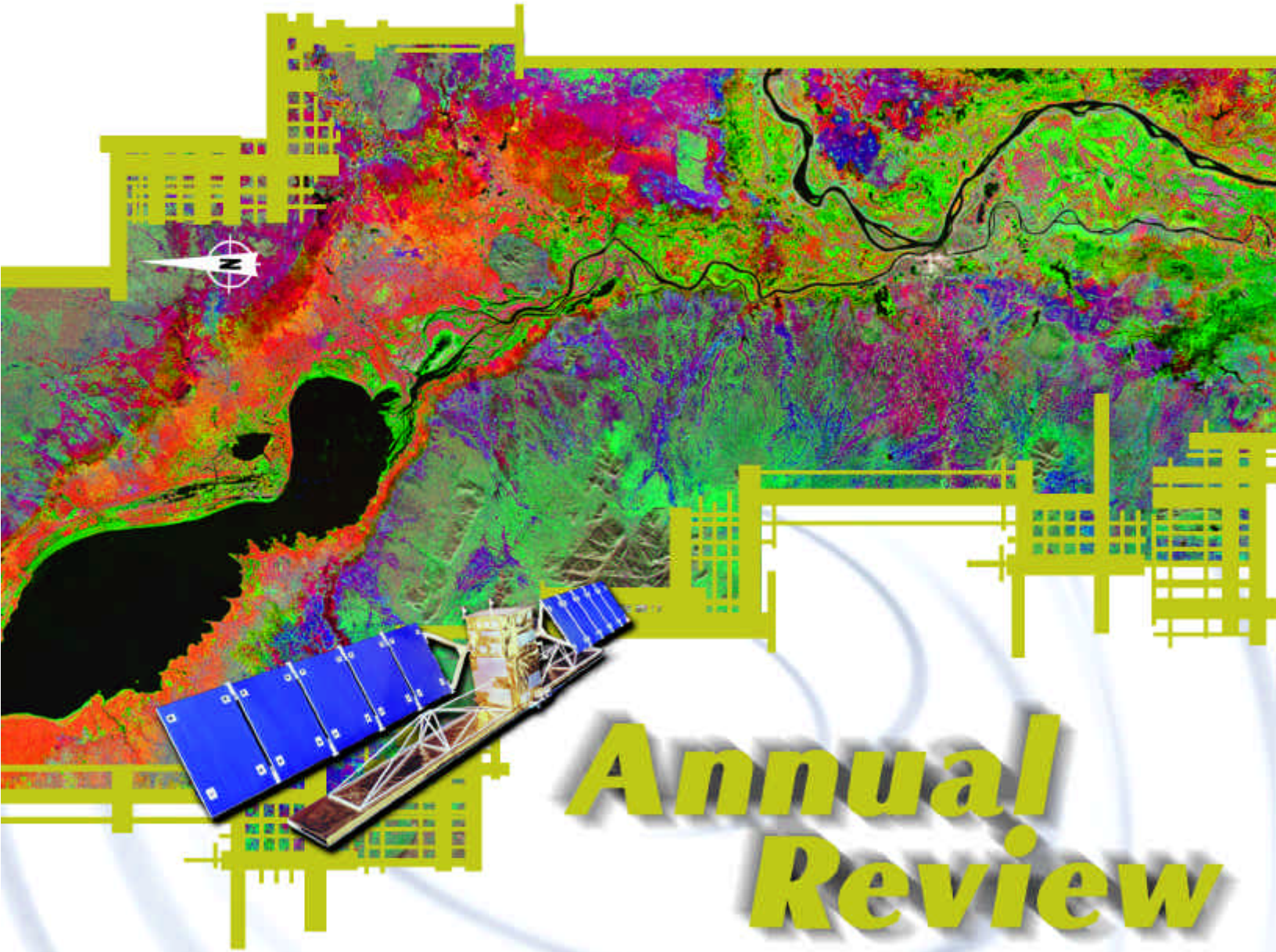
Canadian Space Agency | Agence spatiale canadienne

RADARSAT



Annual Review

2000 - 2001

Canada

RADARSAT-1 is the Canadian Space Agency's first Earth observation satellite. Equipped with a powerful Synthetic Aperture Radar (SAR) instrument, the RADARSAT-1 satellite acquires images of the Earth day or night, in all weather and through cloud cover, smoke and haze.

RADARSAT-1 Program Partners

Canadian Space Agency (CSA)
Space Operations, Satellite Operations Directorate
Space Technologies

Natural Resources Canada (NRCan)
Canada Centre for Remote Sensing (CCRS)

MacDonald Dettwiler and Associates (MDA)
RADARSAT International (RSI)

National Aeronautics and Space Administration (NASA)

National Oceanic and Atmospheric Administration (NOAA)

Canadian Provinces

Canadian Industry

Front cover: Wide mode images acquired in 1999 and 2000 were combined to create this multi-temporal RADARSAT-1 mosaic, which shows the extent of floodplains and wetlands of the Great Lake and Tonle Sap Rivers, as well as the Mekong and Bassac Rivers, in Cambodia. The floodplain of the rivers is indicated in various colours; permanent water bodies are black.

Produced by the Hatfield Group of Companies, RSI, AERDE Environmental Research and the Mekong River Commission Secretariat under a project funded by the Radarsat User Development Program (RUDP).

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Celebrating Five Years of Operational Success

Dr. Rolf Mamen, Director General, Space Operations
Dr. Surendra Parashar, Director, Satellite Operations

Honouring Excellence in Service to Humanity

As we enter the new millennium, we are continuing a unique journey in service to humanity – one founded on innovation and deeply rooted in a commitment to excellence. This year we celebrated the fifth anniversary of the launch of RADARSAT-1 and produced the first SAR-based mosaic of the contiguous United States as part of our ongoing global mapping initiative.

In support of NASA and the Byrd Polar Research Institute at the Ohio State University, RADARSAT-1 carried out the second Antarctic Mapping Mission, providing scientists with the first opportunity to study large-scale ice dynamics and perform change detection on the circumferential ice sheet.

Expanding the reach of this leading-edge technology and our expertise in disaster management, Canada joined the European Space Agency (ESA) and the French Space Agency (CNES) in the signing of the International Charter on Space and Major Disasters. Deploying RADARSAT-1 in support of Charter initiatives will help speed space-based resources and disaster relief to those most in need.

While RADARSAT-1 is providing exceptional value and service beyond its planned lifetime, the construction of RADARSAT-2 continues to support Canada's desire to build Canadian knowledge and expertise, rewarding Canadian innovation with opportunity and strengthening Canada's economy by leading the world in Earth observation.

It is this state-of-the-art Canadian technology that is enhancing our ability to map the present and helping us to better manage our future.

W. M. (Mac) Evans
President
Canadian Space Agency

Early Vision Realized

As Director of the RADARSAT Project Office from 1980 to 1987, Dr. Edryd Shaw played a pivotal role in getting the SAR satellite off the drawing board and into reality. Now Director General of the Canada Centre for Remote Sensing (CCRS), Natural Resources Canada, Dr. Shaw reflects on the success of the RADARSAT-1 program and the key role his organization played – and continues to play – in this world-class SAR satellite system.

"With the successful completion of the nominal five-year life cycle of RADARSAT-1, it is appropriate for us at CCRS to look back with pride and satisfaction at a job well done, as well as look forward with confidence to the RADARSAT-2 era on the horizon. The road to RADARSAT-1 has been long, challenging and, at times, uncertain. Many CCRS employees have quite literally devoted their professional and scientific careers to this initiative.

"It is a tribute to them and the other participating partners that today we have a successful satellite in orbit serving global requirements on an operational, commercial basis and providing a vital service. We are now in a position of well-earned technical strength and experience both in government and in industry to continue to lead the world in Earth observation SAR technologies."

History in the Making

When RADARSAT-1 was launched in November 1995 and commercial operations commenced in April 1996, then Director General and later Vice-President Joe McNally celebrated the successful fruition of nearly six years of leading a team that assembled, launched and put into commercial operation a civilian SAR satellite that remains without peer today. Now retired, Mr. McNally looks back on those groundbreaking years.

"As the largest, heaviest and most expensive satellite ever built by Canadians on Canadian soil, RADARSAT-1 presented many engineering challenges. In fact, the only facility in Canada large enough to conduct the final integration was the David Florida Laboratory in Ottawa, ON. Both the enormous solar arrays and highly complex radar antenna had to be folded up for launch and deployed on orbit. Furthermore, the flatness of the antenna had to remain within one millimetre under all thermal conditions. This extremely difficult engineering problem was so well addressed that post-launch measurements detected no change in antenna performance.

"Once RADARSAT-1 was operational, we were tightly focused on keeping the satellite on schedule, filling the first commercial orders, fine-tuning procedures and producing specialized coverage. When we received the initial images, we were thrilled with the tangible proof of the satellite's superb imaging capabilities. Indeed, I still recall the amazement of our first customers at both the resolution detail and volume of data that RADARSAT-1 could produce."

From the time RADARSAT-1 produced its first image on November 25, 1995, there has been no looking back. This fiscal year 2000/2001 proudly marks the successful completion of RADARSAT-1's planned five-year lifetime.

"Without a doubt, the RADARSAT-1 program has been an unqualified success, performing well beyond expectations and proving its versatility and reliability time and again," noted Dr. Rolf Mamen. "As a result, its reputation as one of the top performing Earth observation satellites is well deserved. It is far and away the most sophisticated civilian SAR system in existence, and has secured a lead role in the international remote sensing community."

Since its launch in 1995, RADARSAT-1 has generated unique and previously unavailable data, which are utilized in a wide range of scientific and commercial applications – from oil and gas exploration and agricultural monitoring through ice reconnaissance and marine surveillance to geologic mapping. It has also demonstrated interferometric capabilities well beyond its original design specifications, and proved its value as a critical source of information when disasters strike and in studying global climate change.

"Furthermore, this powerful remote sensing satellite has produced a series of breakthroughs in imaging the planet, including the first complete, high-resolution SAR coverage of Antarctica, complete SAR coverage of nearly all the Earth's landmass and largest cities, multi-temporal coverage of many of the Earth's small islands, as well as near-instantaneous coverage of Canada," added Dr. Mamen.

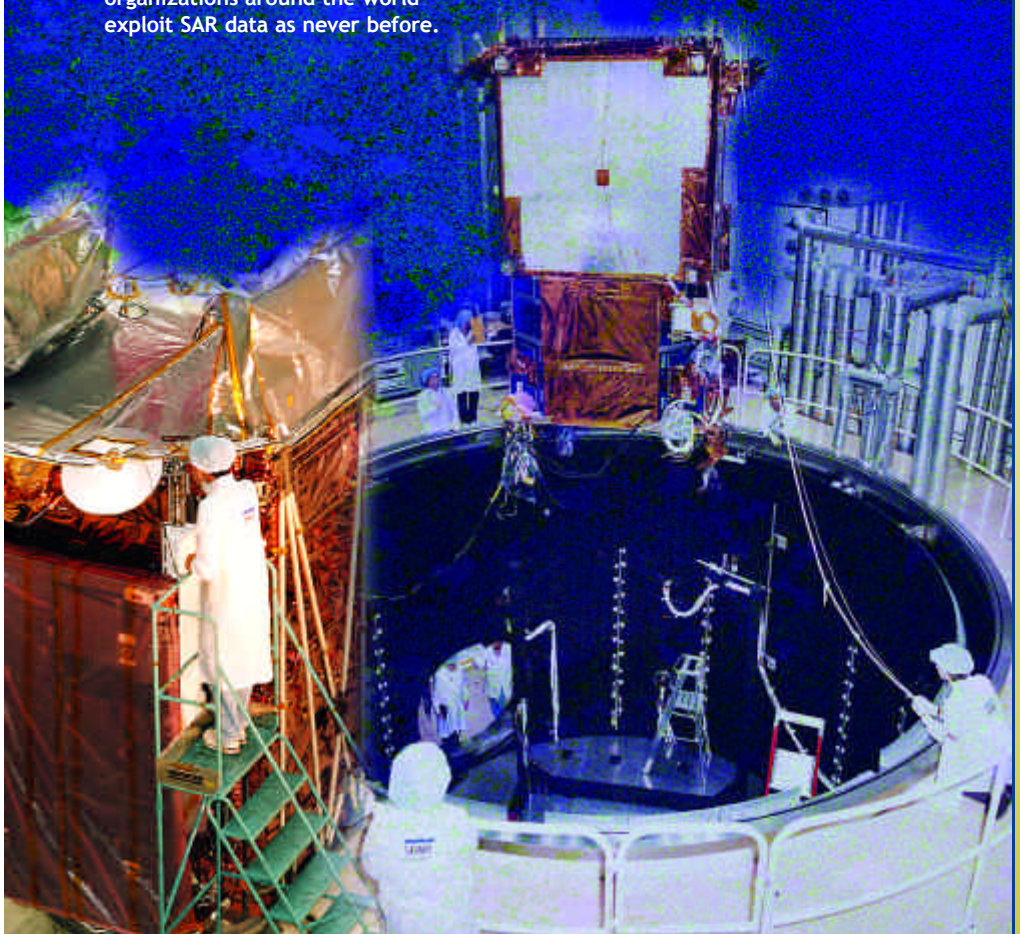
RADARSAT-1's robustness was showcased during the first Antarctic Mapping Mission in 1997 when the spacecraft completed an unprecedented yaw manoeuvre and subsequent re-orientation, both executed flawlessly, and again during this year's Modified Antarctic Mapping Mission (MAMM). The past five years also saw new Near and Far beam positions added to Fine mode, implemented while RADARSAT-1 was in orbit.

Many of these achievements could not have been made without the diligent management efforts of the Satellite Operations team. According to Dr. Surendra Parashar, RADARSAT-1's outstanding technical performance is rivalled only by the expertise of the team that operates this advanced SAR satellite. "The experience gained by our team of satellite engineers, controllers and planners over the past five years is found nowhere else in the world.

"Moreover, this team of dedicated professionals has consistently enhanced the effectiveness of the satellite system. Dramatic improvements have been made in both acquisition planning time and recovery time from payload anomalies, as well as in making the SAR instrument and onboard recorder more efficient. In addition, the implementation of new attitude control software and new operational procedures have conserved the spacecraft's resources – efforts that will help extend RADARSAT-1's lifetime."

The operational success of the RADARSAT-1 program has also been measured by its commercial success. "I am very pleased with the program's commercial results. The marketing and education efforts of RADARSAT International (RSI), the company formed to process, market and distribute data from RADARSAT-1, have been tremendous," said Dr. Mamen. "Today, RSI commands approximately 15 percent of the global remote sensing market, and the company's customer-focused approach, fast turnaround, and unique SAR image products and client services will help ensure the market for RADARSAT data continues to grow in the future."

With RADARSAT-1, Canada has created a truly unique and end-to-end Earth observation system that offers best-of-breed operational capabilities – capabilities that are helping organizations around the world exploit SAR data as never before.



Optimizing RADARSAT-1 Resources

The Mission Planning group of Satellite Operations continues to support commercial, scientific and operational clients around the world, providing planning and operational support 16 hours a day, seven days a week. Experienced mission planners work to develop acquisition plans to maximize the use of spacecraft resources, as well as manage approximately 3 100 requests each month. One notable exception was October 2000 in which the number of requests climbed to 6 500, as acquisition planners worked to achieve the successful completion of both the Modified Antarctic Mapping Mission (MAMM) and the Canadian Interferometric Mission (CIM).

With the addition of new ground stations capable of acquiring RADARSAT-1 data, and an effort to complete the Background Mission, changes in planning, procedures and upgrades to the Mission Management Office (MMO) and its database server were implemented over the past year. These upgrades will also enable the MMO to further extend the system and increase support for RADARSAT-1's customer base, including the growing number of RADARSAT-1 network stations.

Maintaining Image Quality

Throughout 2000, the RADARSAT-1 image quality maintenance program remained fully operational. Resolution-related measures continued to be better than specifications, location accuracy was again excellent, and the radiometric calibration was fully maintained. It is especially significant that the sensitivity of RADARSAT-1's SAR instrument has remained very stable over the past five years of operation.

RADARSAT-1 Station News

International

In 2000, four stations achieved operational certification: Thailand, Brazil and two U. S. mobile stations, Eagle Vision 1 and 2. The operational certification of the Brazil station is especially significant since it is now possible to obtain real-time RADARSAT-1 data over South America. These new certifications bring the number of international RADARSAT-1 network stations up to 14. Moreover, Thailand and Brazil are expected to achieve product certification by early spring 2001.

Canada

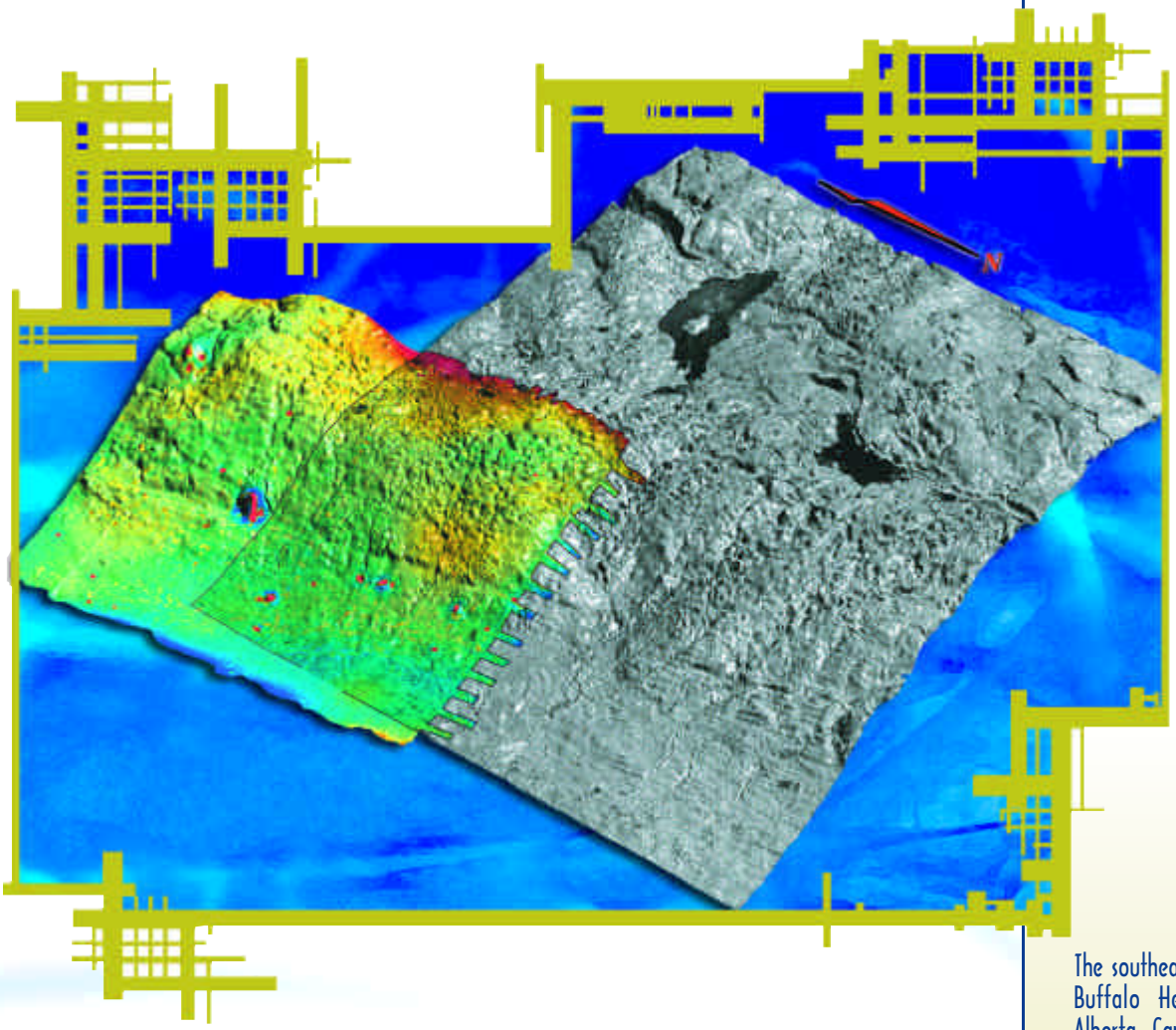
In readiness for the RADARSAT-2 program, CCRS and CSA worked together to initiate upgrades to the RADARSAT-1 ground system infrastructure, including the CCRS-operated receiving stations in Gatineau, Quebec and Prince Albert, Saskatchewan. These stations also successfully participated in MAMM.

The RADARSAT-1 long-term archive of CCRS-received data is now 100 percent complete. After five years, the CCRS RADARSAT-1 archive of real-time and onboard recorder data is more than 73 terabytes in size.

RADARSAT-1 System Performance

2000 acquisition requests	25 712	Max. min. of SAR on-time/orbit	32	Total est. number of requests	97 349
2000 est. minutes of data	52 041	Ave. system performance (%)	96.6	Total est. minutes of data	212 343
2000 orbits	5 217	No. of playbacks/day	5.3	Total orbits	28 215
2000 est. OBR imaging requests	4 104			Total est. OBR imaging requests	51 354

2000 emergency requests under the International Charter on Space and Major Disasters 11



The southeastern margin of the Buffalo Head Hills area in Alberta, Canada hosts a cluster of kimberlite intrusions, a number of which in turn host diamonds. By integrating Fine mode imagery, DEM data and high-resolution aeromagnetics, geologists can detect the larger kimberlite bodies, which display a distinctive aeromagnetic high in conjunction with the intersect of north and northeast trending geologic structures. Also featured in the image is a dominant northerly structural trend that defines the western edge of a Upper Devonian half-graben, which coincides with Alberta's Loon River lowlands.

New methods and software tools were developed to improve operational efficiency. This included a tool to facilitate acquisition planning of calibration images. Also, a new methodology was implemented to assess spacecraft roll variation, using ocean images for improved characterization of spacecraft attitude performance.

Moving Beyond the Satellite's Planned Mission Life

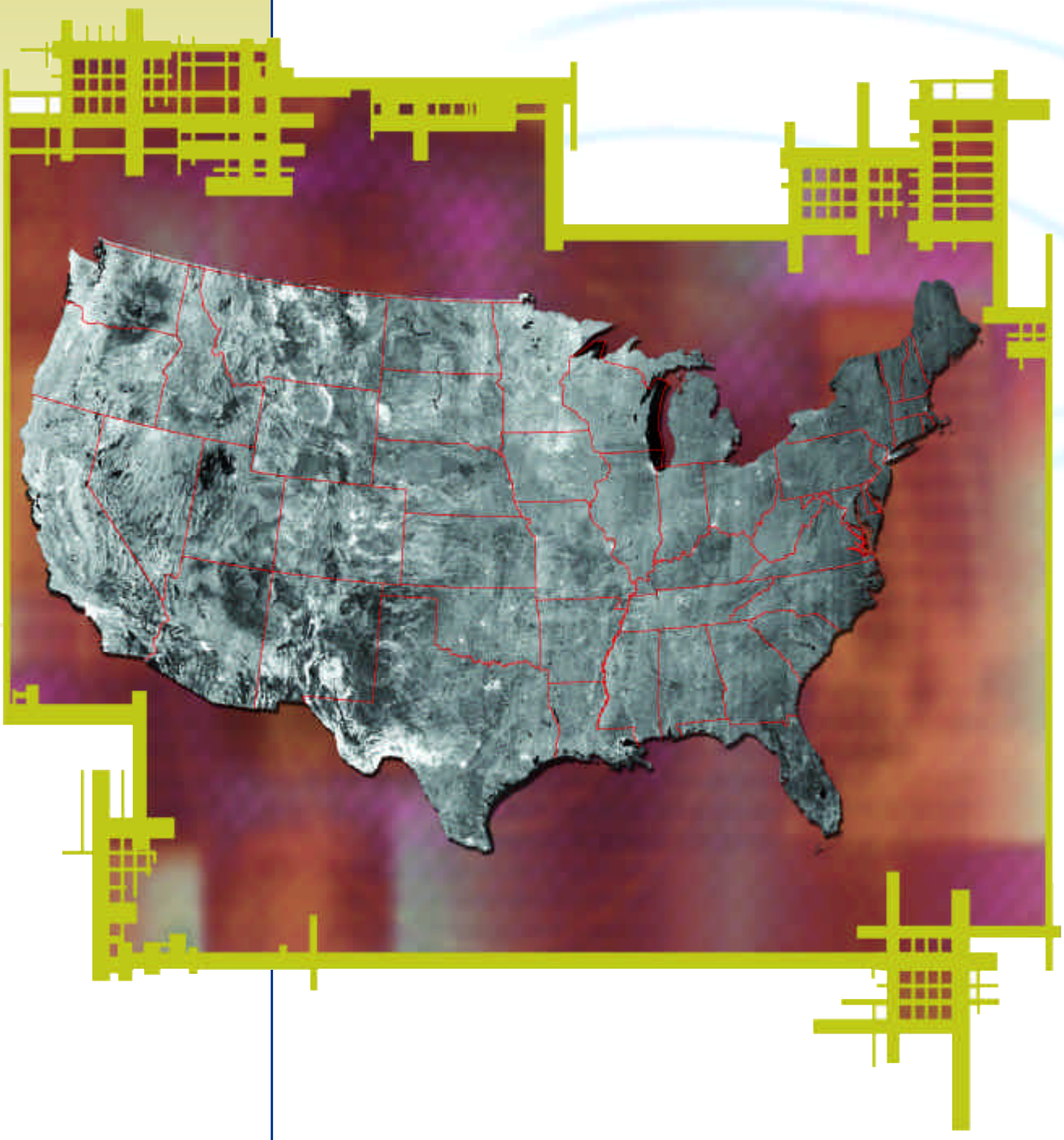
Improvements in alternate control mode performance may be required as RADARSAT-1 moves into the years beyond its planned mission life. This is due to the increasingly erratic motor speed control in the satellite's remaining horizon scanner. As a result, tests were conducted this past year on the performance of alternate control modes and research was initiated on modifying the flight software.

Since the spacecraft clock would automatically reset to zero in April 2001, a System Operation task force has been coordinating efforts to prepare the overall operational system to accept the new time stamp. As a result, the clock was deliberately and successfully reset on January 16, 2001.

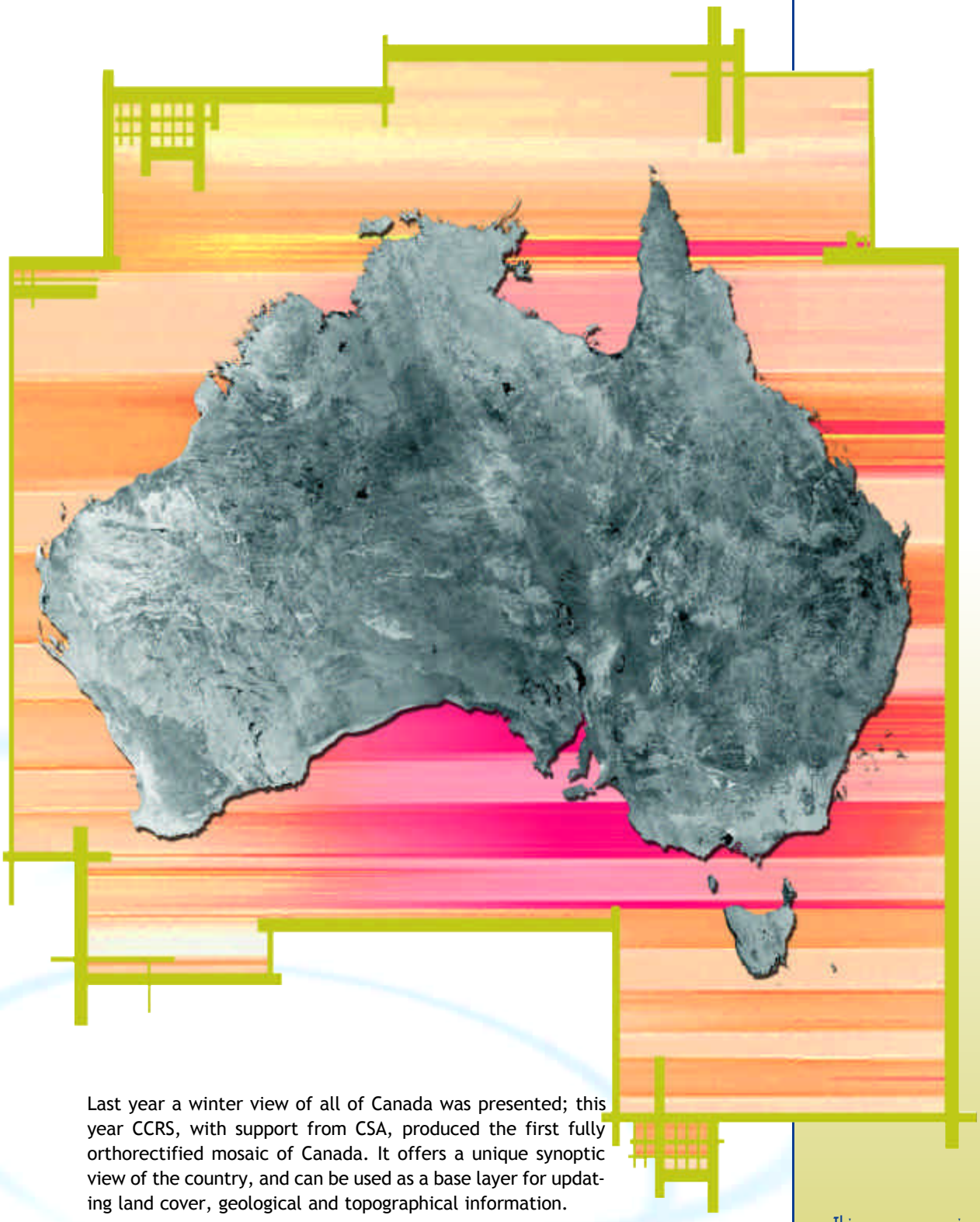
In December 2000, the second Antarctic Mapping Mission was successfully completed without re-orientation of the spacecraft. During this mission, the orbit was controlled more tightly than normal in order to support the selection of interferometric image pairs. Also, based on the success of the Canadian Interferometric Mission, the tighter, two-kilometre orbit (vs. the normal five-kilometre orbit) will be maintained in the near future in order to support commercial interferometric applications. This will increase the value of the RADARSAT-1 archives by ensuring that virtually all acquisition pairs selected for interferometry will meet this important application's criteria.

Continental Snapshots Yield Seasonal Views

Like other radar satellites, RADARSAT-1 can provide timely images of the Earth's surface, regardless of weather and availability of sunlight. RADARSAT-1, however, has the added advantage of an onboard data recorder and the ability to supply large area coverage, using its powerful ScanSAR beam mode. As a result, the satellite is particularly well suited for generating temporal image mosaics as 'snapshots' of entire regions or continents.



Nearly 190 ScanSAR Narrow descending images were acquired to create this spring mosaic of the United States.



Last year a winter view of all of Canada was presented; this year CCRS, with support from CSA, produced the first fully orthorectified mosaic of Canada. It offers a unique synoptic view of the country, and can be used as a base layer for updating land cover, geological and topographical information.

In addition, CSA and RSI are collaborating on the generation of other country mosaics. In 2000, RADARSAT-1 archive images were used to produce summer and spring mosaics of Australia and the United States, respectively. These seasonal views can be used as key benchmarks in studying changes in the Earth's systems due to land use practices and ecological variations.

This summer mosaic of Australia consists of approximately 165 ScanSAR Narrow ascending images, which were acquired from mid-November 2000 to mid-February 2001.

Demonstrating Innovative Interferometric Applications

Collection of multi-mode radar data on various regions and mapping the Antarctic ice sheet in detail are the two baseline objectives of the RADARSAT-1 program. This year, two RADARSAT-1 Fine beam interferometric coverage campaigns took place: the Canadian Interferometric Mission (CIM), a special Background Mission initiative that covered Canada as well as Greenland, Iceland and several of the world's watershed glaciers; and the Modified Antarctic Mapping Mission (MAMM).

Canadian Interferometric Mission

Although a mission devoted to cryospheric applications, several sites were chosen for their landform changes, surface instability and geoscience. Interferometric data collections were made possible thanks to the improved orbit maintenance by CSA over several RADARSAT-1 cycles. The study of ice-covered and permafrost regions of the world is expected to help in better understanding global climate change and in provoking remedial actions.

CIM complemented the Shuttle Radar Topography Mission by covering more northerly latitudes and generating higher resolution data, which can be used to create precision digital terrain models. Interferometric analysis using RADARSAT-1 multi-cycle data acquisitions is expected to contribute valuable data on glacial movements, change detection and geomorphological processes.

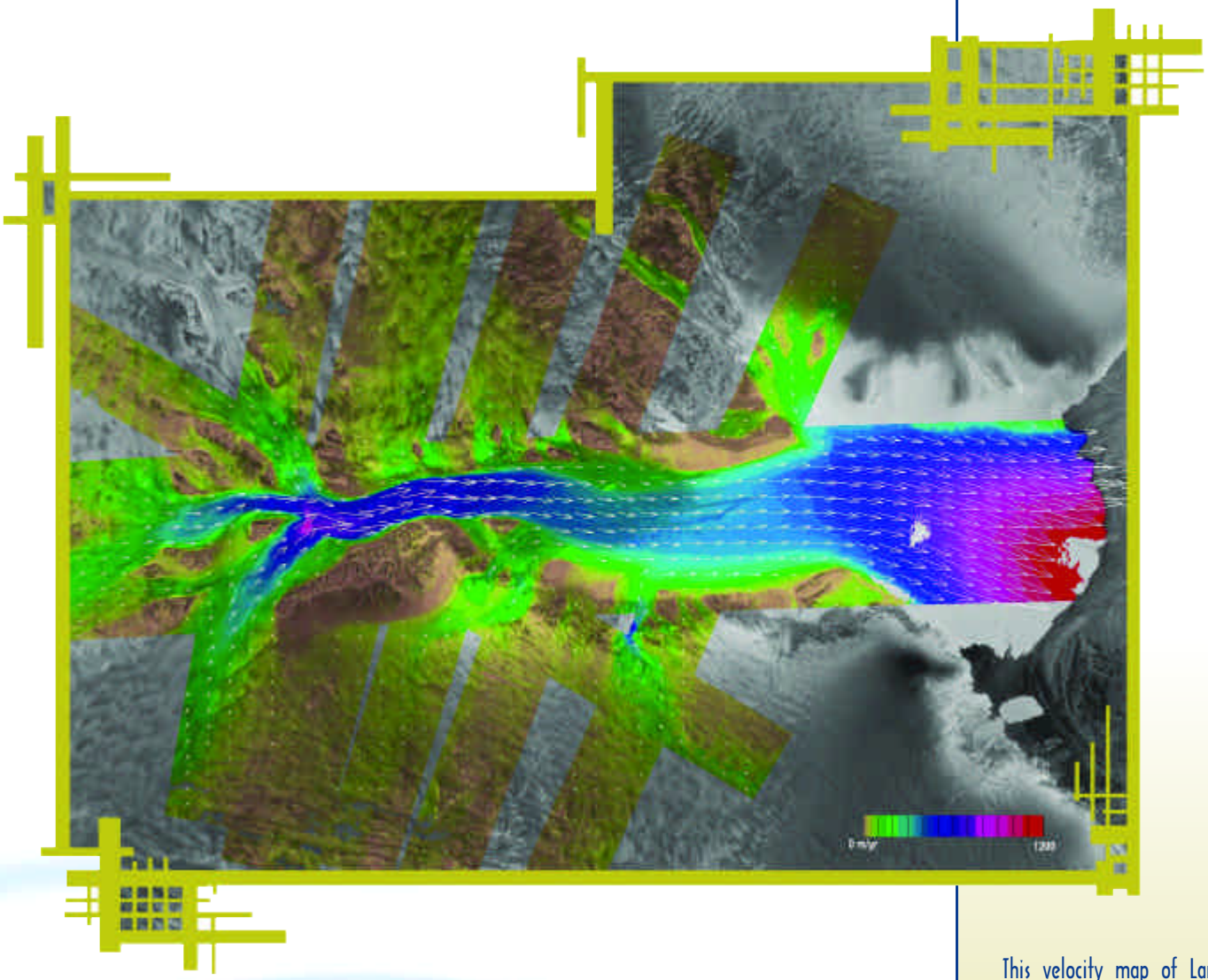
In addition, Background Mission global landmass stereo coverage, using Standard 7 and one other beam with a significantly different incidence angle, is now nearing completion.

Modified Antarctic Mapping Mission

Glacier motion has intrigued scientists for more than a century. In 1880, the American author Mark Twain wrote of his experiences with Alpine glacier motion in his book *A Tramp Abroad*, "I was aware that the movement of glaciers is an established fact; so I resolved to take passage for Zermatt on the great Gorner Glacier. The next thing was, how to get down the glacier comfortably. I marched the Expedition down the steep and tedious mule-path and took up as good a position as I could upon the middle of the glacier, because Baedeker said the middle part travels the fastest. I waited and waited, but the glacier did not move."

While Twain was disappointed with the outcome of his experiment, his approach was essentially correct. Since the International Geophysical Year of 1957-58 and before, scientists have placed markers on the ice sheet and measured and re-measured their positions to calculate motion. More recently, researchers at the Jet Propulsion Laboratory (JPL) have showed that SAR offers a revolutionary new technique for estimating the surface motion of glaciers, with the SAR operating as an interferometer. The most recent demonstration of this powerful imaging technique was MAMM, which was conducted September 3 to November 14, 2000 as part of a joint CSA/NASA project to map the Southern Continent.

MAMM had two primary objectives. The first was to re-map the perimeter of the continent and most of Antarctica's fast-moving glaciers. These are the areas that have most likely experienced change since 1997, when the first Antarctic Mapping Mission was conducted – and already the results have been nothing short of astonishing. For example, the dramatic retreat of the Larsen Ice Shelf seems to add credence to a 1978 prediction that the retreat of the Antarctic Peninsula Ice Shelves would be a precursor signal to more global-scale consequences of greenhouse gas warming.

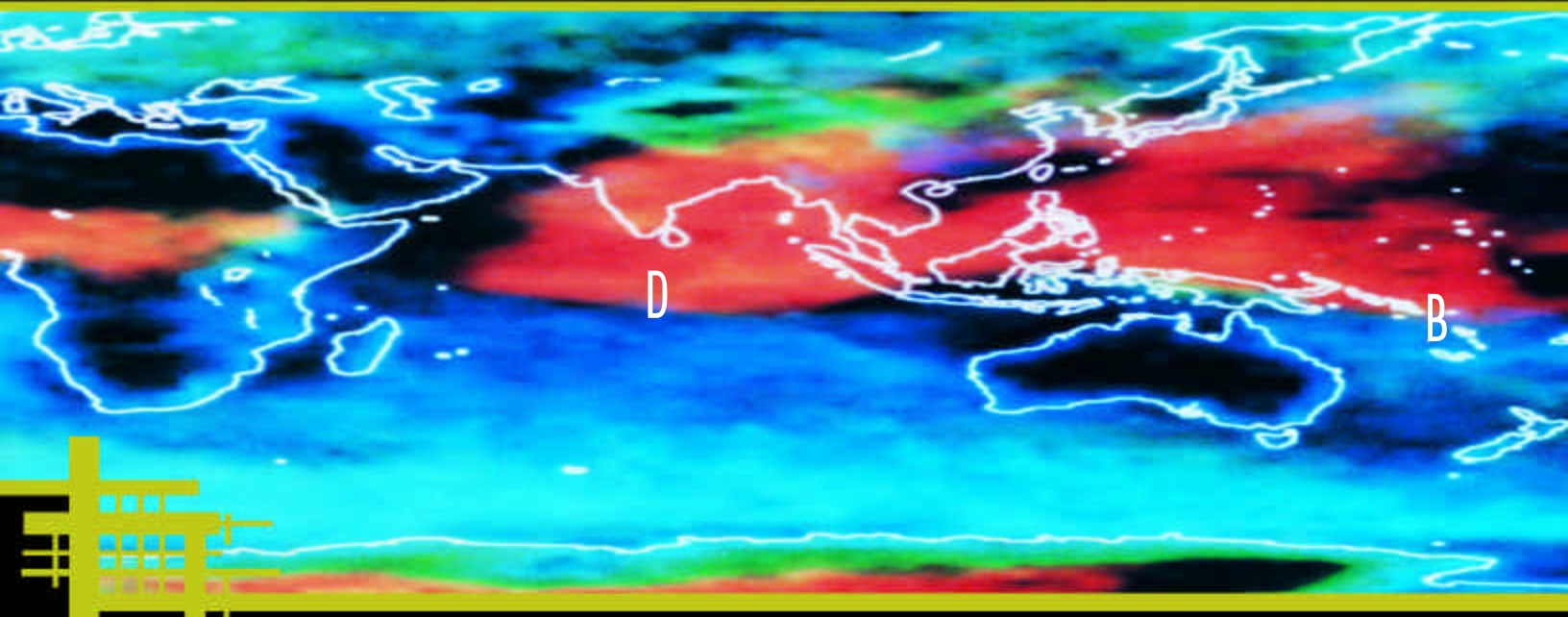


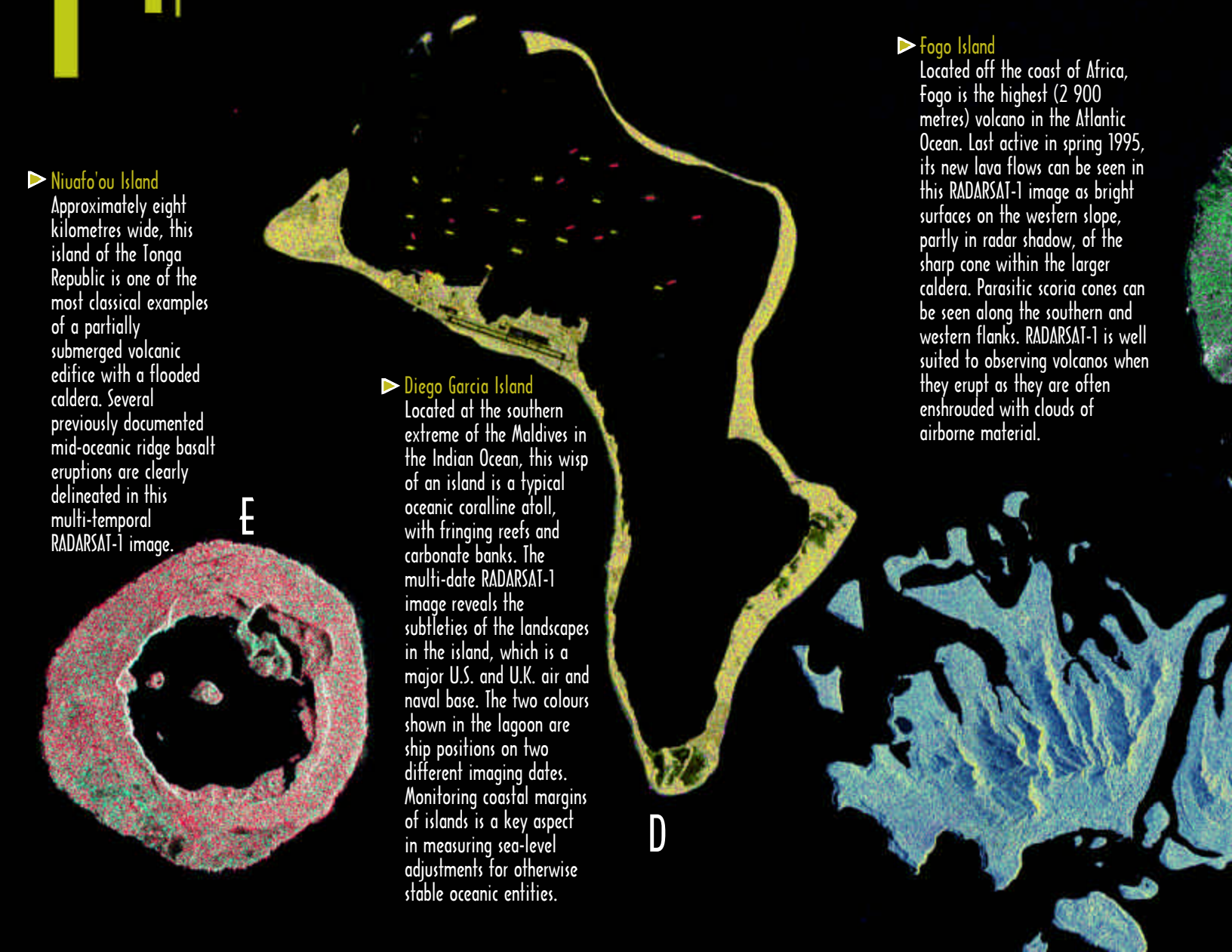
The second objective was to obtain as much surface velocity data as possible on the ice sheet. To realize this goal, data were acquired so that, where possible, the position of structures on the glacier could be compared with the 1997 data set to measure point velocities. Then – and the real challenge of MAMM – interferometric data were acquired to estimate velocity fields. This required the use of RADARSAT-1 Fine and Standard beams and the unprecedented control of the spacecraft orbit by CSA spacecraft engineers.

"This joint CSA/NASA effort is producing extraordinary observations of glacier motion, which were captured over three 24-day RADARSAT cycles," noted Kenneth Jezek, Professor at the Ohio State University's Byrd Polar Research Center. "Data were acquired from approximately 80 degrees south latitude to the Antarctic Coast. Interferometric SAR calculations required that this area be imaged six times during the mission – three times in descending mode and three times in ascending mode. The benefit is twofold: scientists will be able to measure two components of the surface velocity vector as well as remove the effects of surface topography."

At present, the Alaska SAR Facility is processing the MAMM data into images. Ohio State University researchers will then convert the images into maps and velocity fields using a system being developed by Vexcel Corporation and based on the JPL acquisition plan.

This velocity map of Lambert Glacier in Antarctica was created from pairs of RADARSAT-1 images obtained 24 days apart. Areas of no motion (yellow) are generally exposed land or contained ice. The smaller confluent glaciers have generally low velocities (green, 100 to 300 metres per year). However, most of the Lambert Glacier has velocities between 400 and 800 metres per year, with a slight slowing in the middle section. As the glacier extends across the Amery Ice Shelf, velocities increase, approaching 1 000 to 1 200 metres per year, as the ice sheet spreads out and thins.



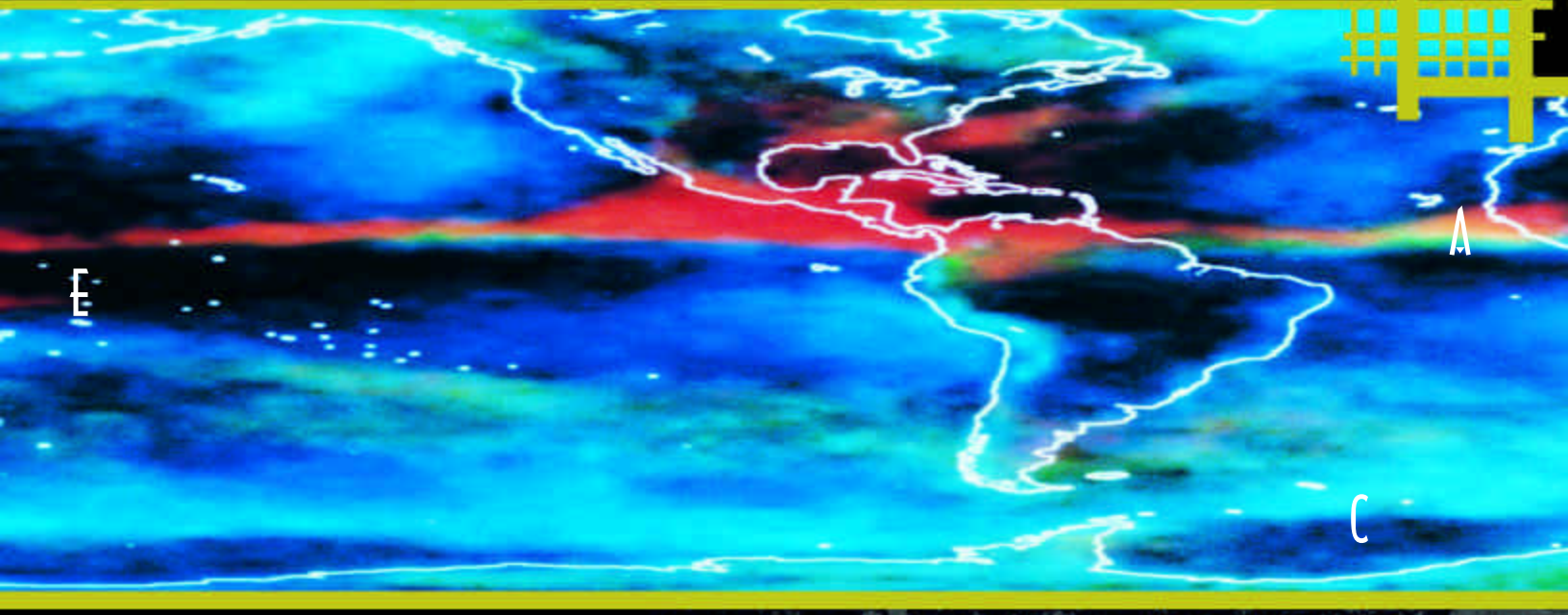


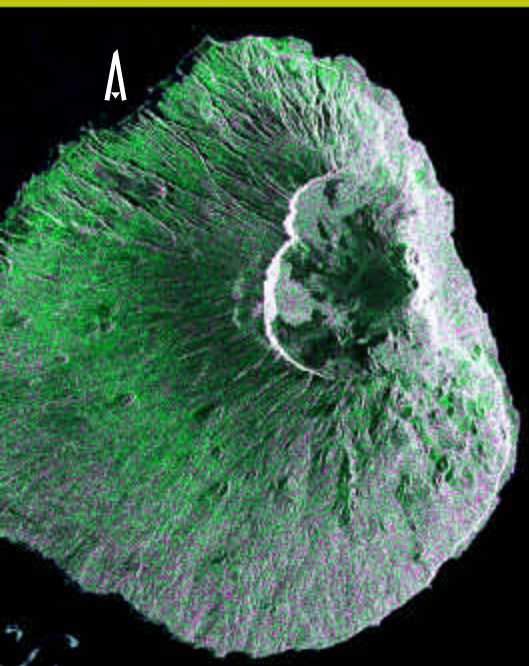
Niuafo'ou Island
Approximately eight kilometres wide, this island of the Tonga Republic is one of the most classical examples of a partially submerged volcanic edifice with a flooded caldera. Several previously documented mid-oceanic ridge basalt eruptions are clearly delineated in this multi-temporal RADARSAT-1 image.

Diego Garcia Island
Located at the southern extreme of the Maldives in the Indian Ocean, this wisp of an island is a typical oceanic coralline atoll, with fringing reefs and carbonate banks. The multi-date RADARSAT-1 image reveals the subtleties of the landscapes in the island, which is a major U.S. and U.K. air and naval base. The two colours shown in the lagoon are ship positions on two different imaging dates. Monitoring coastal margins of islands is a key aspect in measuring sea-level adjustments for otherwise stable oceanic entities.

Fogo Island
Located off the coast of Africa, Fogo is the highest (2 900 metres) volcano in the Atlantic Ocean. Last active in spring 1995, its new lava flows can be seen in this RADARSAT-1 image as bright surfaces on the western slope, partly in radar shadow, of the sharp cone within the larger caldera. Parasitic scoria cones can be seen along the southern and western flanks. RADARSAT-1 is well suited to observing volcanos when they erupt as they are often enshrouded with clouds of airborne material.

Viewing Oceanic Islands





▶ Peter Island
This 19-kilometre long island represents the tip of a gigantic volcano whose summit has been buried and sculpted by snow and ice. This RADARSAT-1 image may be the first satellite image ever acquired of this frequently cloud-covered Antarctic-plate volcano. It shows the complexity of features that were previously unknown and shows a large area near the island where an ice floe is breaking up.

▶ Russell Islands
The series of curving reef terraces and fringes of this Solomon group of islands in the Pacific Ocean is the result of tectonic uplift and erosion. This multi-temporal RADARSAT-1 image illustrates the sensitivity of orbital imaging radar to these phenomena. Much of the relatively flat landscape observed in the image is savannah.

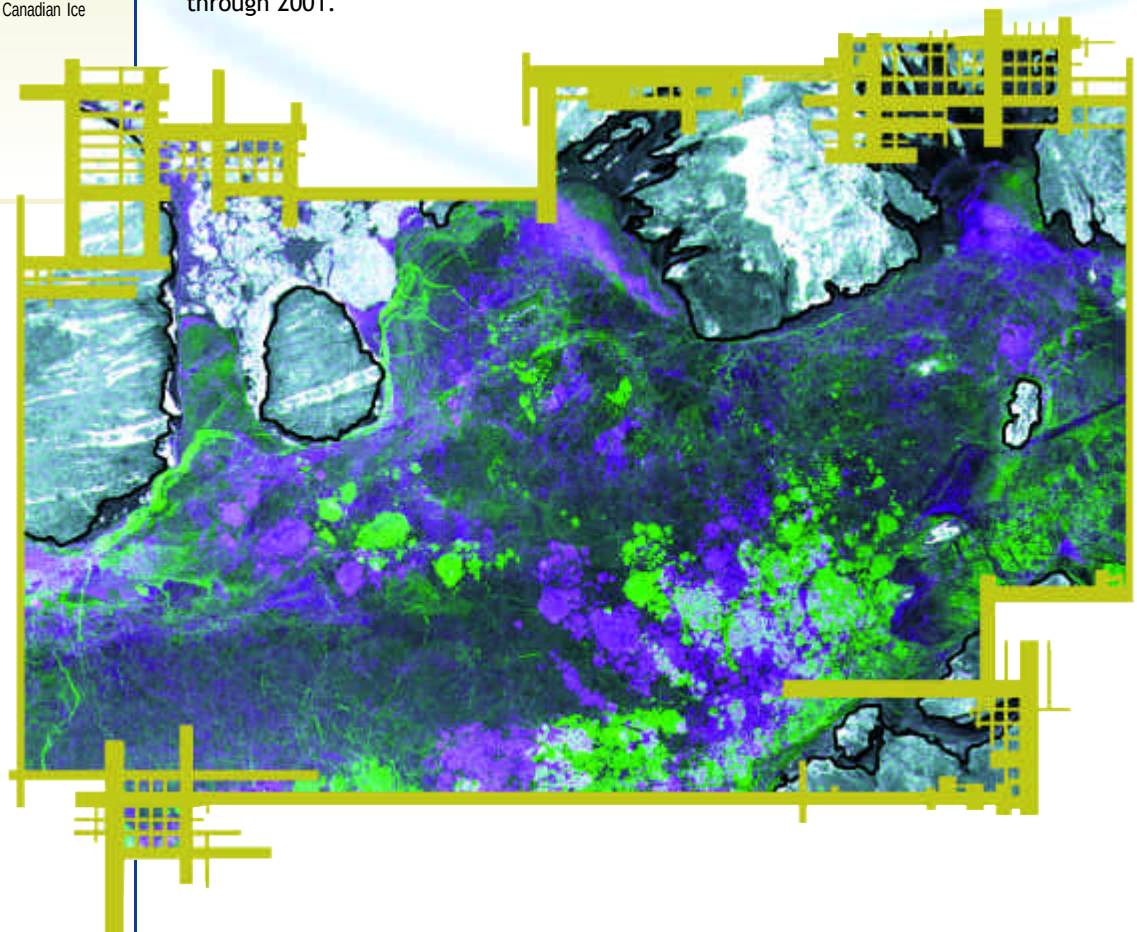
RADARSAT-1 Observes the Arctic

Canadian Ice Service: Top RADARSAT-1 Client

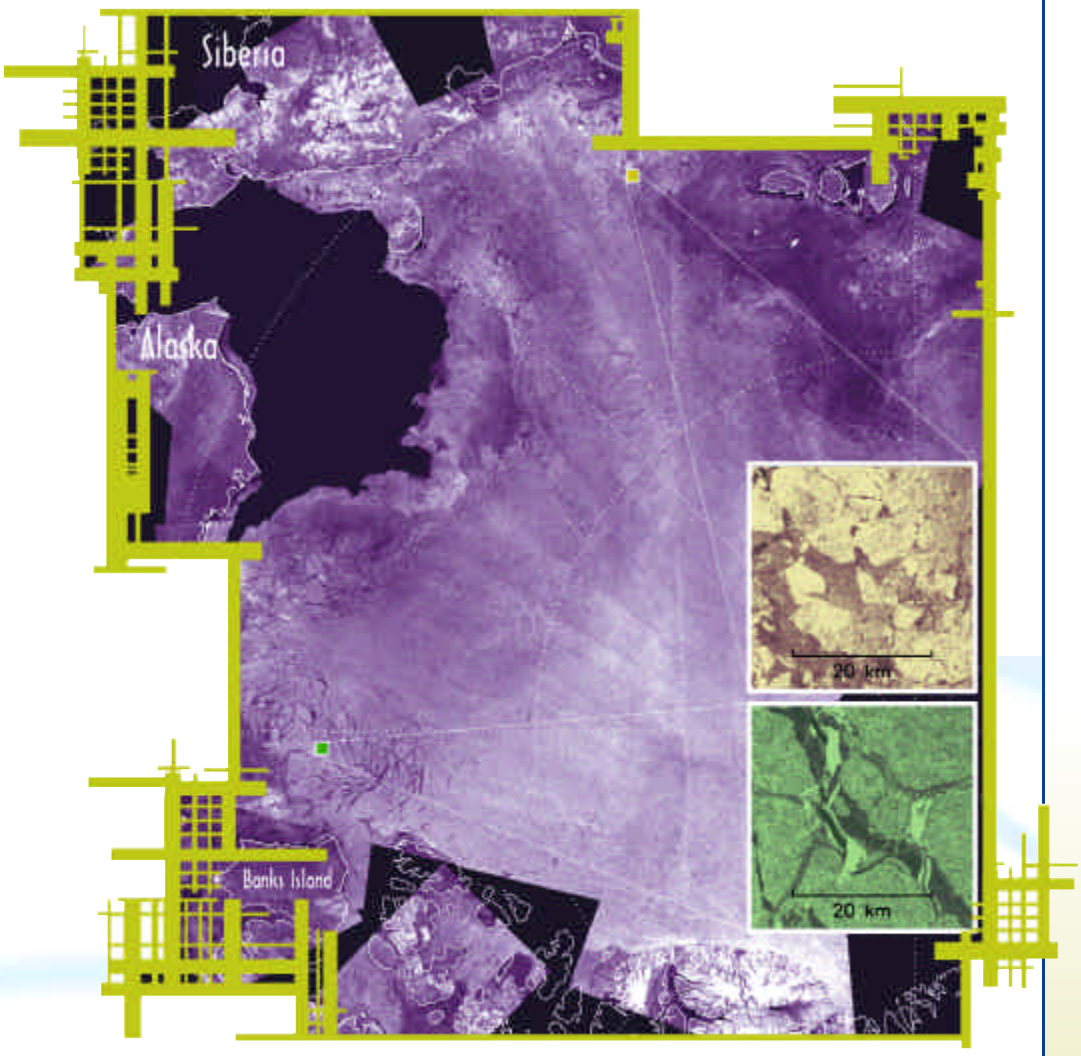
Over the five years RADARSAT-1 has been in operation, the Canadian Ice Service (CIS) continues to be one of the leading users of RADARSAT-1 data. To date, CIS has received more than 17 000 scenes, of which over 13 000 have been archived since July 1997.

Relying on RADARSAT-1 as its primary data source enables CIS to fulfil its mandate and provide products and services to clients. "Without RADARSAT-1, CIS would be spending several additional million dollars each year to acquire equivalent coverage using aircraft to meet its operational needs. During the past five years, the strong relationships that have been forged with and the services provided by both CSA and RSI have been instrumental in making RADARSAT-1 a key success for CIS. We look forward to continued operations and availability of RADARSAT-1 data and SAR data continuity with the future successful launch of RADARSAT-2," said Mr. Dean Flett, Manager, Remote Sensing, Canadian Ice Service, Environment Canada.

In spring 2000, CIS worked with RSI to distribute RADARSAT-1 based ice break-up products to the communities of Arctic Bay and Pond Inlet, Nunavut. As part of a prototype advisory and warning system/service, these image products are intended to provide northern communities with crucial information on the stability of shorefast sea ice to help prevent search and rescue incidents involving people drifting away on ice floes. Dynamic ice edges and dangerous ice areas with a high potential for fracture can be identified in these products, which have been well received by the native communities. Further development and validation of the service and products will continue through 2001.



Using repeat pass RADARSAT-1 imagery, the Canadian Ice Service develops change detection products, which highlight areas of ice cover that have changed over RADARSAT-1's 24-day repeat cycle. In this ScanSAR Wide image, the displacement of the ice cover in the Eastern Viscount Melville Sound is shown. Purple areas show the ice cover on November 11, 2000; green areas show the ice cover on December 5, 2000.



Consisting of 16 RADARSAT-1 scenes, this 100-metre resolution radar mosaic of the western Arctic Ocean sea ice encompasses an area nearly 8.1 million square kilometres in size. The ScanSAR Wide imagery was acquired between November 3 and 6, 1997, at which time a large part of the Beaufort and Chukchi Seas was still covered by open water. Insets show detailed features of the floes and leads in the image.

Understanding the Evolving Arctic Ocean Sea Ice Cover

Routine radar maps of the Arctic Ocean sea ice cover have been acquired by RADARSAT-1 since November 1996 as part of a NASA program to monitor ice motion and deformation. Such observations can be useful in applications including analyzing new ice climatologies, testing ice models or new ideas on sea ice rheology, and assimilating this data into sea ice models.

These complete radar maps of the Arctic Ocean cover an area of approximately seven million square kilometres and are collected every three to six days. High resolution and repeat frequency are crucial for resolving the small-scale motion of the ice cover. At present, RADARSAT-1's ScanSAR beam with its wide swath capability is the only imaging mode that offers this type of spatial and temporal coverage.

Downlinked to both the Alaska SAR Facility and the Tromso Satellite Station and processed to 100-metre resolution, the sequential radar maps provide an amazingly detailed look at how the ice moves and how this motion varies in space and time. For the first time, basin-scale views can be produced of the small-scale ice motion and deformation that are responsible for openings and closings of the ice cover. Openings in the ice cover create areas of open water that produce the most ice growth, the most turbulent heat flux to the atmosphere, and the most salt flux to the ocean. Ridged ice and rafted ice are produced during a closing event.

To date, more than four years of almost continuous observations of the Arctic Ocean have been acquired using RADARSAT-1. This unique data set represents an important contribution to the understanding and monitoring of the climate and evolution of the Arctic Ocean sea ice cover.

Responding When Disaster Strikes

Following the UNISPACE III conference held in Vienna, Austria in July 1999, CSA signed the International Charter on Space and Major Disasters, which was initiated by the European and French space agencies (ESA and CNES). The International Charter aims at providing a unified system of space data acquisition and delivery to those affected by natural or man-made disasters through authorized users. Each partner agency has committed resources to support the provisions of the Charter and thus is helping to mitigate the effects of disasters on human life and property.

In readiness for their respective roles in this internationally cooperative program, the partner agencies together conducted a series of tests to verify the reliability of the integrated data acquisition system procedures and functions. With the success of the test runs, the International Charter was declared formally operational on November 1, 2000.

An authorized user can now call a single number to request the mobilization of the space and associated ground resources (RADARSAT, ERS, SPOT) of the three agencies to obtain data and information on a disaster occurrence. A 24-hour on-duty operator receives the call and helps the user put together the preliminary information. The operator then passes on this information to an emergency on-call officer in the space agency whose resources are tasked to obtain the first set of data. Data acquisition and delivery takes place on an emergency basis, and a project manager, who is qualified in data ordering, handling and application, assists the user throughout the process.

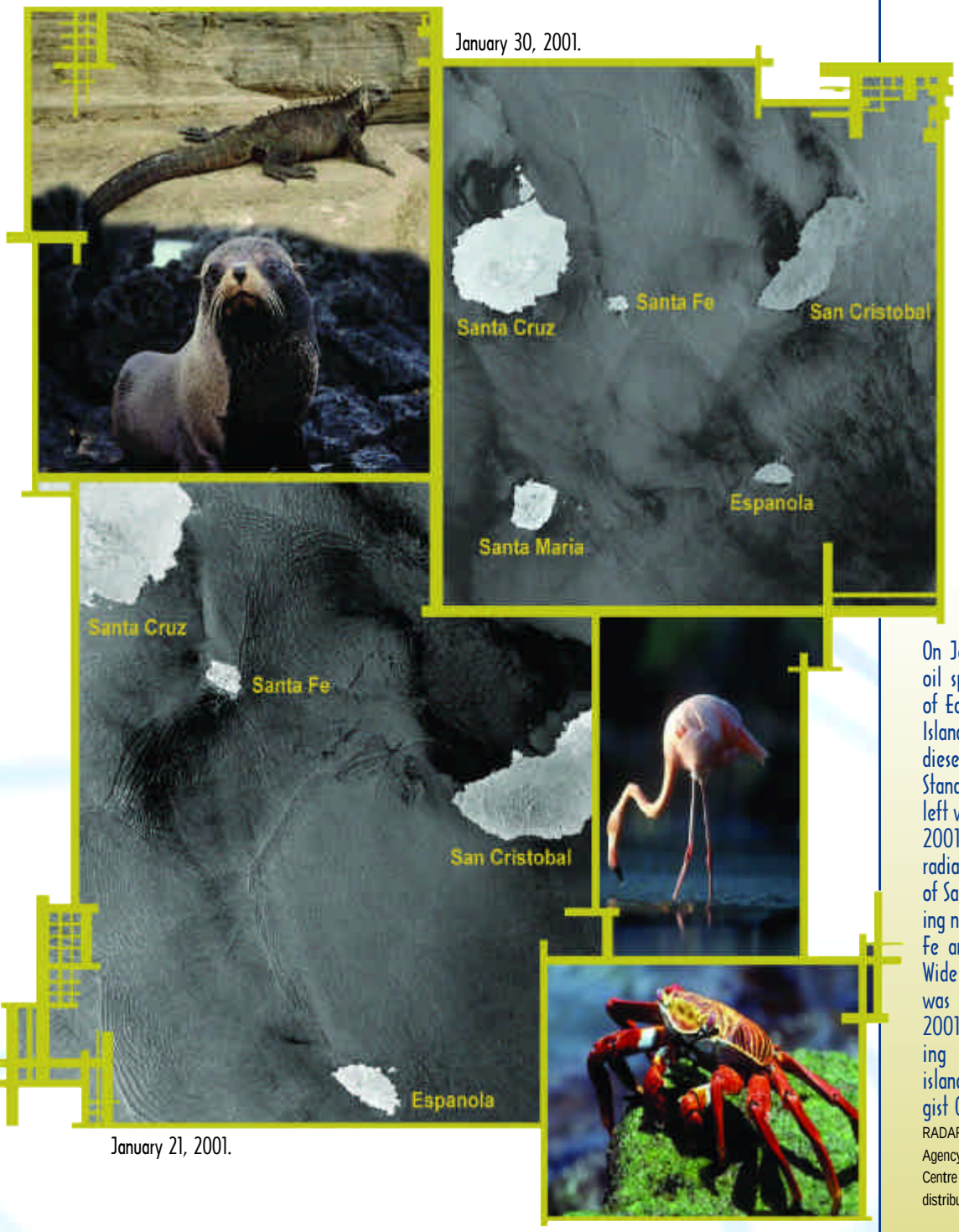
Requests for data under the International Charter have already been fulfilled, covering a wide range of disasters including a landslide in Slovenia, an earthquake and resulting landslides in El Salvador, an oil spill off the Galapagos Islands, and an earthquake in India; all of which occurred from November 2000 to January 2001.

In addition, CCRS provided interpreted RADARSAT-1 imagery in record time in response to an urgent request made on October 19, 2000 to monitor and assess the devastating flooding of Italy's Po River. The imagery was acquired, processed, interpreted and delivered electronically to ESA in less than 12 hours from the time of acquisition, and distributed to the ESA Council on the same day CSA signed the International Charter.

Hurricane Watch 2000

Once again, CSA, CCRS and NOAA teamed up during the Atlantic Basin hurricane season (July to October 2000). ScanSAR Wide images of Hurricanes Alberto, Debby, Florence, Gordon, Isaac and Joyce were acquired concurrently with coordinated flights with NOAA's P-3 hurricane penetration aircraft.

In addition to acquiring images of the eyes of Hurricanes Alberto and Florence, more images were returned this year that show well-organized, secondary atmospheric flow phenomena, such as boundary layer roll vortices that occur between the outer bands of intense precipitation within the storm. The occurrence of these structures was unknown prior to the availability of high-resolution RADARSAT-1 images and helps further the understanding of hurricane dynamics.



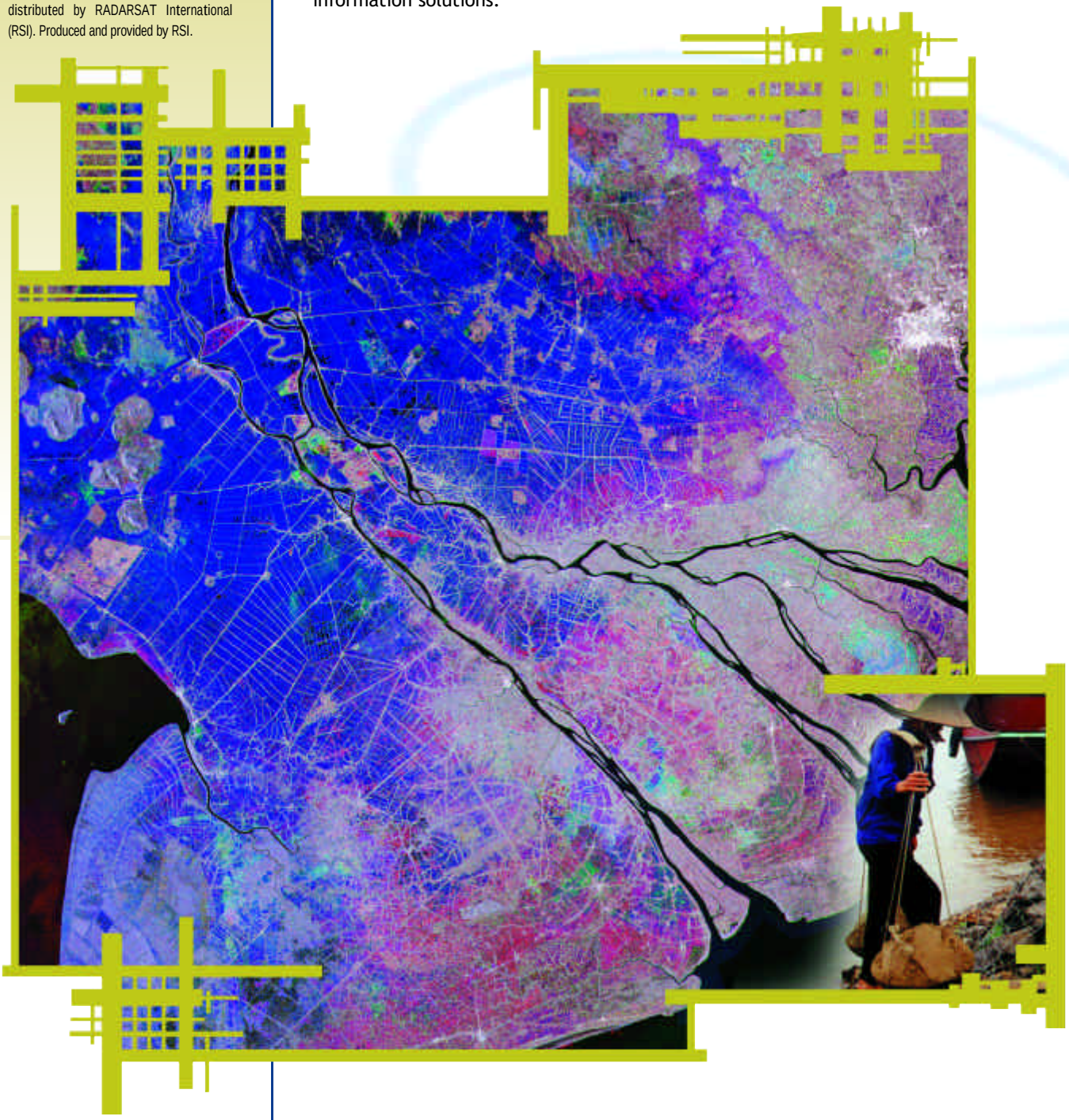
On January 16, 2001, a major oil spill occurred off the coast of Ecuador, near the Galapagos Islands when a tanker carrying diesel fuel ran aground. The Standard beam image on the left was acquired on January 21, 2001, and the spill can be seen radiating from the western tip of San Cristobal Island and moving northwest towards the Santa Fe and Santa Cruz Islands. The Wide beam image on the right was acquired on January 30, 2001, and shows the spill moving north, away from the islands made famous by biologist Charles Darwin.

Disaster Watch 2000

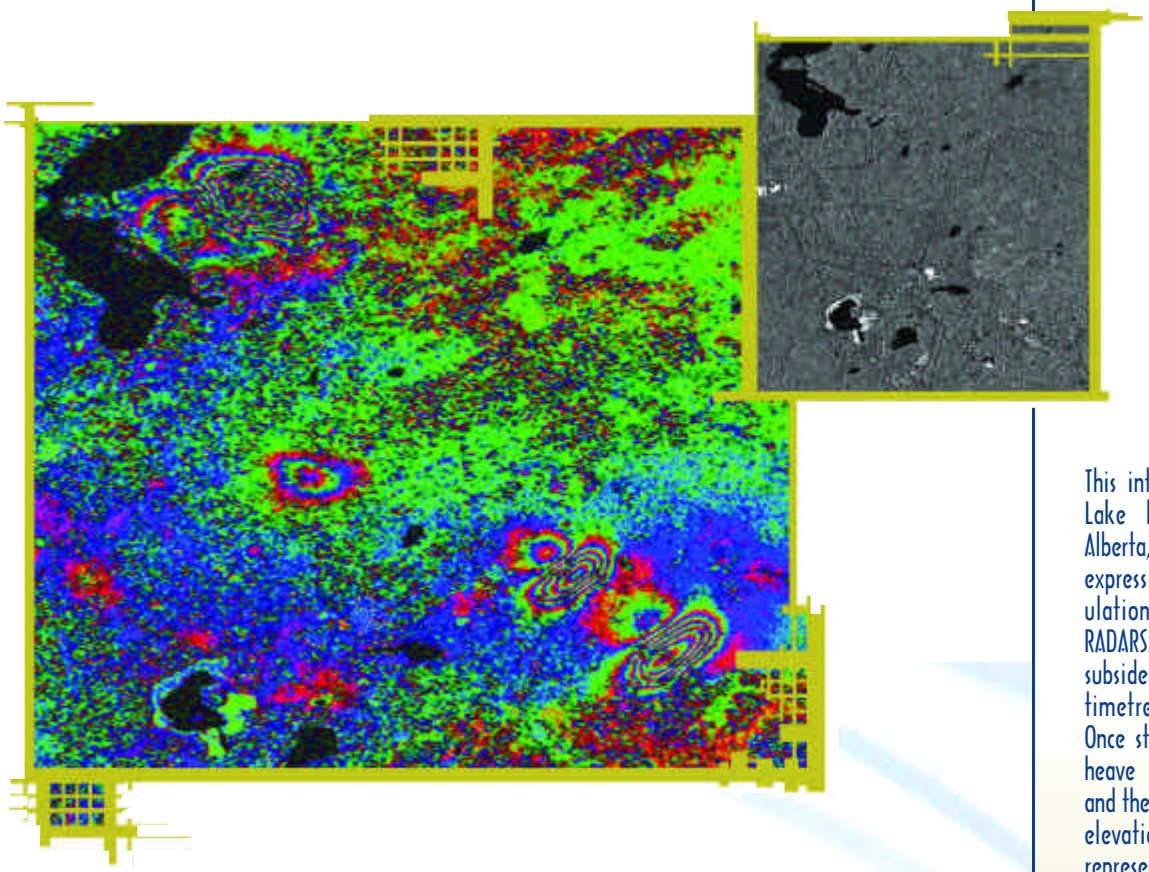
Since April 2000, more than 200 last-minute disaster-related scenes were acquired – more than twice the number of scenes acquired last year. Over the past year, this joint CSA/RSI program covered disasters in El Salvador, India, Vietnam, Brazil, and England, among others. Also, a Disaster Watch Database was created to promote the program and provide a useful search engine for interested clients.

Next-Generation Information Solutions Win Clients

Over the past year, RSI saw a discernible shift on many client projects from standalone satellite data products to multi-data solutions. "A new generation of information solutions that comprise multiple data sources is emerging. Moreover, advances in broadband mobile communications, web-enabled technologies and the upcoming availability of new satellite imaging systems are revolutionizing the way the Earth observation community does business," said RSI President Roland S. Knight. "Indeed, we've already seen how operational and near real-time decision-support tools are rapidly becoming routine. I am confident that RSI is ready to take a leading role in delivering this next generation of information solutions."



ScanSAR Narrow B images were merged to show the extent of flooding in the Mekong River Delta in Vietnam in September and October 2000. RADARSAT-1 data is aiding disaster management agencies in Vietnam through a turnkey RADARSAT Flood Information System, which is helping to improve the country's flood response activities.



This interferogram of the Cold Lake bitumen oil field in Alberta, Canada shows surface expressions of cyclic steam stimulation. It demonstrates RADARSAT-1's ability to map subsidence/absidence at centimetre/millimetre accuracy. Once steam is injected, surface heave occurs, oil is extracted and the surface returns to initial elevation. Each colour cycle represents approximately 3.6 centimetres of vertical motion.

In 2000, a total of 7 564 scenes were processed. Sea ice, surveillance, mapping, hydrology and geology remain top commercial applications. RSI signed up 13 new distributors over the past year, bringing the total to 70 worldwide. With the addition of four more operational network and mobile stations and three new resource centres, RSI now delivers RADARSAT-1 data solutions to nearly 600 clients and partners in 57 countries.

Integral to RSI's business strategy is offering innovative image solutions and services, as well as obtaining substantial and long-term commitments through regional partners. A highlight in 2000 was the formation of the ICT Dev Group, a new division that partners with companies specializing in three areas: information technology, geospatial technology and socio-economic issues, to develop customized information networks. Following the success of several pilot projects, RSI and its partners will implement four new information networks in 2001. These will address illegal fishing, crop insurance/monitoring, oil pollution and flood information services.

RSI signed several new strategic partnership agreements in 2000, including one with ImageONE (Japan). Under the terms of the agreement, RSI granted ImageONE the exclusive rights to distribute non-NASDA RADARSAT-1 imagery in Japan. In return, ImageONE has agreed to a major commitment to purchase RADARSAT-1 data each year for the next three years. Other agreements were signed with value-added companies, such as Spectral Imaging Solutions (Calgary, Alberta) and SYNOPTICS Holding BV (Wageningen, Netherlands), which are generating new cost-effective RADARSAT-1 derived Digital Elevation Model (DEM) and orthorectified image products.

"Over the past five years, we have been delighted to see RADARSAT-1 become a central and ongoing part of many large, operational services such as ice monitoring, flood response and oil seep detection," added Mr. Knight. "As anticipated, our clients are demanding customized solutions for these mission-critical services – solutions that feature both the use of RADARSAT-1 imagery and derived information as standalone products, as well as the use of the imagery in conjunction with other key data sets including climate, baseline and economic information."

Extending the Reach of RADARSAT-1

The year 2000 marked the launch of CSA's Earth Observation Application Development Program (EOADP), which promotes the development of innovative applications that maximize the utilization of Earth observation satellite data generated by CSA-supported missions. EOADP can be viewed as an improved "one-stop" follow-on to previous applications development programs, most of which expired at the end of fiscal year 1999/2000.

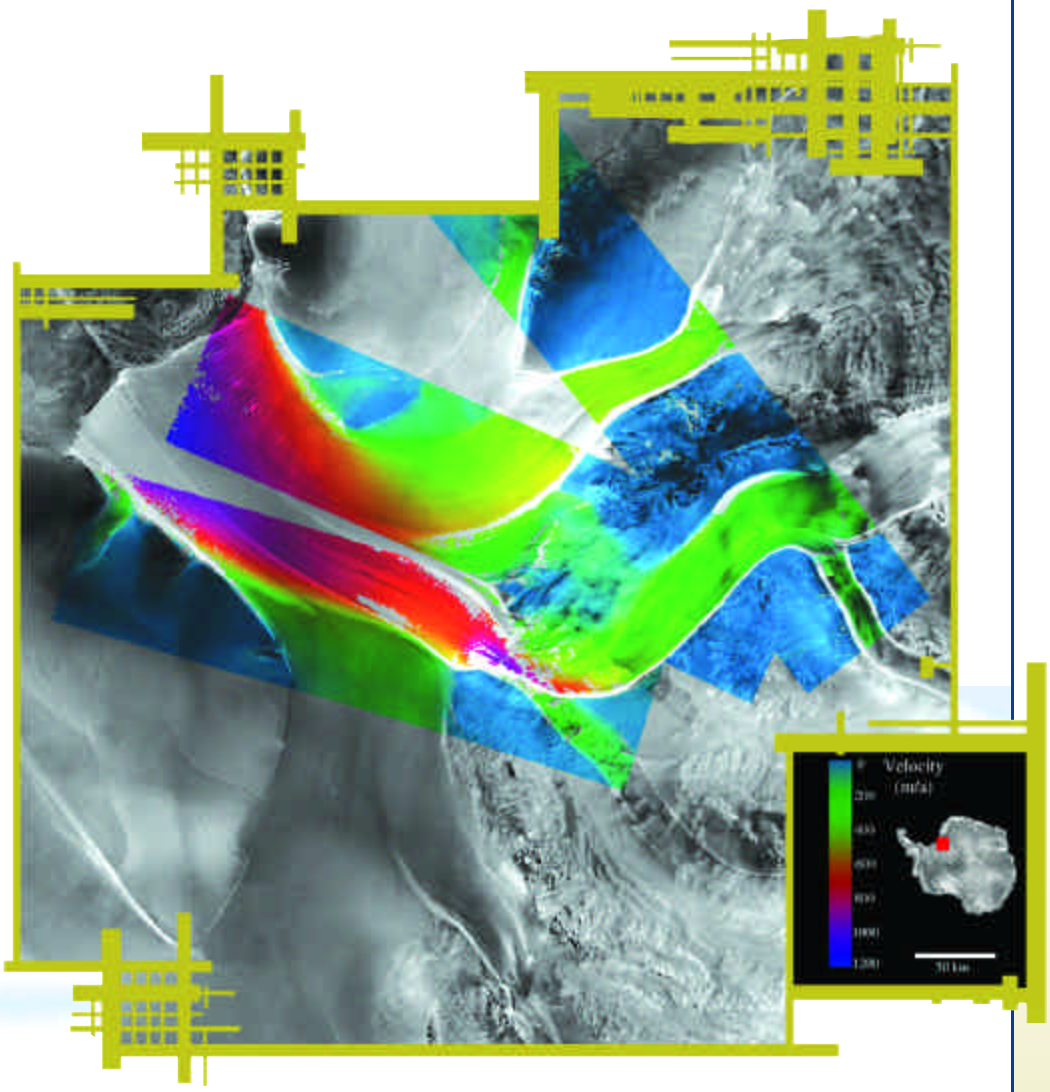
Recently announced was the award of 49 contracts worth a total of 12 million dollars, some of which are highlighted in the table below. "These contracts, awarded to space companies throughout Canada, will support the development of leading-edge technology and applications," said Canada's Minister of Industry Brian Tobin. "Partnerships created through these contracts ensure that the Canadian space industry remains innovative and competitive, and continues to develop niche markets worldwide." The projects awarded flow from both EOADP and the Space Technology Development Program (STDP).

Activities in 2000 also included the sponsorship of a November 7-8, 2000 workshop led by the National Authority for Remote Sensing and Space Sciences (NARSS) in Cairo, Egypt. Approximately 50 people attended from the oil and surveying industry, academic institutions, as well as from NARSS and other government agencies.

In addition, Space Technologies showcased several key RADARSAT-1 successes in 2000 including the Canadian Consulting Engineering Award of Excellence presented to Tecsult International for its RADARSAT-1 based tool that improves the accuracy of finding groundwater sources in developing countries. This application was developed under the Radarsat User Development Program (RUDP) program.

Another major success was the presentation of the Mark-Drake Award to Hatfield Consultants Ltd. by the Canadian International Development Agency (CIDA) and the Alliance of Manufacturers and Exporters Canada. The award recognized the company's excellence in communicating private sector contributions to international cooperation issues through Hatfield's Agent Orange studies in Vietnam. Supported under the RUDP, these studies utilized RADARSAT-1 data to assess the residual environmental effects of the Vietnam War.

Organization	Application
Digital Environmental Management	Develop web-based crop assessment reporting service to help process crop loss insurance claims
Hatfield Consultants	Develop environmental monitoring and management system
LBGI - Le Bureau Geo Info	Develop monsoon flood monitoring system
Viasat Geotechnologies	Develop 3D mapping product to support network layout of third-generation (3G) mobile telephone services
Burnside Environmental	Integrate hyperspectral and RADARSAT-1 data to support mineral exploration and evaluate environmental assessments
Geomat International	Support operations for integrated coastal zone management



This image of the Filchner Ice Shelf from the Antarctic mosaic is overlain with swaths of surface velocity data derived from interferometry. Blue represents low velocities; red and purple represent the fastest flowing areas.

RADARSAT-1 data © Canadian Space Agency 1997, 2000. Received and processed by Alaska SAR Facility. Distributed by RADARSAT International (RSI). Produced and provided by CCRS, courtesy of Byrd Polar Research Center of the Ohio State University.

ADRO-2 Update

This second Application Development and Research Opportunity (ADRO) program focuses on the innovative approaches and applications that were developed mainly under the previous ADRO-1 and ADRO-1 follow-on programs. As well, ADRO-2 encourages researchers and industry to develop new applications and operational programs that take advantage of the vast archive of data acquired by RADARSAT-1 over the past five years. In 2000, CSA awarded 36 projects, NASA awarded 65 projects and RSI awarded five projects.

"By participating in this project, NASA is joining Canada to reaffirm its continuing commitment to foster the development of new applications in the field of Earth observation to further our knowledge and expertise in the management of our natural resources and the monitoring of our global environment," said Mr. Jack Kaye, Director of NASA's Research Division-Office of Earth Science.

RADARSAT-1 Data for Research Use (DRU)

Under a new CSA and RSI agreement, RADARSAT-1 data are now offered at cost-effective prices to the Canadian and international scientific communities for research purposes. Research proposals are being evaluated using pre-established criteria, and if accepted, researchers will receive up to five RADARSAT images per project.

Since the inception of the program in early 2000, proposals from universities, both at home and abroad, have been received. Those accepted cover a variety of application areas including interferometric analysis of active volcanism and ice dynamics, urban land cover mapping, ocean feature analysis, digital terrain modelling and risk assessment.

Trends in Applications Development

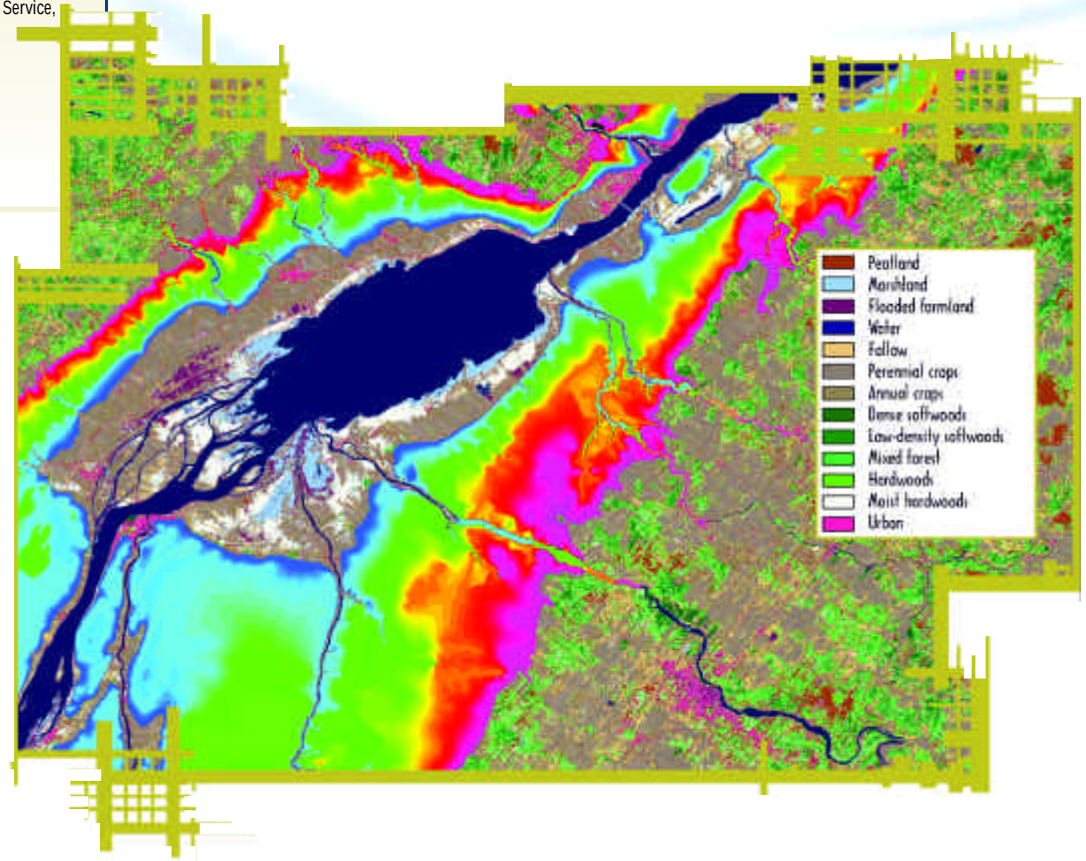
According to CCRS applications development researchers, new developments to integrate RADARSAT-1 data with in-situ measurements and models are emerging. For example, in the area of flood monitoring, RADARSAT-1 data are routinely integrated with maps that show the location of roads and societal structures, and thus increase the utility of the data. Additional developments to integrate in-situ data on stream flows are now under way, which will add a new predictive component to the data analysis.

Similarly, in the area of precision farming and field crop management, the integration of global positioning system (GPS) information, variable rate applicator farm machinery, remotely sensed data, and in-situ based models are paving the way for wide-scale use of remotely sensed data, and helping to predict potential problems. Furthermore, RADARSAT-1 is playing a larger role in climate change studies through the monitoring of ice movement and the subsequent integration of data into the results of climate change scenarios.

Serving Canada's Public Sector

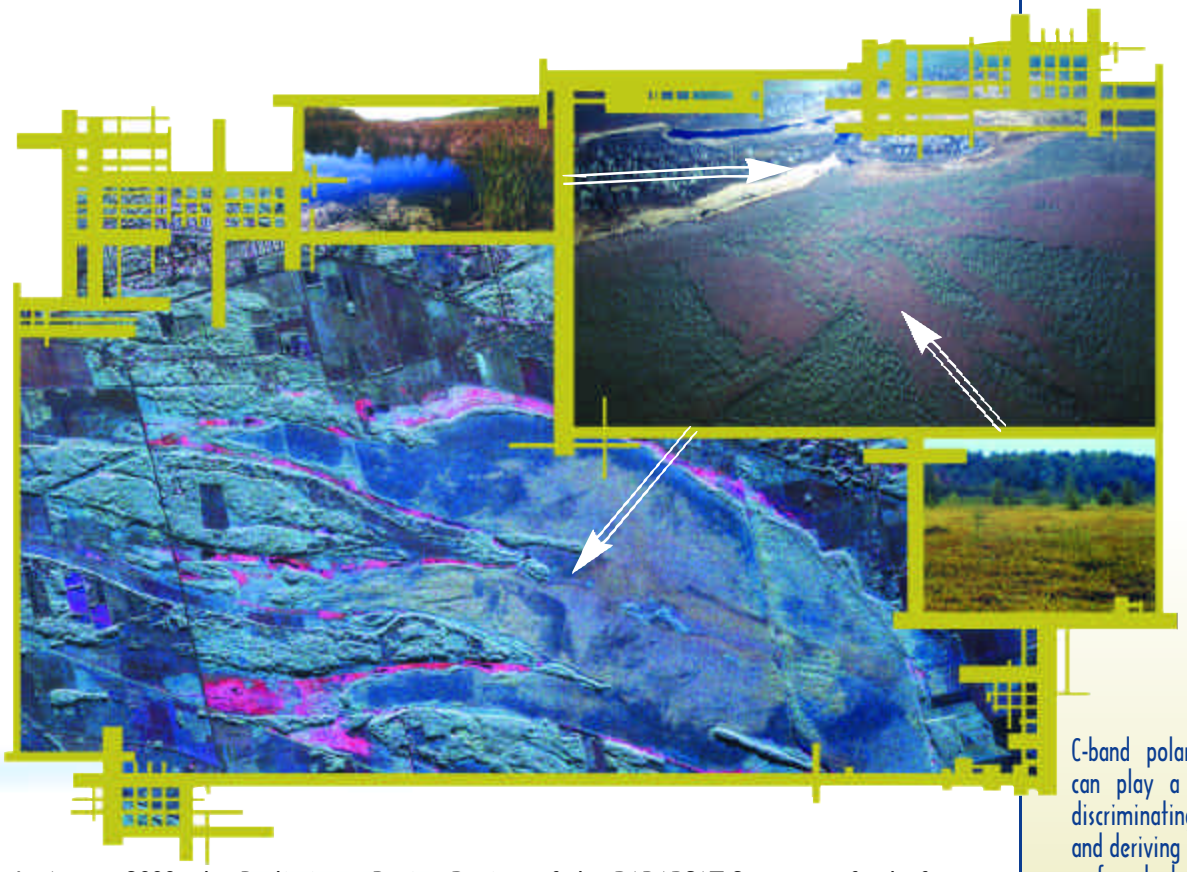
Before the launch of RADARSAT-1 in 1995, most Canadian provinces signed a Memorandum of Understanding (MOU) with CSA to assist the RADARSAT-1 Program in return for preferential access to the RADARSAT imagery. To promote the use of RADARSAT-1 by the provinces, CSA collaborated with provincial agencies to deliver workshops in Nova Scotia, New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan, Alberta and British Columbia. The Canadian value-added industry and RSI actively participated in these workshops by showcasing the applications, tools and services available for utilizing RADARSAT-1 data.

In addition, CSA has been working closely with Canada's Department of Fisheries and Oceans to set up, in partnership with the private sector and other federal departments, an extended operational surveillance pilot project to monitor fishery operations, oil spills and icebergs.



Based on RADARSAT-1 and LANDSAT data, this classified image of Lac St-Pierre, Quebec, Canada is being utilized in a joint project to identify and map all the wetlands in the St. Lawrence River Valley, which covers approximately 16 million hectares. This project is being conducted in partnership with the Canadian Wildlife Service (Environment Canada), Ducks Unlimited, Wildlife Habitat, Université de Montréal and the Canadian Space Agency.

RADARSAT-2: A New Era in Earth Observation



C-band polarimetric SAR data can play a valuable role in discriminating wetland classes and deriving direct estimates on surface hydrology. Acquired by the CCRS CV-580 aircraft, this multi-polarized colour composite shows the Mer Bleue wetland near Ottawa, Canada. The contrast between the bog and surrounding marshland is enhanced through the use of polarimetric data. Offering flexible polarization imaging capabilities, RADARSAT-2 will be able to transmit and receive both horizontal and vertical polarizations.

In August 2000, the Preliminary Design Review of the RADARSAT-2 spacecraft platform was successfully completed. MacDonald Dettwiler Program Manager Hans Baeggli said, "Credit has to be given to Alenia Spazio of Rome, Italy, who was brought late into the game to take over responsibilities of building the spacecraft bus and achieving this very important milestone in a timely manner." Despite the change of platform, the payload subcontractor EMS has also made excellent progress in developing RADARSAT-2. With this achievement, RADARSAT-2 is now firmly on track for launch in 2003.

The RADARSAT-2 program assures RADARSAT-1 users of data continuity and supports the evolution of Canada's Earth observation business. As prime contractor for RADARSAT-2, MacDonald Dettwiler and Associates (MDA) will develop, build, integrate and launch RADARSAT-2. Once operational, RADARSAT-2 will be wholly owned and operated by MDA. In exchange for its investment in the program, CSA will receive an allocation of data from RADARSAT-2 to serve the needs of Canadian government users.

Designed to operate for seven years, RADARSAT-2 features state-of-the-art SAR technology, and supports all the existing RADARSAT-1 beam modes, while offering powerful new capabilities. These include improved spatial resolution (three to 100 metres), fully flexible polarization options and the ability to acquire images to the left and right of the satellite, which will double the accessibility swath. The three-metre resolution data generated by RADARSAT-2 will be the highest-resolution commercially available SAR data, offering enhanced detection of closely spaced objects, as well as enhanced definition of other objects. As the first commercial radar satellite to offer multi-polarization (HH, HV, VH and VV), RADARSAT-2 will offer significantly improved surface discrimination.

This year also saw MDA and CSA enter into an agreement to undertake the first phase of a two-phase RADARSAT-3 mission definition/feasibility study to explore the possibility of a RADARSAT-3 mission, which could operate in tandem with RADARSAT-2.

The mandate of the Canadian Space Agency (CSA) is to promote the peaceful use and development of space, advance the knowledge of space through science, and ensure that space science and technology provide social and economic benefits for Canadians. As a result, CSA promotes an environment where all levels of organizations will pursue excellence collectively, advocate a client-oriented attitude, support employee-oriented practices and open communications, commit to both empowerment and accountability, and pledge to cooperate and work with partners to our mutual benefit.

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