the RDDP. In addition, CCRS supports the Program with substantial direct contributions to projects, personnel, and infrastructure.



Distribution of RDDP expenditures, FY 1987/88 to FY 1991/92. Future expenditures will remain constant at $5M per year.

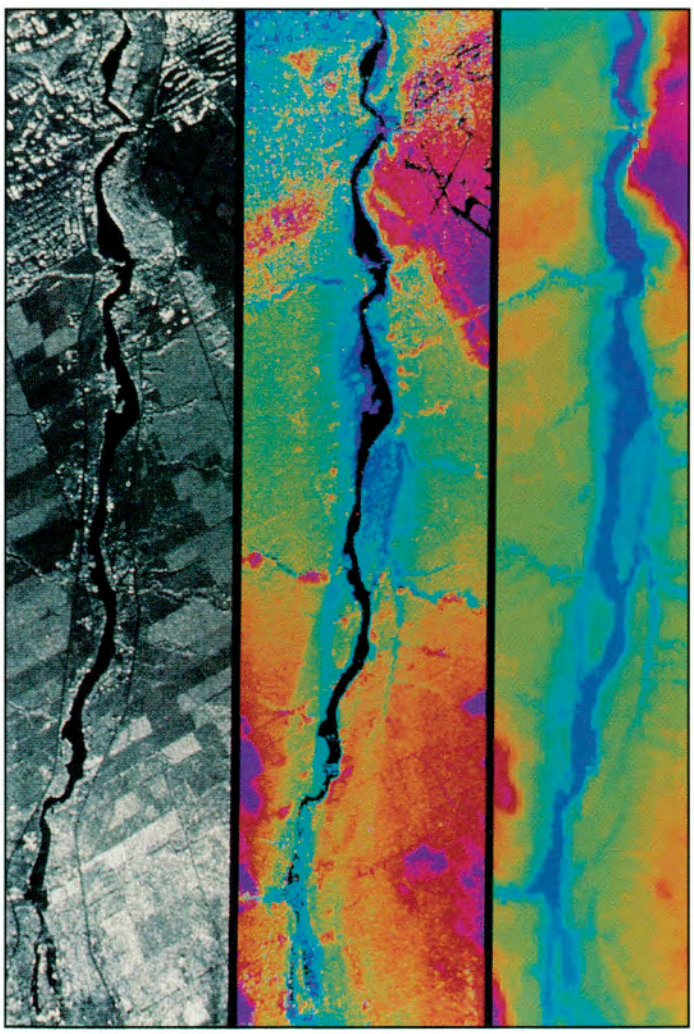
TECHNOLOGY DEVELOPMENT

Development of SAR Technology

The remote sensing community has witnessed a rapid advancement of SAR sensor and processor technology. Achievements include the evolution from analog to completely digital sensor systems, new antenna designs, and SAR processing techniques that can take advantage of a new generation of computers for satisfying their large data handling requirements.

Scientific Exploration of Application Potential

Hand-in-hand with these technology driven developments there has been scientific exploration of the application potential of SAR data. Improved SAR sensor flexibility spawned a series of experiments using either multiple frequency data, multi-polarization data, or multi-incidence angle data. Appropriate SAR calibration techniques and procedures are under development in order to be able to extract quantitative information from this and other types of data.



The monochrome image represents a 'normal' SAR scene of the Rideau River near the Ottawa airport. The second image shows colour-coded terrain differences as derived from SAR interferometry. The third image is a colour-coded map representing actual elevation differences. Note the detail of the interferometric measurements. Higher elevations (in red and purple) in the second image frequently correspond to forest stands.

Polarimetric SAR

As part of the CCRS Airborne C-band SAR system, a polarimetric capability has been implemented. The SAR can now be operated at double pulse repetition frequency (PRF) with alternating transmit pulses between horizontal and vertical polarizations and simultaneous reception of each pulse at both like- and cross-polarization. In order to exploit the full information potential of polarimetric SAR data sets, complex post-flight data manipulation is required.

Interferometric SAR

CCRS has also installed on the CV-580 aircraft a second antenna which, in combination with the existing C-band SAR antenna, now forms a radar interferometer. The system is used on an experimental basis to improve radar mapping. The use of interferometric measurements allows for removal of terrain induced distortions and thus can improve the geometric fidelity of SAR data. Once the proof of concept to operational mapping is achieved, CCRS expects to transfer the technology to Canadian industry.

Multi-date SAR Imagery

The generation of composite SAR imagery from data acquired at different dates shows additional promise. Several RDDP projects have demonstrated that applications involving environmental monitoring activities could rely on the operational advantage of radar remote sensing to provide data at specific times or dates regardless of weather or sun illumination conditions.

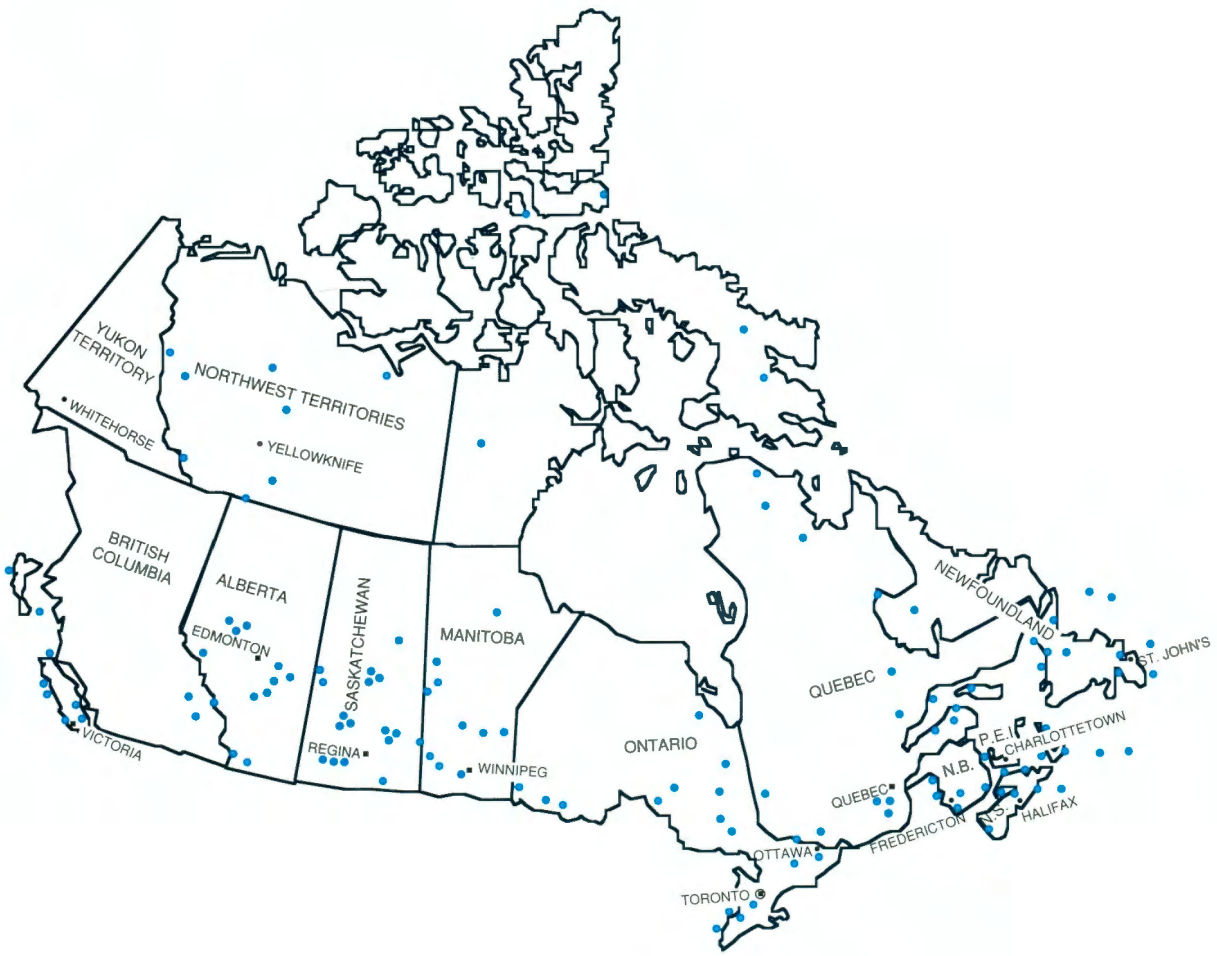
Image Analysis

In the image analysis domain, the development effort concentrates on the provision of SAR-specific analysis techniques as well as software and hardware tools. Areas of active research and development include, for example, geometric correction of SAR data; definition of appropriate image analysis procedures such as segmentation, filtering and calibration techniques; software packages for simulating RADARSAT type data using high-resolution airborne SAR data as input. The RDDP fosters the development of SAR workstations that are capable of handling these tasks. These workstations will facilitate the process of information extraction from SAR data and its integration with information from other sources.

Working toward the RADARSAT Era

Many RDDP investigations focus on the usefulness of RADARSAT design parameters for applications in environmental monitoring and natural resource analysis. RADARSAT will be equipped with a C-band SAR with HH polarization and flexible imaging geometries with incidence angles ranging from 20° to 50°. Studies are also carried out to examine the advantages and constraints of other SAR satellite systems.

RDDP Data Acquisition 1987-1992



RDDP

APPLICATIONS DEVELOPMENT

Disciplines and Common Goals

At the core of the RDDP and the RADARSAT Program is the use of SAR data for applications in natural resource management and environmental monitoring. Several promising application areas, broadly defined as sea ice, oceans, geology, agriculture and forestry, have evolved from previous research and development efforts. The common goal is to develop a user community that has a good knowledge and understanding of the procedures as well as the infrastructure to support the operational use of SAR data.

SAR Capabilities, Information Requirements

In order to maximize the usefulness of remote sensing to the end user, developers of applications are encouraged to evaluate SAR data in combination with existing sources of information, such as field data. Other remote sensing data may be used as well, for instance airphotos, Landsat Thematic Mapper, SPOT HRV or NOAA AVHRR imagery obtained in the visible and infra-red portions of the electromagnetic spectrum.

Coordination at CCRS

Coordination of the applications development effort plays a vital role given the limited resources of the RDDP. CCRS identifies major areas of research and provides the necessary infrastructure. RDDP projects in each of the application disciplines are carried out in a cooperative fashion in order to involve potential end users of SAR data more directly in the development process. Many of the applications development projects are of national scope.

Cooperation with Provincial Governments

The Technology Enhancement Program (TEP) at CCRS has put considerable effort into developing potential users of radar remote sensing data within the provinces. The TEP activities concentrate on training and education initiatives and demonstration projects. Within the framework of federal-provincial Memoranda of Understanding, provincial/territorial partners can rely on a limited amount of SAR data and extensive technical assistance in project planning and execution.

Cooperation with Private Sector Companies

The RDDP is seeking partnerships between industry and government. The private sector is involved in product delivery, for example RADARSAT imagery in the case of RSI, and the provision of value-added services when investment in a particular area of radar remote sensing technology becomes economically viable.

Cooperation with Educational Institutions

Universities and other post-secondary education institutions are participating in the RDDP by conducting cooperative research and development projects and by assisting in the evaluation of others. Through their remote sensing curriculum activities, they advance the education and training of students whose expertise as professionals and technicians will be a valuable future asset in the development of Canadian radar remote sensing capabilities. Teaching and training materials have been prepared by the RDDP through the CCRS Technology Enhancement Program.

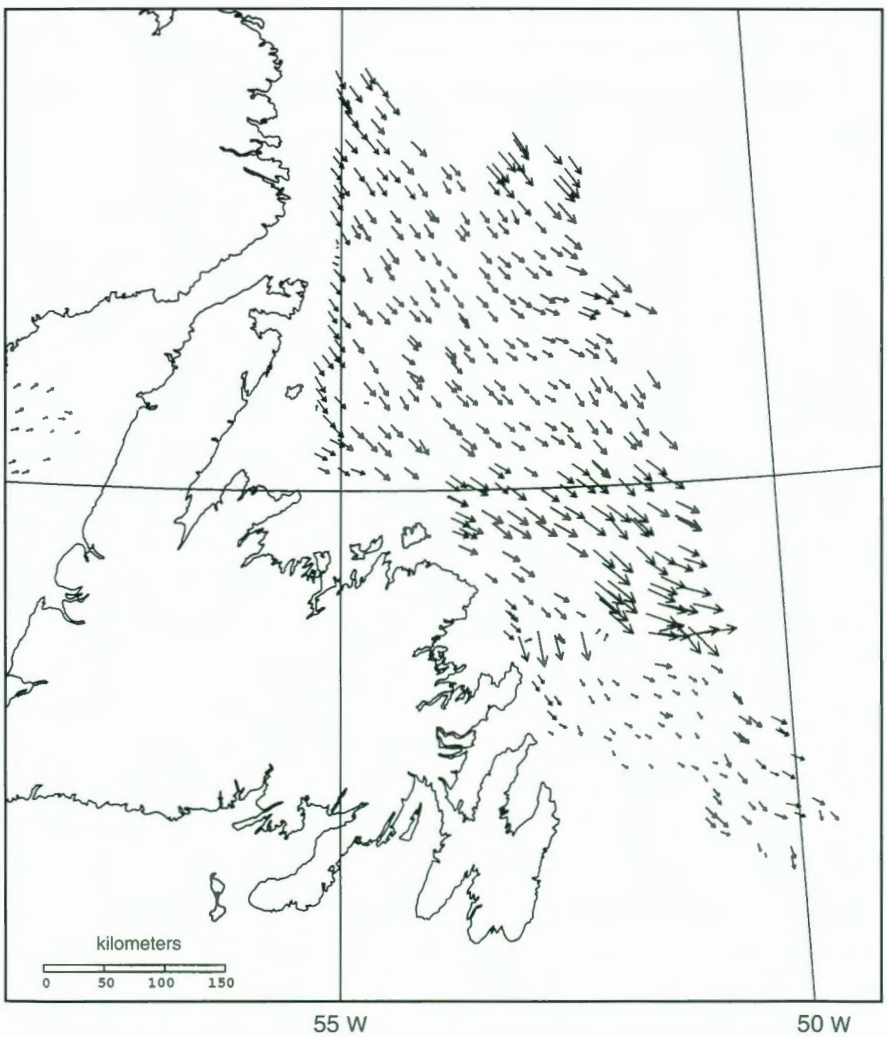
Sea Ice

Potential Applications

One of the prime reasons for developing radar remote sensing capabilities in Canada has been the ability of SAR to provide reliable reconnaissance and surveillance data of sea ice conditions in Canadian waters, particularly during periods of unfavourable weather conditions and darkness.

Goals and Achievements

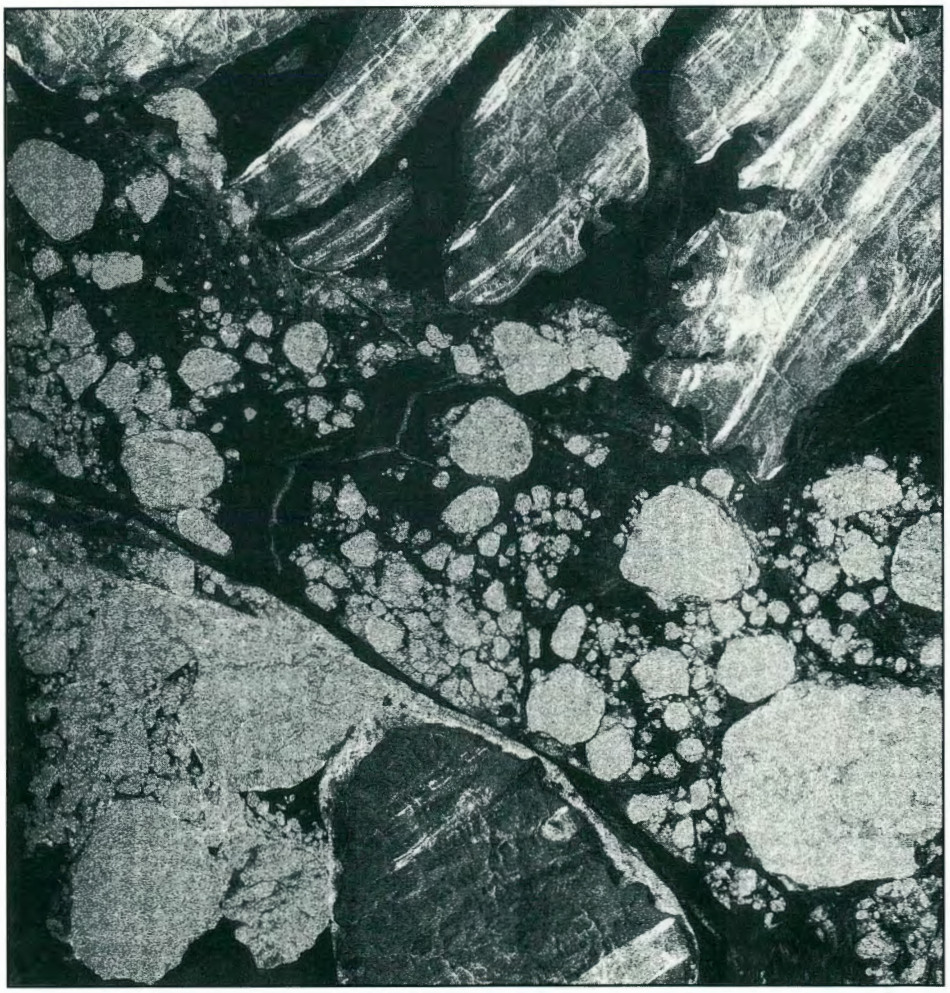
Compared to other radar remote sensing applications investigated under the RDDP, the sea ice applications development effort continues to be the most advanced in terms of its actual progress toward operational use and integration in existing data and information distribution systems. The work is focused on three main goals: preparation of ice forecast charts by Environment Canada's Ice Centre; tactical ice reconnaissance for ship navigation in ice infested waters; and delivery of value-added ice information products to end users, such as offshore operators.



Example of a sea ice motion map product derived from sequential remotely sensed data of sea ice in the Labrador Sea off Newfoundland. Vectors represent direction and velocity of ice movement within a 16 hour period on February 24 and 25, 1992. SAR imagery will be used on a routine basis for input into ice tracking algorithms.

Program Activities

Current objectives and project activities include: implementation of an operational ice motion algorithm for automated tracking of ice between time-sequential images; development and demonstration of techniques for integrating optical, active (SAR) and passive microwave data for deriving ice information; development and implementation of rapid, standardized image products and enhancements suitable for electronic delivery to the user; development and implementation of an ice classification algorithm for the automated identification of ice types from radar and other imagery. Private industry is developing 'niche' markets for standardized, reliable, and timely ice information products derived from RADARSAT imagery.



ERS-1 SAR (C-VV) image of sea ice conditions on May 15, 1992 in the Byam Martin Channel between Bathurst Island and Melville Island, NWT. The image clearly shows the location and extent of sea ice and ice type. The rounded multi-year ice flows provide high radar backscatter mainly because of their porous structure. The surrounding first-year ice appears dark because of its high salinity and smooth surface. (Copyright ESA)

Oceans and Coastal Regions

Potential Applications

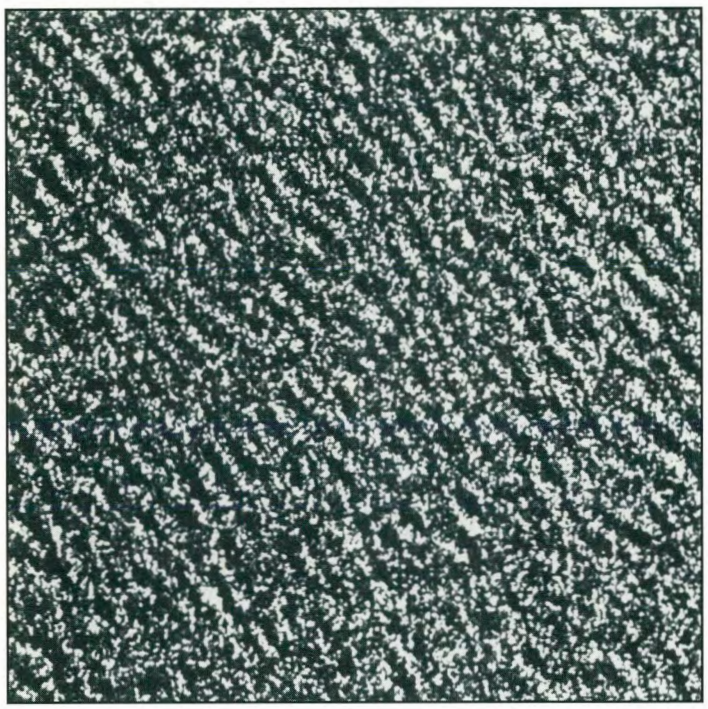
Canada has the longest coastline of the world bordering on the Pacific, Atlantic and Arctic Oceans. Canadian sovereignty extends over a 200-nautical mile economic zone representing an area equal to roughly half that of the country's landmass. Radar remote sensing is a potentially useful tool for environmental monitoring of these extensive areas, and for managing ocean and coastal resources, because of frequent cloud cover, fog, and storms. Much of the work under the RDDP to date has been accomplished using CCRS Airborne C/X SAR data for testing optimum sensor configurations for oceans applications.

Achievements

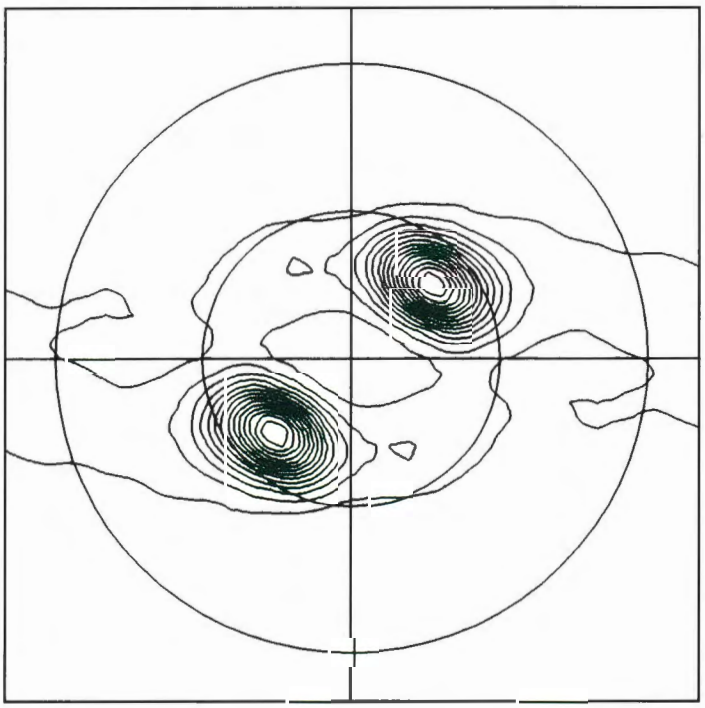
A major milestone includes the development of an ocean wave spectra algorithm in cooperation with Fisheries and Oceans and private industry. The algorithm will be incorporated into an operational wave forecast model of Environment Canada's Atmospheric Environment Service.

Program Activities

SAR application development work concentrates on physical oceanography and involves the extraction of wave spectra from SAR images, and the identification of current patterns and mesoscale features. Several environmental studies are pursued with a focus on aquaculture site monitoring; identification of breaking waves; and identification of coastal zone features that are of interest to coastal engineering and for conducting oil spill contingency planning exercises.



ERS-1 SAR image (left) of ocean waves, Grand Banks, off Newfoundland, acquired in November 1991. This subscene of 512-by-512 pixels is part of a georeferenced fine-resolution product with a nominal resolution of approximately 30 meters. Note that the ocean swell is evident in the absence of wind driven waves. (Copyright ESA)



The spectrum of wavelengths in this ERS-1 image is shown as a function of their direction. The azimuth direction is plotted from top to bottom; the range direction is plotted from left to right. The circles on the spectrum represent 100 meter (outer) and 200 meter (inner) wavelengths, respectively, indicating that the wavelength of the dominant swell is more than 200 meters. The data cannot be interpreted in terms of wave height. (Copyright ESA)

Forestry

Potential Applications

The primary goal is to improve the management of forests through the application of microwave remote sensing technology. The most pressing need for timely information is in the area of clearcut mapping and delineation of areas damaged by forest fires. Most provincial forestry agencies desire yearly updating of their entire inventories. Additional information on stand species composition, mean tree diameter, and stand biomass appear feasible with a dual-frequency polarimetric SAR which may be carried by future satellites.

Development of Change Detection Techniques

Certain applications, particularly clearcut and burn mapping, were found to be more difficult than originally expected. Recent quantitative investigations using change detection techniques in conjunction with multi-seasonal C-HH data have indicated that winter is the best season for detecting clearcuts. Multi-seasonal C-HH data have been shown capable of providing information on broad forest cover classes; conversely, forest regeneration studies were not very encouraging because of the level of detail required from regeneration surveys.

Program Activities

The following activities are carried out in support of the clearcut mapping application: evaluation of clearcut mapping accuracy; recommendations for geocorrection; assistance in the development of operational GIS software for updating digital forest inventories with SAR data; and an assessment of the information content of polarimetric SAR data for determining forest stand characteristics.

Tropical Forest Initiative

The RDDP contributed to the successful execution of the Tropical Forest Initiative. Imagery from an airborne SAR campaign to Latin America will be used to assess C-HH SAR data for many different applications in tropical forest environments and to train potential users of SAR data.

A

B

Multi-temporal airborne C-band SAR imagery of clearcut logging sites in a boreal forest near Whitecourt, Alberta, acquired during the winter of 1991 (A) and 1992 (B). Logged areas provide little radar backscatter under snow cover conditions and appear in dark tone. The colour composite imagery (1991 = red, 1992 = green/blue), clearly indicates areas of clearcutting activities between the two dates in red while the edges of the clear cuts facing the radar appear in bluish/greenish colour.

Geology / Non-renewable Resources

Potential Applications

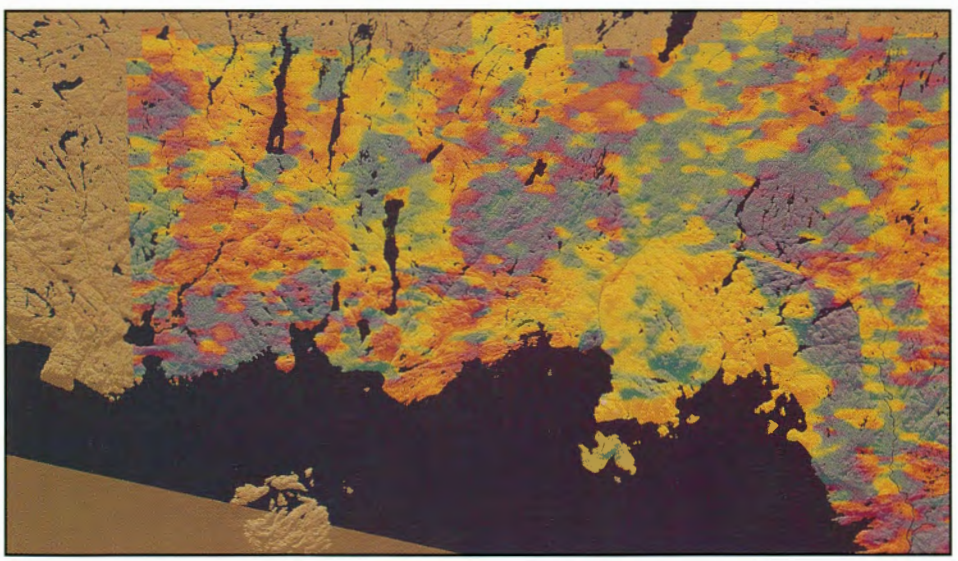
Since 1987, the RDDP has provided SAR imagery for 50 test sites across Canada. The radar data have been used for improving lithological, structural and lineament maps, exploration for base metals, precious metals and for industrial minerals as well as for oil and gas deposits. The data have also been used for geobotanical studies and the analysis of quaternary landforms, recent seismic disturbances and meteorite impact craters. Investigations have included the effects of look direction and view angle on radar image interpretability, reducing speckle in SAR images, while others have developed algorithms to combine radar with geological and geophysical datasets, models of mineral deposits as well as digital techniques for analyzing lineaments.

Storefront Office

In 1991, the Geological Survey of Canada (GSC) and the RDDP installed a remote sensing laboratory at the GSC. It is equipped with an image analysis system providing access to and information about SAR and other remotely sensed datasets. Basic training in the use of digital image analysis techniques is offered for cooperative geological studies.

Program Activities

Activities are designed to reach geologists across Canada who are interested in using remotely sensed data. More than 70 geologists have been, or are currently involved in the analysis of radar data. Participation in international radar satellite experiments will prepare Canadian geologists for the launch of RADARSAT in 1995. For instance, Canadian geologists participated in the Shuttle Imaging Radar (SIR-A and SIR-B) and the SEASAT experiments. They will also evaluate imagery from the ERS-1 satellite using a test site at Sudbury, Ontario. Experiments using JERS-1 imagery over test sites in western Canada are also planned.



Intensity-Hue-Saturation (IHS) image combining airborne SAR and gamma-ray spectrometer data of the Coldwell Complex, Hemlo-Marathon area on Lake Superior, Ontario. SAR data have been used to enhance terrain and structural features by modulating image intensity, while the uranium, thorium and potassium radiometric anomalies provide the hue information (eU = red, eTh = green, K% = blue). (Source: gamma-ray data produced by the Geological Survey of Canada)

Hydrology

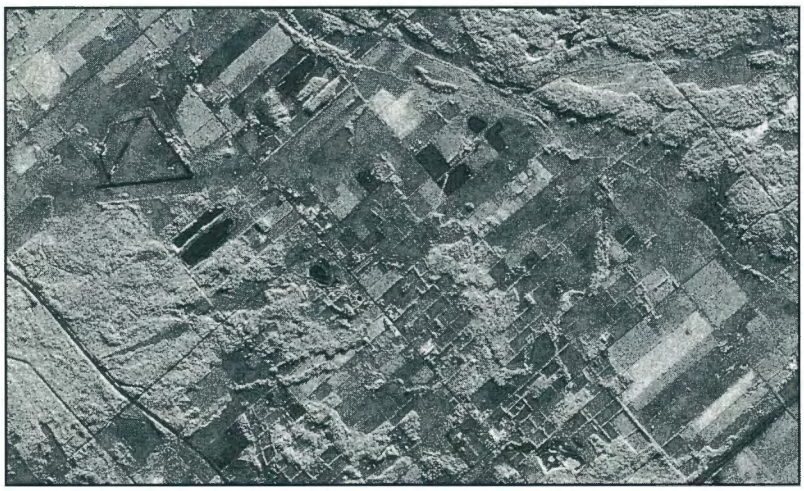
Potential Applications

SAR application development work has been carried out with two main objectives in mind. The first objective is the development of methodologies and techniques for measuring, monitoring and mapping soil moisture, snow cover and snow water equivalent, river ice dynamics, flood extent and flood damage, and wetlands. The second objective is the development of techniques to assimilate remotely sensed data into hydrological models for runoff forecast.

Program Activities

The use of radar for flood mapping, and the use of distributed hydrological models should be operational within a few years. Areas such as snow hydrology and soil moisture still require considerable research before the application potential for operational use of SAR in those areas can be realized.

A



B

Airborne SAR subscenes (C-HH) of a test area near Carp, Ontario, acquired within several hours before (A) and during (B) a rainfall event. Note the sensitivity of radar to moisture differences. SAR data acquired during rainfall reveal a pronounced increase of backscatter intensity and hence brighter image tone compared to the data set acquired under relatively dry conditions.

Agriculture

Potential Applications

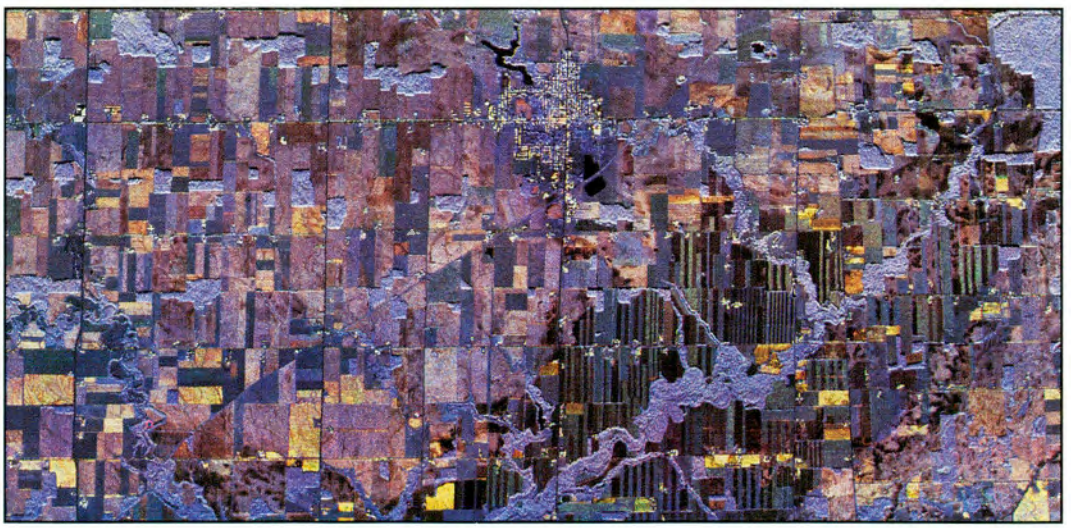
Interest in the use of SAR for applications in agriculture arises from the requirement for data timeliness with regard to crop discrimination and analysis of soil criteria.

Program Activities

Activities in these areas include the determination of crop area, type and condition by means of SAR. The integration of analysis results into an existing Canadian crop information system is a field of active research. Techniques are being developed to use SAR for determining soil moisture as well as the presence of saline soils, and in soil conservation practices. Studies have been performed to assess changes in radar backscatter of various crop types as a function of time of day; this may play an important role in the interpretation of RADARSAT imagery which will be acquired at dawn and/or dusk. Investigations are also underway with respect to rangeland monitoring and identification of bird nesting habitat.

Program Components

Several data sources are available. A ground-based K_u-, C- and L-band scatterometer is used to develop the quantitative relationships between the radar backscatter and agricultural target parameters. The airborne program extends the analysis of scatterometer data to larger areas. ERS-1 and JERS-1 satellite SAR data are used in order to determine the validity of the airborne SAR analysis results.



Colour composite of airborne SAR imagery of an agricultural area in Oxford County, Ontario. The data were acquired at different C-band polarizations, i.e. C-HH (blue), C-HV (red) and C-VV (green), all of which are candidate SAR parameters for follow-on RADARSAT satellites. Field crops include wheat, alfalfa, corn, cut hay, and pasture on sandy soils (right) and heavier clay soils (left).

Cooperative Agreements & Supporting Programs

Involvement in the ERS-1 and JERS-1 Programs

In 1991, the European Space Agency (ESA) launched its first experimental radar Earth observation satellite, ERS-1. ERS-1 carries three principal instruments: an active microwave instrument with SAR imaging capabilities; an altimeter; and a radiometer. The C-band (C-VV) SAR is capable of producing high-resolution (approx. 30m by 30m) imagery along its 100 km wide swath. The viewing geometry of the sensor is restricted to small incidence angles (23 at mid swath) which is suitable primarily for ice and oceans related applications. The Canadian Government contributed to the design, construction and operational phases of the ERS-1 project and built data reception and processing facilities to meet Canadian needs.

Similar arrangements for using JERS-1 SAR data have been in place between CCRS and the National Space Development Agency of Japan since the launch of that satellite in 1992. The experimental JERS-1 SAR is primarily aimed at applications involving terrain analysis.

Canadian reception and processing capabilities for both the ERS-1 and JERS-1 SAR data present excellent opportunities for applications development prior to the launch of Canada's own RADARSAT in 1995.

Announcements of Opportunity

Participants in the RDDP can access ERS-1 and JERS-1 SAR data following an announcement of opportunity issued by CCRS. Emphasis is on effective data utilization in application areas that are of interest to commercial and operational users. Qualified investigators are provided with reasonable amounts of imagery at no charge for their applications development projects.

An announcement of opportunity is expected to be issued before the launch of RADARSAT. This announcement will have three facets, including international science, domestic requirements and commercial applications.

Looking Ahead - The RDDP in the 1990s

New emphasis and Requirements

Over the next few years, the RDDP will emphasize cooperative pilot and demonstration projects with limited support to science components. Significant participation is required from the user community and other government departments to identify and achieve specific project objectives. The Program will concentrate on the utilization of ERS-1 SAR imagery for applications development and encourage the use of existing data sets. The CCRS airborne C/X SAR system will be used for research projects requiring its frequency and polarization diversity. The RDDP will foster the development of complementary data sets which include the integration of SAR, and other remotely sensed data. Sample data sets, documentation, and training materials will be prepared in order to communicate recent achievements to the user community at large.

RDDP Unsolicited Proposal Fund

Since 1992, the RDDP includes an industrial development component in the form of an unsolicited proposal fund of more than $400,000 per year. The objective is to strengthen the development of commercial products and services provided by the private sector in Canada, and to assist provincial agencies in the development of their capability to utilize SAR data in their operations.

Conclusion

There are many practical issues facing the development of potential applications for the Canadian RADARSAT. Through continuing research at CCRS and cooperative efforts with industry, other government agencies, and educational institutions, the effective utilization of SAR data for environmental monitoring and natural resource analysis will expand, taking strength from the Radar Data Development Program.

List of Acronyms

AO	Announcement of Opportunity
CCRS	Canada Centre for Remote Sensing
CSA	Canadian Space Agency
EMR	Energy, Mines and Resources Canada
ERS-1	European Remote Sensing Satellite
ESA	European Space Agency
GIS	Geographic Information System
GSC	Geological Survey of Canada
JERS-1	Japanese Earth Resources Satellite
RDDP	Radar Data Development Program
RSI	Radarsat International Inc.
SAR	Synthetic Aperture Radar
SIR	Shuttle Imaging Radar
SMRSS	Surveys, Mapping and Remote Sensing Sector, EMR
RESORS	Remote Sensing On-line Retrieval Service
TEP	Technology Enhancement Program at CCRS

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Image Credits

Airborne radar imagery were acquired under the Radar Data Development Program (RDDP) by the CCRS airborne C/X SAR system. Copyright for ERS-1 SAR imagery resides with the European Space Agency (ESA).

Further Information

Further information on the Radar Data Development Program (RDDP) may be obtained from the Major Projects Office, Canada Centre for Remote Sensing / EMR Canada, 588 Booth Street, 4th Floor, Ottawa, Canada K1A 0Y7, Fax.: 1 (613) 947-1383

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ERS-1 SAR image/enlargement, Alberta-Montana border / (Copyright ESA, courtesy RSI)

Canada