RADARSAT

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Compiled By Kevin Rokosh - IEEE

Introduction to RADARSAT

RADARSAT is an advanced Earth observation satellite system developed by Canada to monitor environmental change and to support resource sustainability.

With the launch of RADARSAT-1 in November 1995, Canada and the world have access to the first fully operational civilian radar satellite system capable of large scale production and timely delivery of data. The data from the satellite meets the needs of commercial, government and scientific programs and provides a new and reliable source of high quality radar data.

The RADARSAT program, led by the Canadian Space Agency (CSA), builds on the history of achievement in remote sensing by the Canada Centre for Remote Sensing (CCRS), Natural Resources Canada. With its creation in 1989, CSA took over the implementation and operation of the RADARSAT project as a key component of the Canadian space program. CCRS continues to participate in the RADARSAT program by operating Canada's two RADARSAT ground receiving stations located in Prince Albert, Saskatchewan and Gatineau, Québec, and conducting applications research.

The RADARSAT program is supported by strong industry, provincial government and international partnerships. Under the aegis of CSA, Canada is responsible for the design and integration of the overall system, its control and operation in orbit, the operation of data reception and processing stations in Canada, and the distribution of data from the satellite.

All Canadian provinces participated in planning the RADARSAT program. Approximately 100 Canadian and international organizations were involved in the design and construction of the space and ground segments. The U.S. National Aeronautics and Space Administration (NASA) launched RADARSAT in exchange for the right of access to the satellite on a pro rata basis.

The RADARSAT program demonstrates CSA's commitment to generate economic benefits for Canadians. Spin-offs associated with the development and operation of RADARSAT-1 are expected to create 10,000 person years of employment in Canada, and to provide upwards of C$800 million in benefits to the Canadian private and public sectors.

RADARSAT Background

Introduction

RADARSAT is a sophisticated Earth observation (EO) satellite developed by Canada to monitor environmental change and the planet's natural resources. Launched in November1995, RADARSAT provides Canada and the world with an operational radar satellite system capable of timely delivery of large amounts of data. RADARSAT also provides useful information to both commercial and scientific users in the fields of agriculture, cartography, hydrology, forestry, oceanography, ice studies and coastal monitoring.

Background

The RADARSAT system was developed under the management of the Canadian Space Agency (CSA) in cooperation with provincial governments and the private sector. Industrial team members who designed and built RADARSAT-1 include Spar Aerospace (prime contractor), MacDonald Dettwiler & Associates, SED Systems, CAL Corporation, COM DEV, Fleet Industries, IMP and FRE Composites. Under an agreement signed in February 1991, the National Aeronautics and Space Administration (NASA) launched RADARSAT-1, on a Delta II rocket, in exchange for access to data. Total cost of the project, excluding launch, is estimated at $620 million, with the federal government contributing about $500 million, the four participating provinces (Québec, Ontario, Saskatchewan and British Columbia) about $57 million, and the private sector about $63 million.

Why RADARSAT?

Optical satellite remote sensing depends on sunlight illuminating the Earth in order to obtain useful imagery. Its performance is restricted by the presence of clouds, fog, smoke or darkness. However,

RADARSAT does not have these limitations. At the heart of RADARSAT is an advanced radar sensor called Synthetic Aperture Radar (SAR). SAR is a microwave instrument that sends pulsed signals to Earth and processes the received reflected pulses. RADARSAT 's SAR-based technology provides its own microwave illumination and thus operates day or night, regardless of weather conditions.

Data Acquisition

RADARSAT-1 circles the Earth at an altitude of 798 kilometres at an inclination of 98.6 degrees to the equatorial plane. Because RADARSAT has a sun-synchronous (dawn-dusk) orbit, its solar arrays are in almost continuous sunlight, enabling it to primarily rely on solar rather than battery power. The sun-synchronous orbit also means that the satellite overpasses are always at the same local mean time, which is important to many users. RADARSAT-1 offers users a wide variety of beam selections. The satellite's SAR has the unique ability to shape and steer its beam from an incidence angle of 10 to 60 degrees, in swaths of 45 to 500 kilometres in width, with resolutions ranging from 8 to 100 metres.RADARSAT-1 covers the Arctic daily and most of Canada every three days, depending on the swath selected. Data is downlinked in real time or stored on the onboard tape recorder until the spacecraft is within range of a receiving station.

Data Management

RADARSAT data is received in Canada at the ground stations operated by the Canada Centre for Remote Sensing, Natural Resources Canada. These are located in Prince Albert, Saskatchewan and Gatineau, Québec. Additional data reception capabilities are provided through an international network of receiving stations. Data can be made available to users within four hours after it has been acquired. RADARSAT International (RSI), a private Canadian company, was established in 1989 to process, market and distribute RADARSAT-1 data. RSI pays royalties to CSA on the commercial sales of RADARSAT-1 data, which are used to support satellite operations during its five-year lifetime. RSI also manages the Canadian Data Processing Facility in Gatineau, Québec and promotes the development of commercial data applications.

Benefits and Applications of RADARSAT

RADARSAT is keeping Canada on the forefront of Earth observation satellite technology and setting new standards for the remote sensing industry. It is also creating significant social and economic benefits contributing to Canada's prosperity. Spin-offs associated with the development and operation of RADARSAT-1 are estimated at 10,000 person-years over 10 years of employment in Canada and up to $800 million in new revenues to the Canadian private and public sectors. As the world's first fully operational civilian SAR Earth observation satellite, RADARSAT is an important and reliable source of environmental and resource information. For example, RADARSAT is providing the first routine surveillance of the entire Arctic region, offering daily coverage regardless of weather conditions. This information is useful to shipping companies in North America, Europe and Asia, and to government agencies with ice reconnaissance and mapping mandates. SAR is also a valuable tool for mapping the Earth's structural features such as faults, folds and lineaments. These features provide clues to the distribution of ground water, mineral deposits and oil and gas in the Earth's crust. In addition, RADARSAT can facilitate the mapping and planning of land use and monitor disasters such as oil spills, floods and earthquakes. The use of satellite remote sensing technology is growing both in Canada and abroad, driven by the need to better monitor the environment and the availability of more affordable information integration systems, including Geographic Information Systems (GIS). Major natural resource industries such as mining, fishing, farming and forestry can be better managed if monitored effectively and accurately. RADARSAT is helping to fulfil that need by providing high quality radar data in a timely manner.

Canada's Leadership in Satellite Technology

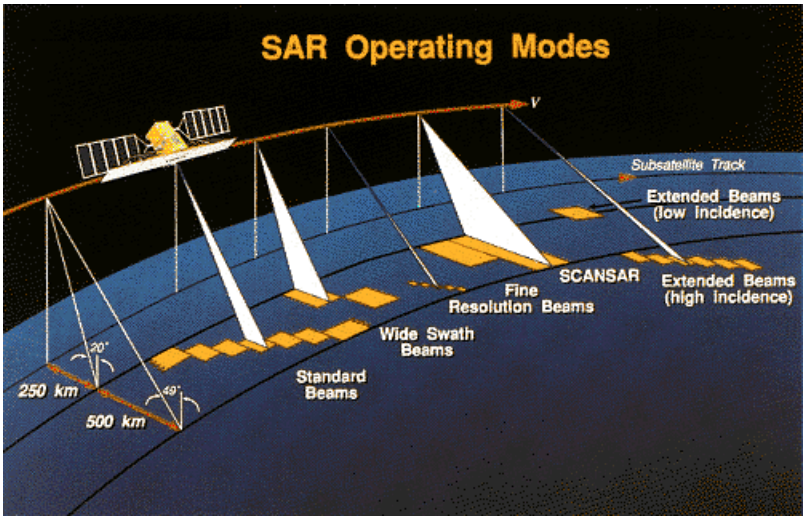
Canada has a long and impressive history in space. Being the second largest country in the world, with a variety of landscapes and climatic conditions, Canada recognized the practical and economic benefits of using space for Earth observation early on. RADARSAT enhances Canada's global remote sensing competitiveness and provides Canada and other countries with new and valuable data on an operational basis. Canada's experience in SAR technology builds on achievements in airborne SAR sensor

development, participation in NASA's SEASAT project, and its collaboration with the European Space Agency in designing the ERS series of SAR satellites.

Description of RADARSAT

RADARSAT-1, with a planned lifetime of five years, is equipped with an advanced radar sensor called a Synthetic Aperture Radar (SAR). The SAR is a powerful microwave instrument that transmits and receives signals to "see" through clouds, haze, smoke, and darkness, and obtains high quality images of the Earth in all weather, day or night. This provides significant advantages in viewing the Earth under conditions that preclude observation by aircraft or optical satellites.

Using a single frequency, CBand, the RADARSAT SAR has the unique ability to shape and steer its radar beam over a 500-kilometre range. Users have access to a wide variety of beam selections that can image swaths from 45 to 500 kilometres in width, with resolutions from 8 to 100 metres and at incidence angles from 10 to 60 degrees.



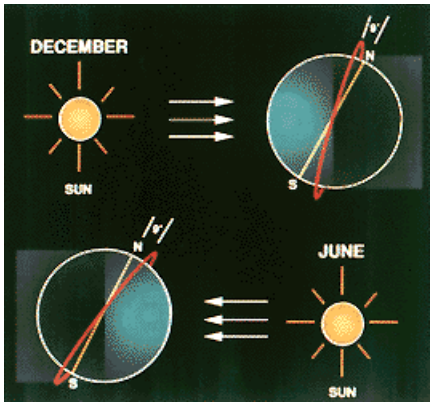
RADARSAT Imaging Modes

RADARSAT provides complete global coverage with the flexibility to support specific requirements. Although the satellite's orbit path is repeated every 24 days, RADARSAT can provide daily coverage of the Arctic, view any part of Canada within three days, and achieve complete coverage at equatorial latitudes every six days using the 500-kilometre wide swath.

RADARSAT uses a sun-synchronous polar orbit. This dawn-dusk orbit places the satellite's solar arrays in almost continuous sunlight, which ensures that the RADARSAT SAR primarily relies on solar rather than battery power, providing users with the optimum number of viewing opportunities.

This orbit also ensures users can revisit a scene at the same local time and minimizes conflict in downlinking data to ground stations; most remote sensing satellites use a midday orbit.

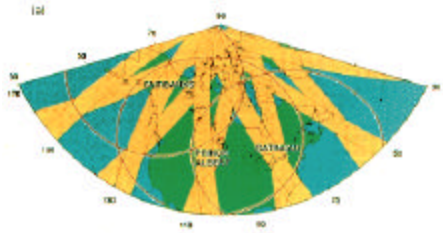
RADARSAT orbits the Earth at an altitude of 798 kilometres with an inclination of 98.6 degrees. The satellite circles the Earth 14 times a day, and each orbit takes 100.7 minutes to complete.



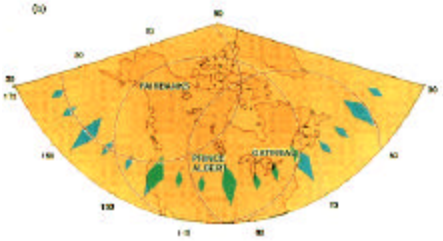
Dawn-Dusk Orbit. The orbit is sun-synchronous which means that satellite over-passes are always at the same local time. This is particularly important in obtaining multi-temporal data sets used for crop prediction, minimizing the influence of effects due to diurnal variations. The descending equatorial crossing is at 06:00, which is a dawn-dusk orbit. This means that the satellite is rarely in eclipse and can acquire data at any time

The RADARSAT SAR can acquire up to 28 minutes of data per 101 minute orbit. Data is downlinked in real time to ground receiving stations or stored on the onboard tape recorder until RADARSAT is within

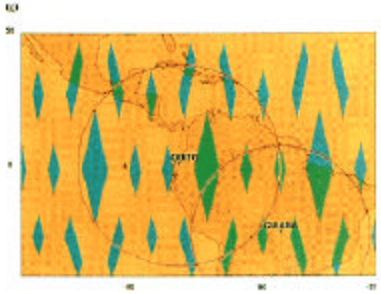
range of a receiving station. To satisfy mission-critical requirements, data can be processed and delivered in less than four hours after it has been acquired.



Typical coverage available from RADARSAT using the 500-kilometre wide swath:
(a) North America, one-day coverage;



(b) North America, three-day coverage;



(c) Amazonia, an example of equatorial coverage for three days.

In all cases, available image data is shown as yellow.

Data Acquisition

Using a single frequency, C-Band, RADARSAT's SAR has the unique ability to steer its radar beam over a 500-kilometre swath. Users have access to a variety of beam modes and positions; swath widths range from 45 to 500 kilometres with resolutions from 8 to 100 metres at incidence angles from 10 to 60 degrees.

RADARSAT provides complete global coverage with the flexibility to support specific observation requirements. Although the satellite's orbit path is repeated every 24 days, most regions on the Earth can be visited more frequently. Using the 500-kilometre wide swath, RADARSAT provides daily coverage of the Arctic, views any part of Canada within three days, and achieves complete coverage at equatorial latitudes in less than five days.

RADARSAT's SAR can acquire up to 32 minutes of data per 101-minute orbit. Data is downlinked in real time or stored on the onboard recorder until the spacecraft is within range of a receiving station. The tape recorder can store up to 10 minutes of SAR data. To satisfy user requirements for timely data, RADARSAT's processing system can deliver data to users within four hours of scene acquisition.

RADARSAT Network Stations

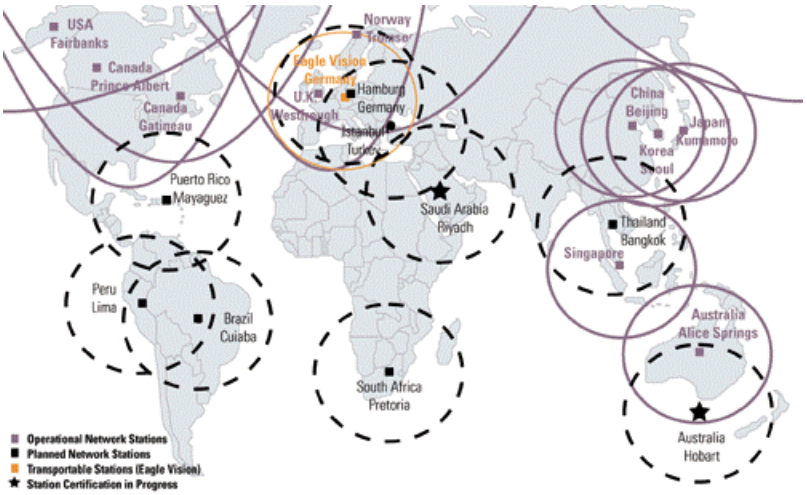
Canada

A new wide area network installed by CCRS in 1998 now transfers low resolution RADARSAT imagery from the two RADARSAT receiving stations located in Gatineau, Québec and Prince Albert, Saskatchewan to Ottawa, Ontario where it is placed on a web-accessible browse and catalogue service. In addition, CCRS has implemented a new RADARSAT raw data archive system.

International

In 1998, network stations in Australia and Japan achieved both operations and product certification; South Korea and Saudi Arabia achieved operations certification. Combined with stations in Canada and the United States, the RADARSAT network stations, which also include already operational stations in China, Norway, Singapore, and the United Kingdom, provide coverage of virtually all of the Earth's landmass.

New coverage opportunities are emerging with the advent of transportable ground stations. Canada's SENTRY system, developed by IOSAT Inc., and the Eagle Vision system in the Unitede States are demonstrating the capability of portable stations to receive and process RADARSAT data. In 1998, SENTRY was successfullly deployed in an operational demonstration during Exercise MARCO/UNIFIED SPIRIT '98, which took place in Nova Scotia, Canada. MARCO is Canada's largest annual joint military training exercise, and as UNIFIED SPIRIT '98, one of the premier annual training events for NATO.



Network station visibility mask provided by RADARSAT International

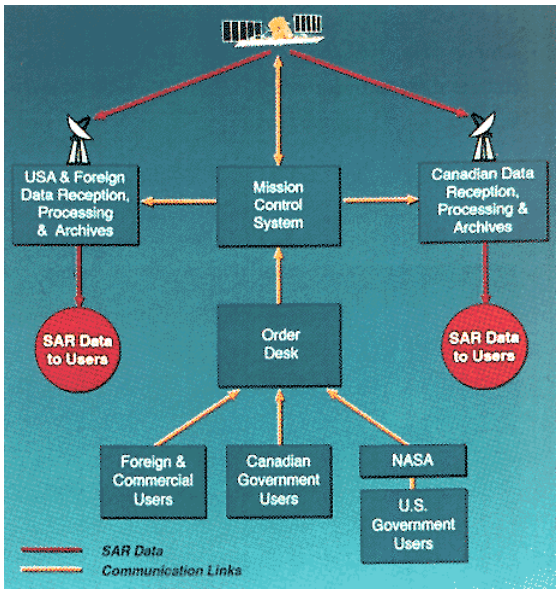
The use of the portable station gave Canadian defence personnnel experience with real time delivery, processing and interpretation of RADARSAT-based surveillance data. As noted by D.E. Miller, Rear-Admiral, Commander, Maritime Forces Atlantic, Department of National Defence, "During Exercise MARCO 1/98, MARLANT was able to make use of RADARSAT imagery processed through the technology, the talented individuals operating the systems, and the results obtained."

Combined, the RADARSAT network stations now provide coverage for nearly all of the Earth's landmass.

RADARSAT Data Handling and Distribution

RADARSAT data is downlinked in real time to compatible ground stations or stored, when required, on the satellite's onboard tape recorder. In North America, data is downlinked to receiving stations in Prince Albert, Saskatchewan, Gatineau, Québec, and Fairbanks, Alaska. In addition, network stations in the United Kingdom, Norway, Singapore, China, Australia, South Korea, Japan, and Saudi Arabia receive RADARSAT-1 data. Combined, the coverage masks of these stations cover nearly all of the Earth's landmass.

A Canadian private company, RADARSAT International, Inc. (RSI), was formed in 1989 to process, market and distribute RADARSAT-1 data. RSI also conducts research and supports the development of commercial applications, manages the Canadian Data Processing Facility, and negotiates, in cooperation with CSA, international reception and distribution agreements for RADARSAT-1 data. RSI pays royalties to CSA on the commercial sales of RADARSAT-1 data. To date, approximately 500 commercial clients in 52 countries are using



Mission concept

RADARSAT data.

RADARSAT Specifications

Overview on RADARSAT

RADARSAT-1 is a Canadian-led project involving the Canadian federal government, the Canadian provinces, the United States, and the private sector. This sophisticated remote sensing satellite was launched in November 1995. RADARSAT-1 carries a Synthetic Aperture Radar (SAR), a powerful microwave instrument that can transmit and receive signals to "see" through clouds and darkness, obtaining detailed images of the Earth. It is used to monitor the Earth's resources and environmental change, and support commercial industries such as fishing, shipping, agriculture, and oil and gas exploration. The development and operation of the RADARSAT-1 system is expected to generate 10,000 person years of employment in Canada and provide more than $1 billion in benefits to the Canadian private and public sectors.

RADARSAT SAR Characteristics

Frequency / Wavelength	5.3GHz/C-band 5.6 cm
RF Bandwidth	11.6, 17.3 or 30.0 Mhz
Transmitter Power (peak)	5 kW
Transmitter Power (average)	300 W
Maximum Data Rate	85 Mb/s (recorded) - 105 Mb/s (R/T)
Antenna Size	15m x 1.5m
Antenna Polarization	HH

Spacecraft Characteristics

Launch mass (total)	2,750 kg
Array power	2.5 kW
Batteries	3 x 48 Ah NiCd
Design Lifetime	5 years

Orbit Characteristics

Altitude	793-821 kilometres
Inclination	98.6 degrees
Period	101 minutes
Ascending node	18:00 hours
Sun-synchronous	14 orbits per day

Coverage Access Using Maximum Swath Width

North of 70 degrees N	Daily
North of 48 degrees N	Every 4 days
The Whole Earth (north of 80 degrees S)	Every 6 days

Imaging Modes

MODE	NOMINAL RESOLUTION (m)	NO. OF POSITIONS / BEAMS	SWATH WIDTH (km)	INCIDENCE ANGLES (degrees)
Fine	8	15	45	37-47
Standard	30	7	100	20-49
Wide	30	3	150	20-45
ScanSAR Narrow	50	2	300	20-49
ScanSAR Wide	100	2	500	20-49
Extended (H)	18-27	3	75	52-58
Extended (L)	30	1	170	10-22

Contact Information

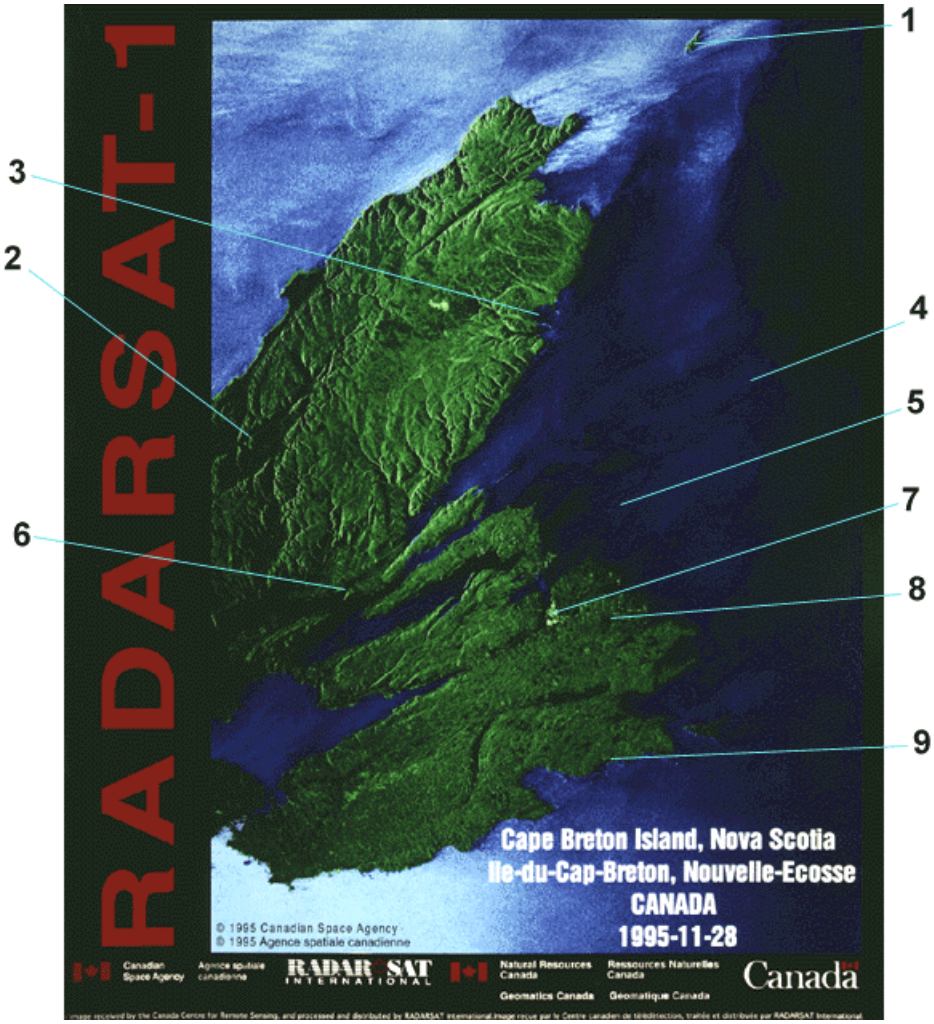
Canadian Space Agency
Satellite Operations Directorate
6767, route de l'Aeroport
Saint-Hubert, (Quebec)
CANADA, J3Y 89Y
FAX: (450) 926-4433

RADARSAT 1 - First Image

Cape Breton Image - Orbit 348 - Standard Beam Mode 1 - November 28, 1995

The image is of a portion of Cape Breton Island, Nova Scotia, Canada, and is centred at latitude N46:27:05 and longitude W 060:18:50. Cape Breton is one of the oldest settled areas in Canada. The Cabot Trail rings the cape and is named after John Cabot, one of the first explorers who arrived in Cape Breton 500 years ago.

Visible are geological and land use patterns as well as wind and current patterns in lakes and the surrounding oceans. Several ships and their wakes are visible as well as the city of Sydney.



1 - St-Paul Island off the tip of Cape Breton

2 - Margaree River and Valley

3 - Ingonish Area

4 - Outbound Ship

5 - Inbound Ship

6 - Baddeck Bay

7 - City of Sydney

8 - Sydney Airport

9 - Historic Fortress of Louisbourg

Cape Breton Island, Nova Scotia, Canada
1995 - 11 - 28

Image Parameters

This image was obtained viewing the island from the west (left side) on the first ascending pass after the payload was turned on. The local incidence angle is 23 degrees measured from the zenith. Each image pixel represents 12.5 by 12.5 metres square. Image resolution is nominally 25 metres. The image is 132 kilometres in range by 127 kilometres in azimuth and was acquired using Standard beam Mode 1. The data was not calibrated.

Weather

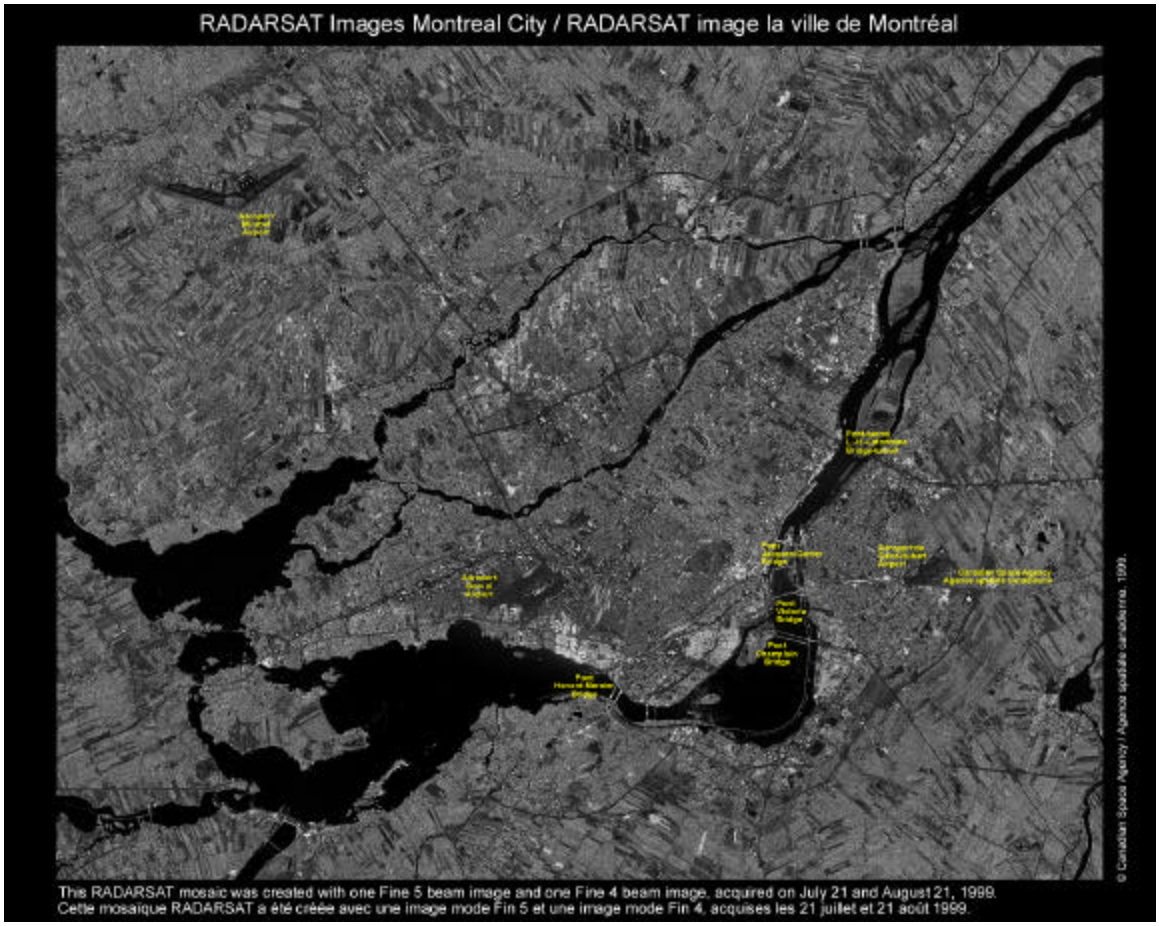
A strong front was passing over the island at the time that the image was obtained (17:41 local time). There is visible evidence of strong winds (14-29 knots) from the southwest, particularly the strong turbulence in the sea to the west of the high hills at the northern tip of the island. Winds are from the south in the eastern and mid-portion of the image. At the time the image was acquired, it was dark and raining in Sydney.

First Image - Colour

This image provides a enhanced coloured view of the Cape Breton Image where the oceans and lakes are in blue tones and the land in green tones. The image was enhanced at CSA by Francois Beaulieu and Salvatore Carboni using our PCI EASI/PACE image analysis system, then printed at Imagetech in Montreal, Quebec, Canada on their FIRE film recorder.

RADARSAT-1 - Featured Image

This RADARSAT-1 image is the new fine beam mosaic of Montreal, with landmarks identified.



RADARSAT Image Products

RADARSAT image products are designed to provide operational and scientific users with a wide range of resolution, format and delivery options. For each RADARSAT beam mode, image products are processed to different levels of geometric accuracy and radiometric calibration. There are seven types of RADARSAT image products: Signal Data, Single Look Complex, Path Image, Path Image Plus, Map Image, Precision Map Image, and Orthorectified.

RADARSAT image products are available on digital media and in hard copy to meet individual user needs. These include CD-ROM, computer compatible tape, data cartridges, film, and print. In addition, image products are increasingly being delivered electronically via the Internet.

Support Programs

The launch of Canada' s first Earth observation satellite, RADARSAT, in 1995 demonstrates this country' s commitment to supporting sustainable resource development through the use of remote sensing. It also confirms the ongoing cooperation between the public sector and private industry in the development and commercial exploitation of this technology.

Approved in 1994, Canada's Long Term Space Plan (LTSP) includes four new Earth observation applications programs designed to foster the use of remote sensing, and in particular RADARSAT. A brief description and contact points for these programs follow. In addition, four other applications and research programs in support of RADARSAT are also described.

RADARSAT User Development Program (RUDP)

As RUDP enters its last year, the program continues to help Canadian companies develop new RADARSAT products and services. Final RUDP contracts are expected to be awarded in spring 1999.

The favourable introduction of two image products helped revenues grow in 1998. Orthoengine RE, developed by PCI Geomatics Group (Richmond Hill, Ontario), produces orthoimages from RADARSAT imagery and corrects for distortions caused by the satellite, earth terrain and curvature, as well as cartographic projection, which are, in turn, used to generate stereo-assisted DEMs. Multi-date RADARSAT imagery is being used by Tecsult Foresterie Inc. (Québec City, Québec) to generate land use maps of cloud-covered tropical areas in Africa.

RUDP projects are stimulating other work for contract winners. Both Dendron Resource Surveys Inc. (Ottawa, Ontario) and R.J. Burnside International Limited (Orangeville, Ontario) started new flood mitigation and infrastructure building work in Honduras as a result of RUDP projects.

A significant program highlight is the development of the IOSAT transportable ground station (SENTRY), which is partially funded by RUDP. In June 1998, SENTRY was successfully utilized for operational maritime surveillance in support of Exercise MARCOT/UNIFIED SPIRIT '98. MARCOT is Canada's largest annual joint military training exercise, and as UNIFIED SPIRIT '98, one of the premier annual training events for NATO.

The use of the portable station gave Canadian military personnel experience with real time delivery, processing and interpretation of RADARSAT-based surveillance data. "During Exercise MARCOT 1/98, MARLANT was able to make use of RADARSAT imagery processed through the IOSAT transportable ground station (SENTRY). I was impressed with the technology, the talented individuals operating the systems, and the results obtained," noted D.E. Miller, Rear-Admiral, Commander, Maritime Forces Atlantic, Department of National Defence.

RUDP Facts (1995 - 1999)

- Total contracts: 32
- Value of contracts: $10 million
- Products and services generated: 21
- Total products and services revenues: $14 million (excl. data sales)
- Leveraged RADARSAT data sales: $3 million (est.)

Contact:

Don Ball (CSA)
Telephone: (450) 926-4471

Earth Observation Pilot Projects Program (EOP3)

EOP3, now in its third year, emphasizes the operational use of Earth observation data, especially from RADARSAT, to improve resource management and environmental protection and to assist the Canadian geomatics industry in promoting their products and services. Because bringing new technology to market (or customizing existing technology for new markets) can be a formidable challenge, EOP3 provides scientific and technical advice, as well as partial funding support for pre-operational pilot projects.

In 1998, EOP3 funded 20 RADARSAT-based projects, supporting applications ranging from topographic mapping in South America to precision farming in Alberta, rice crop monitoring in Vietnam to snow cover measurement in northern Quebec. To ensure a smooth transition from research through development to operational application and user acceptance, EOP3 works closely with other CSA funded programs. For example, the development of the SENTRY transportable station is partially funded by RUDP, and the SENTRY operational demonstration is partially funded by EOP3.

Earth Observation Data Sets Program

Now in its third year, EODS supplies RADARSAT and other Earth observation data to researchers for the development of new algorithms and the extraction of information from image data products. Of the 42 proposals received, 26 are now active projects. Expected contributions for the use of RADARSAT imagery include landscape change detection algorithms, monitoring ice break-up, ship detection algorithms, mapping hidden archaeological sites, algorithms for quantifying coastal zone erosion, and various algorithms for the mapping and delineation of geological structures and mineralization.

Under the EODS Marine Remote Sensing Scholarship program, one scholarship has been awarded for graduate work on the spectral classification of coral biology. As a result of the Entente Canada-Québec in the context of the Action Concertée RADARSAT, six projects at four Québec academic institutions are utilizing RADARSAT data for precision mapping with interferometric techniques, precision geolocation with GPS data, hydrological watershed modelling, urban change mapping, hydrometeorology and wetland dynamics modelling.

User Education and Training Initiative Program (UETI)

The UETI program, now in its third year, has effectively demonstrated the role of remotely sensed data in operational environments. Canadian industry is marketing educational and Earth observation materials and services, developed with co-investment from UETI, and assisting third-party users in developing the required skills to use RADARSAT data. Five UETI projects were completed in 1998, bringing the program's total to 39.

Results from this year include the RADARSAT Distance Learning Program (RDLP), a popular and freely distributed CD-ROM developed by Geomatics International (Burlington, Ontario). It covers basic imaging radar theory and RADARSAT application examples in an easy-to-use format suitable for researchers, educators, and earth and environmental science professionals.

Another highlight was the RADARSAT Lesson Plan for User Education and Training and the Geomatics Education Forum developed by Intermap Technologies Ltd. (Calgary, Alberta). The Lesson Plan introduces RADARSAT to educators and consultants, enabling them to deliver information on the satellite system to students and trainees. The Education Forum addresses the available remote sensing and geomatics resources, the role of industry and others to map future educational needs, centralizing information on the web, and test educator in-service training courses.

A Québec-based company, Groupe Perspective D'Avenir, produced a practical guide (using Canadian examples) for interpreting and integrating remotely sensed data into cartographic applications.

UETI also co-funded the first phase of a CD-ROM training tool for wetland sustainability. Developed by IQ Media (Toronto, Ontario), it will be an interactive, environmental conservation product aimed at international development officers.

GlobeSAR-2 Program

GlobeSAR-2 is developing radar expertise in 11 Latin American countries mainly through RADARSAT applications demonstration projects. Now in its second year, GlobeSAR-2 is sponsored by the Canadian International Development Agency (CIDA), the International Development Research Centre (IDRC), RADARSAT International, PCI Geomatics Group, and Atlantis Scientific, and managed by the Canadian Center for Remote Sensing. By the end of 1998, more than 200 RADARSAT images had been acquired to support GlobeSAR projects.

Preliminary results from the more than 60 demonstration projects were presented at the GlobeSAR-2 Mid-Term Symposium held in Cartagena, Colombia, April 20-24, 1998. Attended by 120 participants, including 13 Canadian geomatics companies, the conference highlighted the technical progress of the projects and the advancement in knowledge of radar and RADARSAT techniques. Full project results will be presented at the GlobeSAR-2 Final Symposium in Buenos Aires, Argentina, May 17-20, 1999.

Application Development and Research Opportunity Program (ADRO)

ADRO is an acronym for RADARSAT's Application Development and Research Opportunity. The program was jointly sponsored by the Governments of Canada and the United States, and the licenced commercial distributor of RADARSAT data, RADARSAT International Inc.

The sponsors selected projects through a competition according to specific criteria that were published in the formal announcement issued in December 1994.

There were four sub-programs within ADRO:

- International Science sub-program which is sponsored by CSA;
- International Science sub-program which is sponsored by NASA;
- Canadian Applications sub-program sponsored by CSA and
- International Demonstration and Product Development sub-program sponsored by RADARSAT International Inc (RSI).

ADRO sponsors sought two types of projects, namely:

1. Those that exhibit innovative scientific research utilizing RADARSAT data.
2. Demonstrations of new radar applications or the development of products for specific applications.

The Canada Centre for Remote Sensing (CCRS) assisted the sponsors in the evaluation of the proposals for the International Science sub program, the Canadian Applications sub-program and the International Demonstration and Product Development sub-program. In addition, CCRS acted as a technical resource to both the ADRO office and the project leaders throughout the program.

Three of the four sub-programs were completed in the fall of 1998 with the results presented at the final symposium in October 1998. The NASA portion did not complete at this time. The results of the research presented at the symposium are available on this website and in CDROM format.

Contact:

ADRO Coordination Office (CSA)
6767 Route de l'Aeroport
Saint-Hubert, Quebec
J3Y 8Y9

Applications Development

An important new source of remotely sensed data, RADARSAT will be used by decision makers in many fields including:

- Ice
- Coastal Surveillance
- Coastal and Open Oceans
- Cartography and Land Use
- Geology

- Environmental Monitoring
- Hydrology
- Agriculture
- Forestry

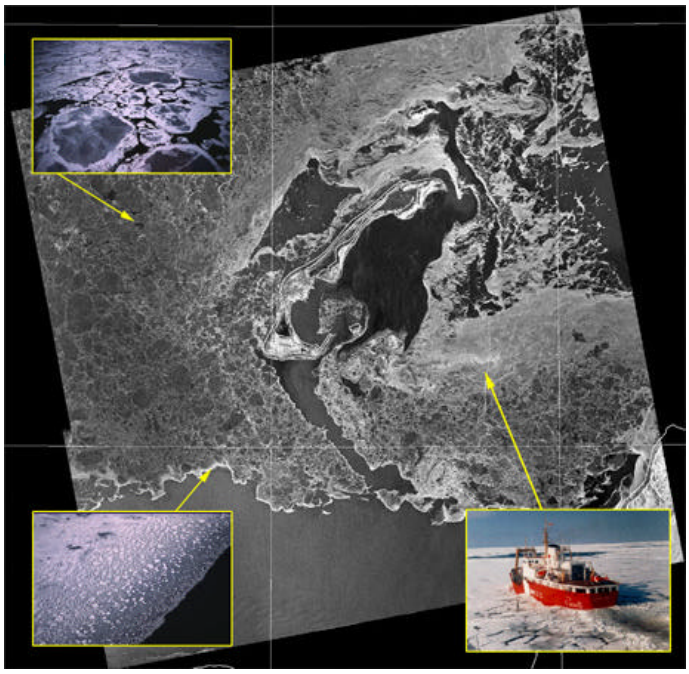
Many professionals in these disciplines already use Geographic Information Systems (GIS) to integrate and analyze large amounts of data from a variety of sources.

RADARSAT supplies these users with another valuable source of resource and environmental information.

Depending on the application, RADARSAT data serves end users in three ways: as a stand-alone source of new information, as a complement to data from aircraft and other satellites, or as a replacement for existing data.

Ice

RADARSAT's ability to map sea ice distribution and to identify ice type is of particular value to Canada and to other countries that have large polar areas enveloped in darkness for long periods. Since it provides the first routine surveillance of the entire Arctic region, RADARSAT imagery is used to produce daily ice charts. These provide strategic information in planning safe ship routes and supply operations for offshore exploration platforms and ocean research stations. In the Antarctic, RADARSAT provides new data to create better maps of the ice fields.



This RADARSAT image shows how the satellite can monitor
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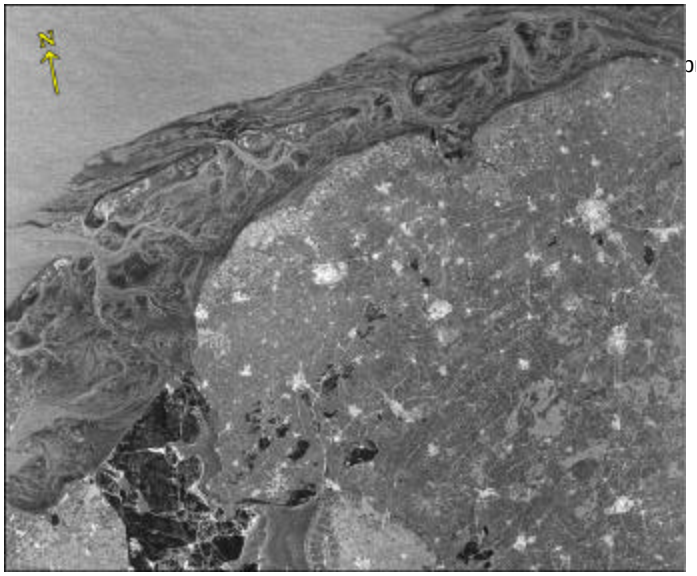


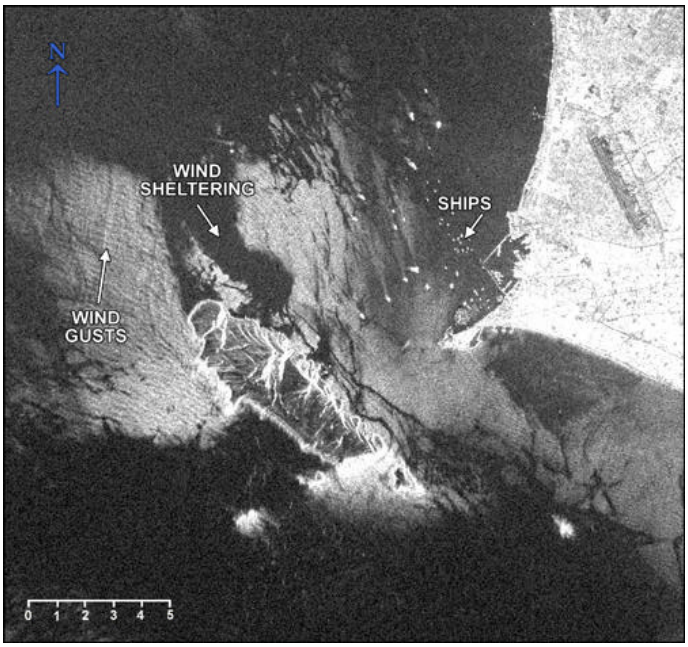
This RADARSAT image of the Leeuwarden Lowlands in northwestern Netherlands, shows the seaice on the top left, the mud tidal flats exposed during low tide to the right of this and a large area of dry land. The dark area at the bottom left represents new ice formed behind a dam.

Coastal Surveillance

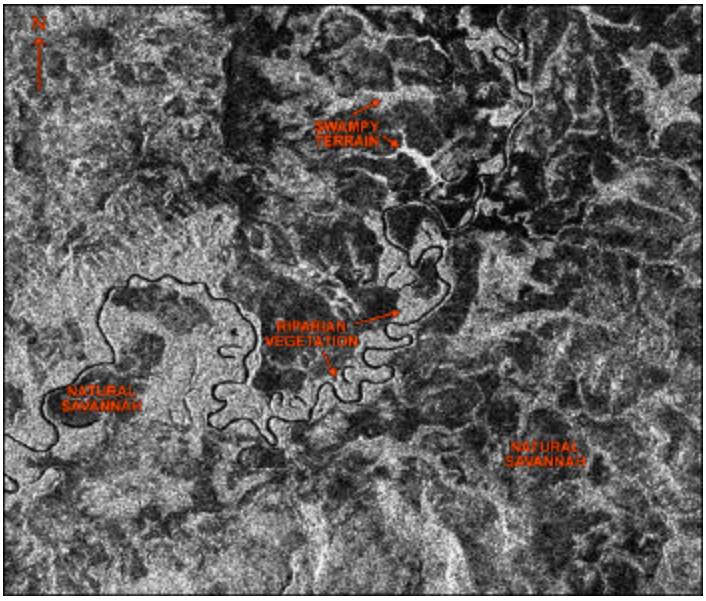
RADARSAT is a rich source of information about the world's coastal areas. RADARSAT can routinely detect changes in coastal erosion, monitor aquaculture activities, map intertidal seaweed distribution, and detect shipping and fishing operations in near shores.

Coastal and Open Oceans

RADARSAT is an important source of new data on the world's oceans. Regardless of cloud, fog or darkness, RADARSAT's SAR can accurately measure changes in ocean waves and winds. This information is useful to offshore exploration and ocean research operations and in locating potentially productive fishing areas.



The dark tones in this RADARSAT image, taken off the coast of Callao, Peru, are due to the damping of surface roughness by the wind lee effects. Light patches appear where the wind has increased the surface roughness of the water, and ships appear as very bright spots.



This RADARSAT image of southeast Venezuela shows a forested environment interspersed with riparian vegetation. The dark areas represent Savannah grasslands and steppe vegetation, while the riparian areas appear lighter in tone.

Cartography and Land Use

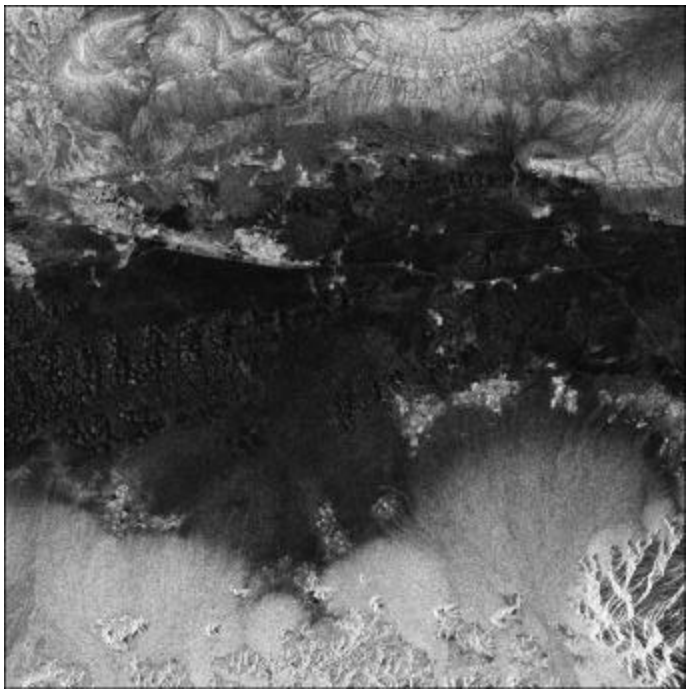
RADARSAT is an effective tool to map rugged or flat terrain. It images large regions, many of which have never been mapped at useful scales, views specific areas that require frequent updating, and images areas where clouds and poor light conditions have so far limited the usefulness of other surveying techniques.

RADARSAT maps the Earth stereoscopically to develop three-dimensional digital elevation models (DEMs). These can be used to plan operations, prepare engineering designs, and monitor erosion in high relief areas.

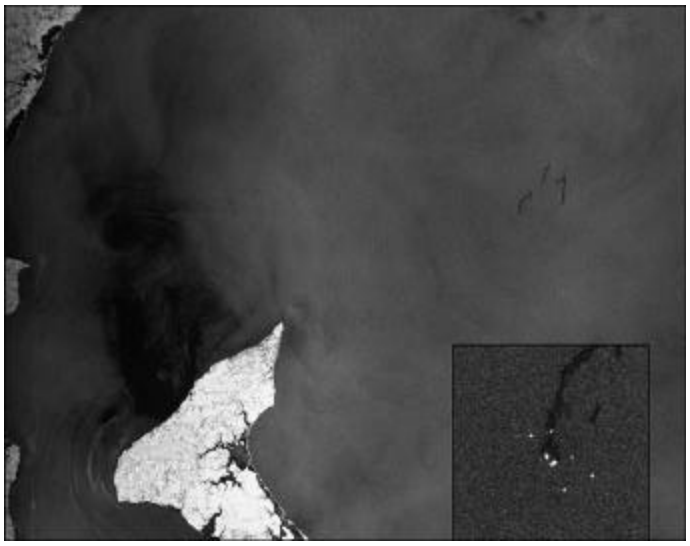
Land use monitoring is another productive application. RADARSAT imagery makes it easier to map and monitor land use changes such as the expansion or decline of urban areas and farmland.

Geology

Many significant geological structural features are mapped using RADARSAT data. Mapping features such as faults, folds, and lineaments supplies new information on groundwater distribution, economic mineral deposits, and oil and gas potential. It also helps identify appropriate sites for hazardous waste. In addition, seismic and fault data acquired by RADARSAT assists studies on the nature and causes of earthquakes.



The numerous alluvial fans found in the Balochistan Desert in western Pakistan appear very bright on this RADARSAT image. The dark area is a structural depression separating the Chagai Hills and Ras Koh Range. Wet flood plains and areas covered with thin layers of salt also have a dark appearance.



This RADARSAT image shows salvage operations after the Irving Whale oil spill off the coast of the Maritimes, and three small oil spills are easily identified by their very dark tones. The seven ships making up the salvage operation are visible as very bright dots.

Environmental Monitoring

Monitoring environmentally sensitive areas represents a major application of RADARSAT data, especially when combined with historical optical satellite data.

Because the RADARSAT SAR penetrates heavy cloud cover, many of the world's rain forests and coastal regions can now be mapped effectively for the first time. RADARSAT can also map the extent of marine oil spills, providing vital information for spill control and clean up operations. These same data also have considerable value in settling legal questions related to oil spills.

Hydrology

Because RADARSAT is particularly responsive to the presence of water, many hydrological applications can benefit from its data. These include monitoring river ice build-up and movement and mapping the distribution of melting snow-covered areas.

RADARSAT data is especially useful for flood monitoring because it helps in assessing the impact of flooding, predicting the extent and duration of flood waters, analyzing the environmental impact of water diversion projects, and developing flood mitigation measures.

RADARSAT provides excellent land/water delineation, as this image clearly shows. The forests adjacent to Lago Grande, Brazil experience seasonal flooding, and the dark areas on this image represent the high water mark and flooded areas, while the forested areas are of a lighter tone.

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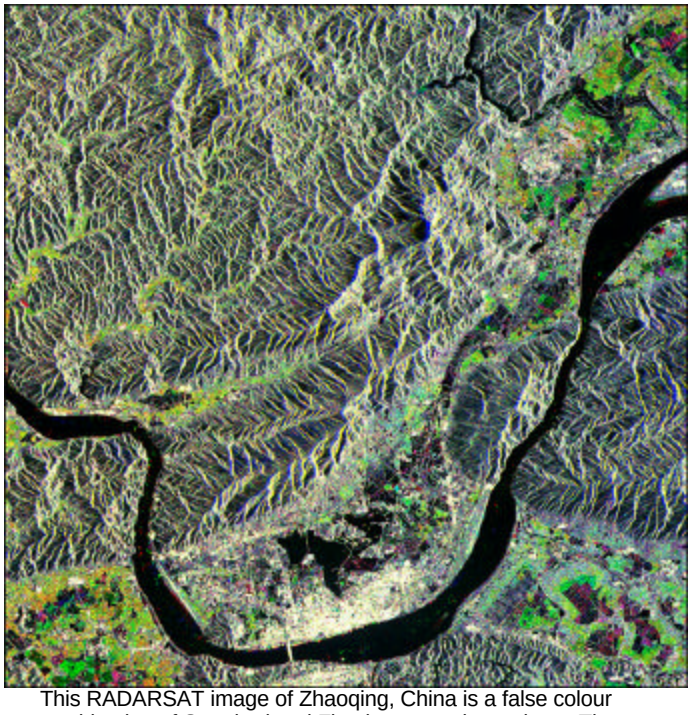
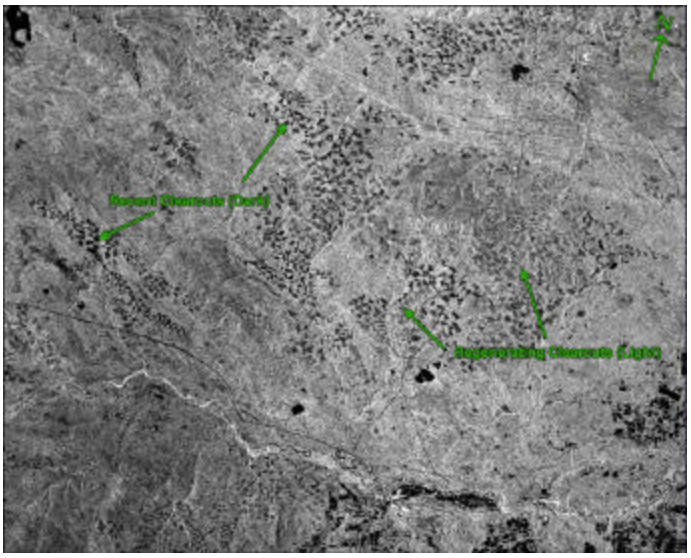


This RADARSAT image of Zhaoqing, China is a false colour combination of Standard and Fine beam mode products. The range of colour represents different types of vegetation and differences in crop growth stages. Aquaculture sites and flooded rice paddies are seen as black, while the village areas and banana fields are a light colour.

Agriculture

Using RADARSAT data, agricultural planners can examine and assess crop characteristics and planting practices to better forecast crop yields. Under favourable conditions, soil characteristics such as moisture content and surface roughness can be identified to determine crop conditions, erosion susceptibility and irrigation needs



This RADARSAT image of Whitecourt, Alberta, Canada shows the extensive clearcutting of boreal forest that has occurred in this region. Recent clearcuts are quite visible as dark areas, while regenerating clearcuts, seen as grey tones, are harder to distinguish from the light tones of the remaining

Forestry

RADARSAT provides valuable data to help map and monitor the world's forests. Using these data, accurate maps of clear cuts in boreal and tropical forests can be created to assess environmental impacts and measure the success of replanting operations.

Antarctic Mapping Mission (AMM)

Antarctica, a region the size of Canada and Alaska combined, has never been fully mapped from space at high resolutions. The Antarctic Mapping Mission (AMM) is a mission aimed at completing this mapping. Such a coverage was not possible with existing or previous space borne high resolution sensors because of their orbit inclination and/or field of view capability.

The RADARSAT satellite was rotated 180 degrees in yaw to allow the radar to image to the left of the satellite track instead of to the right, and to steer the radar beam up to cover the South Pole. This manoeuver was performed between September 9 and 11, 1997. The mapping of Antarctica with high resolution RADARSAT images began on September 26 and was completed October 14. Routine operations in the right-looking mode resumed November 4, 1997.

The AMM is a commitment with respect to RADARSAT, Canada's first Earth Observation satellite, that was negotiated and agreed to by the CSA in an International Memorandum of Understanding (IMOU) signed with NASA and NOAA on February 27, 1991. In exchange for the launch of the RADARSAT satellite by NASA, Canada agreed to provide the USA with access to a pro-rata share of RADARSAT's SAR on-time and to execute a "yaw" manoeuver of the spacecraft twice during the mission to allow the mapping of the Antarctic Continental Ice Sheet.

Participants

Partners in the Antarctic Mapping Mission (AMM) include the Canadian Space Agency (CSA) and NASA. CSA support draws upon the Canada Centre for Remote Sensing (CCRS) and RADARSAT International (RSI). NASA support draws upon its own facilities: Alaska SAR Facility (ASF), Jet Propulsion Laboratory (JPL), and the Goddard Space Flight Center (GSFC), as well as the Byrd Polar Research Center of Ohio State University (OSU), Vexcel Corporation, the Environmental Research Institute of Michigan and the National Imagery and Mapping Agency.

Role of Canada

Canada, through the Canadian Space Agency, was responsible for the management of the AMM, calibration of the payload in each phase, execution of the AMM data acquisition plan (prepared by the USA) and for ensuring successful data downlinks to specified receiving stations, i.e. ASF being the main

station, followed by the Canadian Gatineau (GSS) and Prince-Albert (PASS) stations. McMurdo, an American Antarctica receiving station, was also used to receive data directly from RADARSAT and retransmit them to ASF via the US's Tracking and Data Relay Satellite System (TDRSS). The AMM data acquisition plan and strategy depended largely on RADARSAT's on-board tape recorders. The Fastscan system developed by Array Systems Computing of Toronto was also used to validate the data received at each station and make decisions about updating the data acquisition plan to ensure completeness of coverage of Antarctica.

Role of USA

The preparation of a digital mosaic of Antarctica was conducted under a NASA Pathfinder Project awarded to the Byrd Polar Research Center of Ohio State University (OSU). The Jet Propulsion Lab was responsible for the preparation of the AMM data acquisition plan, while OSU was responsible for the production of a complete mosaic of the Antarctic Continent within one and a half years of the completion of data acquisition. ASF processed data into images, which were sent to OSU for compositing into map products using state-of-the art equipment designed by Vexcel Corporation of Boulder, Colorado. Final products will be distributed by the ASF and the National Snow and Ice Data Center. The mosaics and ancillary information will be made available on a CD-ROM to the science community through NASA's Distributed Active Archive Centers.

Science Benefits and Opportunities

The RADARSAT Antarctic Mapping Mission (AMM) has important significance for the scientific community. Almost 70% of the Earth's fresh water is contained in the Antarctic region, and changes in this enormous reservoir directly influence world sea levels and climate. The new digital radar map will provide an unprecedented detailed portrayal of the surface form and features of the icesheet. This RADARSAT based map will help scientists to better understand the dynamic behaviour of the ice sheet and provide them with a greater insight into the effects of human activity on the Southern Continent.

The RADARSAT AMM data will also serve as a benchmark for testing the predicted effects of global warming on the interior ice sheet and the bounding ice shelves, some of which have recently under gone rapid retreat especially in the Antarctic Peninsula. Using the images taken by RADARSAT, scientists will be able to examine for the first time the effects of complex climatological, glaciological and geological processes on the Antarctic at high resolution and on a continental wide scale.

Glaciology:

The AMM will allow the study of the dynamics and variability of the Antarctic ice sheet, including regions such as the Wordie Ice Shelf and the Largen Ice Shelf which have recently experienced unexplained and nearly catastrophic retreat.

Other opportunities are related to:

- Ice sheet stream flow regimes (fast glacier flow, ancient features, outlet glaciers)
- Stability of West Antarctic Ice Sheet (grounding lines, surface velocities)
- Ice sheet mass balance (calving rates, ice sheet margins, topography)
- Surface melt regimes

Geology:

Geological applications will include large scale mapping of faults, volcanic features, and mountain building processes:

- Uplift of the Transantarctic Mountains (fault and lineament mapping)
- History of subduction beneath the Antarctic Peninsula
- Geologic mapping (Sirius formation)
- Vulcanology

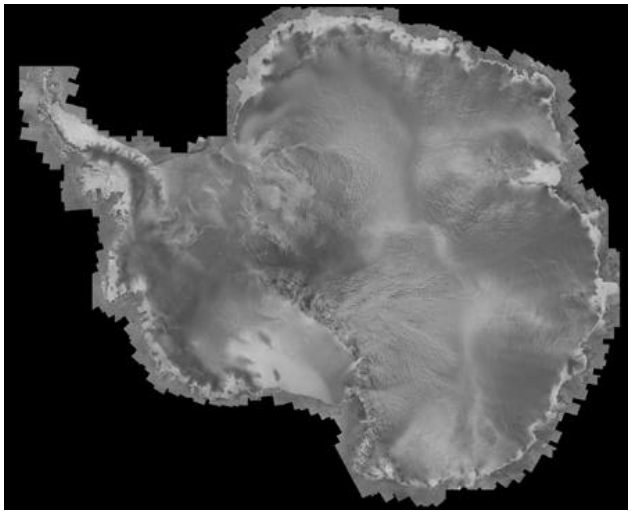
Geomorphology:

- History of glaciation (moraines, raised beaches)

Exploration:

The digital maps will provide an unprecedented opportunity to study many previously unexplored areas of the Southern continent.

Finally, the availability of this unique data set will be welcomed by scientists from many of the nations interested in the governance and protection of Antarctica in accordance with the Antarctic Treaty System.



The above figure is a low-resolution version of the first seamless mosaic of Antarctica, which was compiled from RADARSAT SAR images acquired in September and October 1997. They were acquired as part of the RADARSAT Antarctic Mapping Project which is a collaboration between the U.S. National Aeronautics and Space Administration and the Canadian Space Agency to completely map the Antarctic with RADARSAT-1.

South Pole Image

The mosaic was created at the Byrd Polar Research Center using a mapping system developed by Vexcel Corporation. The Alaska SAR Facility processed all of the raw signal data to images. The Jet Propulsion Laboratory developed the mission acquisition plan. In addition, the project received assistance from the National Science Foundation and the National Imagery and Mapping Agency.

Final products will be distributed by the Alaska SAR Facility and the National Snow and Ice Data Center. Further information about the mosaic can be obtained by writing to:

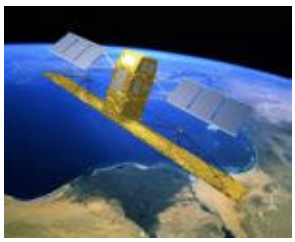
Kenneth C. Jezek, Professor
Byrd Polar Research Center
The Ohio State University
1090 Carmack Road
Columbus, OH 43210
jezek.1@osu.edu

RADARSAT-2 Investment in the Future

To maintain Canada's world leadership in satellite SAR technology and contribution to global resource management and environmental monitoring programs, the Canadian Space Agency is collaborating with the private sector to develop an industry-led, follow-on radar satellite program.

Building on the accomplishments of the first RADARSAT, the Government of Canada and MacDonald Dettwiler Associates Limited (MDA) will invest $225 million and $80 million respectively for the construction of RADARSAT II (http://radarsat.mda.ca/). Space technology organizations across Canada will benefit from this partnership through the awarding of subcontracts by MDA. The four-year construction phase is expected to generate approximately 300 jobs. The arrangement with MDA marks the first step in the transition of spaceborne Earth observation from government to private sector.

Using space to respond successfully to the challenge of a changing planet is the essence of the draft Long Term Space Plan (LTSP) III - Sustainable Earth Program (1999/2000 - 2008/2009). Comprising three inter-related subprograms (Environment, Resource Management, and Disaster Management and Surveillance), the Sustainable Earth Program aims to better understand, protect and manage Canada's resources and the environment. Working with domestic and international partners, the LTSP III will continue to provide the leadership that has contributed to the excellent reputation and solid track record Canada has established with the RADARSAT program.



To be launched in 2001, RADARSAT II will be lighter, cheaper, more capable, and will assure data continuity well into the new millennium. Its enhanced capabilities include additional beam modes, higher resolution, multi-polarization, more frequent revisits, and an increased downlink margin enabling reception of data from lower-cost receiving antenna systems. With a planned operations phase of seven years, RADARSAT II will maintain Canada's position as a leader in the internationally competitive Earth Observation market.