Agence spatiale canadienne | Canadian Space Agency

EARTH AND ENVIRONMENT

Significant Canadian Events and Achievements Report-2003

www.space.gc.ca

GOVERNMENT OF CANADA SPACE ACTIVITIES FOR THE EARTH AND ENVIRONMENT SECTOR

Canada

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Cover: Scisat satellite

The year 2003 marks a significant milestone in Canada's Earth and Environment (E&E) activities. A number of events have shaped E&E activities in a lasting fashion, including the launch of Scisat-1, the initiation of a large number of multilateral, user-driven Earth observation projects, the convening of the first Earth Summit of the world's leading spacefaring nations and the completion of the initial phase of the Global Monitoring for Environment and Security (GMES) program.

Scisat-1 is an all-Canadian science satellite and a symbol of Canadian scientific excellence. Scisat-1 also marks a renewed commitment to space science and atmospheric research of importance in areas of global interest. Scisat-1 carries the Atmospheric Chemistry Experiment, whose principle goal is to investigate the chemical processes that are involved in the distribution of ozone in the atmosphere. The mission will work in conjunction with other instruments and missions planned by the National Aeronautics and Space Administration (NASA) in the U.S., the European Space Agency (ESA), and other international partners over the next decade to gain a better understanding of the chemistry and dynamics of the atmosphere that affect the Earth's protective ozone layer. The analysis of the large amount of data that will be collected will support and validate Canada's compliance with international environmental policies such as the Montreal Protocol on Substances that Deplete the Ozone Layer.

A second significant achievement is the launch of a series of new initiatives under the Canadian Space Agency's Government Related Initiatives Program. The activities have been defined multilaterally and focus on challenges facing Canadians at the national level. They constitute a reaffirmation of the interest in space by a growing number of Government of Canada Departments. The joint investments under this program also underline the Canadian Space Agency's determination to increase operational use of space resources and data in the delivery of the mandates, programs and services of government departments.

Finally, building on the success of recent initiatives such as the International Charter "Space and Major Disasters", the world's leading spacefaring nations met in Washington at an Earth Summit and created an ad hoc Group on Earth Observations. This Group was commissioned to develop a conceptual framework and implementation plan for building comprehensive, coordinated and sustained Earth observation systems. At the same time, the European Union (EU) and ESA are forging a vision of how space assets can enable Global Monitoring for Environment and Security. The GMES program completed its initial phase in 2003 and begins its implementation period in 2004. These landmark commitments to promote collaborative use of space assets are characterized by newly affirmed high-level political support within the G-8 and other leading countries and may herald greater cooperation among international partners through targeted Earth observation activities.

This E&E Significant Events and Achievements Report is presented according to key themes and includes sections documenting the design and development of new sensors and technologies. This Report aims to be a comprehensive source of Canadian Earth observation achievements for the year 2003. We trust it will constitute a solid reference for you on Canadian activities and increase your appreciation of the vast contribution space assets are making to E&E activities both here in Canada and abroad.

Marc Garneau
President
Canadian Space Agency

THE CANADIAN SPACE AGENCY AND ITS CANADIAN SPACE PROGRAM PARTNERS

CANADIAN SPACE AGENCY

Since its creation in 1989, the Canadian Space Agency has ensured that all Canadians learn and benefit from the innovations of space science and technology to the greatest extent possible. Its objectives are to support and promote a highly competitive space industry and address the needs of Canadian society. The Agency plays the lead role in the implementation of the Canadian Space Program. With almost half of Canada's Gross Domestic Product growth in the knowledge-intensive sectors of the economy, the space program is a key driver behind continued leadership on the world stage, new opportunities for industry and scientists, and long-term social and economic benefits for all Canadians. In its implementation of the Canadian Space Program, the Canadian Space Agency works in close partnership with a large number of Government of Canada departments and agencies, provinces and territories, university science and research communities, domestic space industries and international space agencies.
www.space.gc.ca

NATURAL RESOURCES CANADA

Natural Resources Canada is the federal government department specializing in the sustainable development and use of natural resources, energy, minerals and metals, forests and earth sciences. Natural Resources Canada deals with natural resource issues that are important to Canadians and looks at these issues from both a national and international perspective, using its expertise in science and technology, policy and programs. In addressing this mandate, space data and assets have long been used, particularly through the leadership roles played by the Canada Centre for Remote Sensing and the Canadian Forest Service. Natural Resources Canada is also developing the GeoConnections Discovery Portal (formerly known as CEONet), including the Canadian Geospatial Data Infrastructure to provide users with real-time access to remote sensing satellite and other spatial databases, both land and ocean, through the Internet. www.nrcan-rncan.gc.ca

ENVIRONMENT CANADA

Environment Canada's mandate is to preserve and enhance the quality of the natural environment, including water, air and soil quality, to conserve Canada's renewable resources, including migratory birds and other non-domestic flora and fauna, to conserve and protect Canada's water resources, to carry out meteorology, to enforce the rules made by the Canada - United States International Joint Commission relating to boundary waters, and to coordinate environmental policies and programs for the federal government. In the past, two sectors within Environment Canada have been major users of Earth observation services and data: the Meteorological Service of Canada uses space data for research into climate change and for weather prediction and reporting, while one of its branches, the Canadian Ice Service, is the single largest Canadian user of RADARSAT.
www.ec.gc.ca

CANADA CENTRE FOR REMOTE SENSING

Within the Earth Sciences Sector of Natural Resources Canada, the Canada Centre for Remote Sensing, founded in 1972, is an internationally-recognized leading centre of excellence in the use of Earth observation data, and supports an expanding industry sector including world leaders in global ground station, image analysis and radar mapping markets. The Centre is responsible for the reception, processing, archiving and dissemination of remotely sensed data for Canada. In conjunction with the private sector and academia, it develops remote sensing technology and applications. Through its National Atlas of Canada team, the Centre also works with industry to develop geospatial information applications. www.ccrs.nrcan.gc.ca

CANADIAN ICE SERVICE

The Canadian Ice Service, a branch of the Meteorological Service of Canada, is the leading authority for information about ice in Canada's navigable waters. Its mission is to provide timely and accurate ice information. The Canadian Ice Service annually collects vast amounts of ice and iceberg data - mostly from remote sources (satellites, reconnaissance aircraft and ships). Applying sophisticated computer models and drawing on years of experience, Canadian Ice Service experts use this data to prepare and issue charts, bulletins and special warnings for safe and efficient marine operations in Canada's ice-encumbered waters, particularly for navigation in Canada's North and the Gulf of St-Lawrence and Great Lakes waterways. ice-glaces.ec.gc.ca

CANADIAN FOREST SERVICE

The Canadian Forest Service promotes the sustainable development of Canada's forests and competitiveness of the Canadian forest sector. Science and technology (S&T) research is undertaken and policy created with the knowledge that 94 percent of Canada's forests are publicly owned. As the premier forest research and national policy coordination agency in Canada, the Forest Service plays a pivotal role in building consensus on key forest issues, shaping national and international forest agendas and generating and transferring knowledge through world-class forest research.
Canada requires a new forest measuring and monitoring system that responds to key policy drivers related to climate change and to report upon sustainable forest development both nationally and internationally. The Canadian Forest Service, in partnership with the Canadian Space Agency, is using space-based technologies to create products for forest inventory, forest carbon accounting, and monitoring sustainable development. www.nrcan.gc.ca/cfs-scf/

AGRICULTURE AND AGRI-FOOD CANADA

Agriculture and Agri-Food Canada provides information, research and technology, policies and programs in order to achieve security of the food system, health of the environment and innovation for growth. The agriculture and agri-food sector is vital to Canada's economic success, generating $130 billion in sales annually and accounting for almost two million jobs. The Agricultural Policy Framework was designed to ensure continuation of this success and to position Canada as the world leader in food safety, innovation and environmentally responsible production. The federal government and all of Canada's provinces and territories have now signed this framework accord. Information about the agricultural resource base and about the management of this resource will be key to the success of the Agricultural Policy Framework, and imagery acquired from orbiting satellites offers a wealth of information about land resources. www.agr.gc.ca

FISHERIES AND OCEANS CANADA

Fisheries and Oceans Canada is responsible for policies and programs in support of Canada's economic, ecological and scientific interests in oceans, coastal zones and inland waters, for the conservation and sustainable utilization of Canada's fisheries resources in marine and inland waters, for leading and facilitating federal policies and programs on oceans, and for safe, effective and environmentally sustainable marine services responsive to the needs of Canadians in a global economy and of using space data in support of both scientific research and operational mandates. Under the aegis of Fisheries and Oceans Canada, the Canadian Coast Guard uses space-based, Earth observation-derived ice products produced by the Canada Centre for Remote Sensing and the Canadian Space Agency, in cooperation with the Canadian Ice Service.
www.dfo-mpo.gc.ca

DEPARTMENT OF NATIONAL DEFENCE

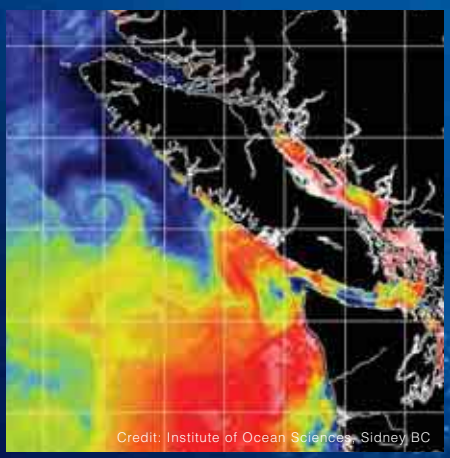
The Department of National Defence is responsible for Canada's military space program, and undertakes activities in conjunction with the Canadian Space Agency and other federal government departments when a dual military-civilian use is identified. The Department of National Defence is responsible for the Office of Critical Infrastructure Protection and Emergency Preparedness, which uses space data for disaster management and mitigation activities and to protect infrastructure. Space assets are also brought to bear in support of Canadian Forces overseas activities such as United Nations-sponsored peacekeeping missions.
www.dnd.ca

METEOROLOGICAL SERVICE OF CANADA

The Meteorological Service of Canada is Canada's source for meteorological information. It monitors water quantities, provides information and conducts research on climate, atmospheric science, air quality, ice and other environmental issues, making it an important source of expertise in these areas. The Service stretches from the high Arctic, at air quality research stations, to weather offices and water stations across the country, to buoys in three oceans, and to space.
www.msc-smc.ec.gc.ca

Oceans

Space contributes in many ways to our ability to understand, manage and develop our environment and its resources. Data are collected in relation to water – oceans and inland waters –, land-cover, and the atmosphere and assist us in understanding and acting in a broad range of areas including climate change and disaster management.



Sea surface temperature off the West coasts of British Columbia and Washington State

Ocean Productivity

Ocean temperature and salinity have been routinely measured, in situ, since the earliest oceanographic expeditions, and they comprise the two most basic physical variables that define the state of the ocean. For the past 30 years, sea surface temperature has been monitored operationally from space, but the concomitant capability to assess sea surface salinity has not existed. The sensors capable of measuring salinity from space are now under development, and Fisheries and Oceans Canada is preparing for the launch of salinity satellites by determining how sea surface salinity can be assimilated into global and regional ocean circulation models and by studying the effects of cold water and ice on sensor sensitivity.

In a joint project with industry, Fisheries and Oceans Canada has evaluated the solar stimulated fluorescence signal from phytoplankton chlorophyll as observed by the Sea-viewing Wide Field-of-view Sensor (SeaWIFS) and Moderate Resolution Imaging Spectrometer (MODIS) for estimating chlorophyll, identifying water masses, and assessing the efficiency of the chlorophyll fluorescence process. This project is being expanded to include data from the Medium Resolution Imaging Spectrometer (MERIS) aboard the European Space Agency's environmental satellite ENVISAT, which now produces similar imagery with higher spatial resolution, enabling monitoring of coastal zone productivity.

Under the Canadian Space Agency's Government Related Initiatives Program, Fisheries and Oceans Canada has launched a study of ocean productivity entitled "The Ocean's Pulse", in collaboration with Environment Canada, Dalhousie University, the University of Manitoba, the Government of British Columbia, Borstad Associates, the University of Calgary, the Royal Canadian Military College, Sherbrooke University, ISMER (Rimouski) and the Laboratoire océanographique de Villefranche-sur-Mer (France). The study aims to develop the capability of operationally using satellite-sensed ocean colour data, merged with in situ measurements and integrated modelling efforts, to implement ecosystem-based resource management and to protect the offshore and coastal marine environments. The four components of the project are data products, algorithm development and validation, optical properties and ocean colour assimilation into ecosystem models. One key result of the project will be an ocean model comprising biological as well as physical variables, which can serve as a new tool for integrated ocean management.

The Canadian Space Agency this year conducted an in-depth review of MODIS and MERIS data use in Canada and potential new areas of application.

Ocean Dynamics

Satellite altimetry is used to map sea level from space on Canada's east and west coasts. Sea level change will be one of the most evident effects of climate change and is one that directly affects a number of coastal activities. Coupled with information on the thermal and saline structure of the ocean, sea level data can be used to infer the transport of heat and salt, both of which are critical to the study of climate change.

Altimetric data is also being used in conjunction with high-resolution coastline and wind data to better predict storm surges and coastal flooding on Canada's east coast. Wind information derived from RADARSAT enhances the ability to study the impact and effects of winds on the accuracy of abundance surveys of fish eggs and larvae and ultimately on the estimation of fish stock abundance in the coastal zone.

Satellite data is also critical in the measurement and modelling of the interaction between oceans and the atmosphere, and is the subject of a study initiated in 2003 with funding from the Canadian Space Agency's Government Related Initiatives Program. The project is led by the Meteorological Service of Canada in cooperation with Fisheries and Oceans Canada, Agriculture and Agri-Food Canada, and Natural Resources Canada. A wide range of sub-projects are being undertaken, including assimilation into numerical weather prediction models of data from new satellite atmospheric sounding instruments (high-resolution infrared sounders starting with the Atmos-pheric Infrared Sounder on NASA's Earth Observing System (EOS), and Global Positioning System radio-occultation receivers in low earth orbit starting with the Gravity Recovery and Climate Experiment or GRACE mission), assimilation of satellite altimeter data into a model of the North Pacific Ocean, use of RADARSAT Synthetic Aperture Radar data for validation of very-high-resolution (2-3 km) numerical weather prediction wind fields in coastal regions, validation of satellite atmospheric chemistry measurements from MAESTRO and instruments on ENVISAT, and development of a coupled land-surface-atmosphere data assimilation system focussed on application of satellite soil moisture measurements. Work will initially be based on the Advanced Microwave Scanning Radiometer for EOS instrument, but will later rely on data from other satellites such as HYDROS and SMOS.

Ocean Surveillance

In support of environmental enforcement activities, the Canadian Space Agency's Government Related Initiatives Program is funding a new effort to develop operational monitoring of marine polluters to support environmental enforcement activities: Integrated Satellite Targeting of Polluters (I-STOP). Using RADARSAT data validated with data from traditional aerial resources, the project improves government action targeting polluters on Canada's east and west coasts and in the Gulf of St-Lawrence. This Government of Canada project is undertaken jointly with the Canadian Space Agency, Environment Canada, Fisheries and Oceans Canada/ Canadian Coast Guard, Department of National Defence, Transport Canada, and the private sector's RADARSAT International.

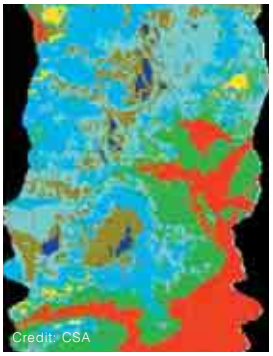
Significant achievements in relation to "Oceans" in 2003 include:

- Use of the MERIS sensor for the production of high-resolution ocean productivity measurements
- Study of Ocean productivity: "The Ocean's Pulse"
- MERIS and MODIS use study
- I-STOP Project Charter
- Operational surveillance "pilot projects" and extension of I-STOP coverage from Atlantic to west coast and Gulf of St-Lawrence.

Freshwater

Lake, River and Watershed Management

Under the aegis of the Canadian Space Agency's Government Related Initiatives Program, the "Wealth of Water" project was initiated in cooperation with Environment Canada's National Water Research Institute, Fisheries and Oceans Canada's Freshwater Institute, the University of Manitoba and the Government of Manitoba. The three-component program



Hyperspectral data used for watershed monitoring

focuses on using satellite observations to link water quality products to land use, chlorophyll mapping of Lake Winnipeg and eco-hydrological mapping from space. The project will allow satellite data and in situ measurement to be combined with algorithms and modelling activities to an unprecedented extent, leading to a better understanding of inland water quality and the processes that affect water quality, and to better mapping of flooding and its impact on hydrological models.

The Canadian Space Agency commissioned a major study on the role of satellite imagery in watershed management. The final report highlights the critical role that satellite data can play in support of landscape and water resource planning. One of the main conclusions of the report is that indicators are being identified as a means of tracking natural change and human activities in watersheds. Space data required to nourish these indicators are broadly available and in many cases already reside in government archives. For much of the simple analysis, low cost or free data sources are available. Linkages are required to ensure available human resources in industry and government are teamed with the growing number of stakeholders interested in playing a role in environmental stewardship to avoid duplication and delay. Watershed management is clearly an area where space assets can be brought to bear to the benefit of populations in Canada and internationally.

Significant achievements in 2003 include:

Production of the Report on watershed management

Initiation of the "Wealth of Water Project: wise watershed, lake and river systems management"

Land-Cover

Forestry

Canada's forests cover some 45 percent of Canada's total landmass, or 418 million hectares. Approximately 94 percent of Canada's forested area is under public ownership.

Forests play an essential role in Canada's economy and contribute to Canadians' high quality of life. Forestry is the largest industry in Canada, supporting 373,000 direct jobs and contributing over $37 billion to our balance of trade. Canada's forests also support a multibillion-dollar recreation and tourism industry and make a significant contribution to global cycles by filtering air and water, regenerating soils and preventing erosion.

Canada is committed to a balance of economic, social and environmental demands on its forests. Canada has a National Forest Strategy and is a party to the United Nations Framework Convention on Climate Change, the Convention on Biological Diversity and the Montreal Process on criteria and indicators for sustainable forest management. Sustainable forest management continues to be one of the key environmental issues in Canada today.

Canada requires forest measuring and monitoring systems that are responsive to key policy drivers related to climate change and will report on sustainable development of Canada's forests both nationally and internationally. This new measuring and monitoring system is being developed to address key policy issues by integrating the best available remote sensing data, geographic information and inventory data. Remote sensing from space will play an essential role in obtaining timely and accurate information on forest cover, biomass, forest change and health.

In terms of Canada's new plot-based National Forest Inventory, satellite data will be used to extend the inventory beyond the one-percent sample and to assess change. In Canada's North, satellite imagery is used to provide key forestry inventory attributes. Remote sensing plays an important role in quantifying the impacts of management, land use, and land use change as identified in the United Nations Framework Convention on Climate Change.

The recent catastrophic wildfires that raged through western Canada serve as reminder of the destruction and losses that forest fires can cause. Remotely-sensed data play an increasing role in wildfire attack planning, monitoring and reporting.

Canadian Land Cover Initiative

The Canadian Land Cover Initiative is an open initiative to facilitate consensus on national land-cover standards and to

Landcover change in Ontario can be monitored using Landsat-5 (left, 1987) and Landsat-7 (right, 2000) data. Scale 1:100,000

integrate land-cover mapping initiatives. It is supported by federal agencies involved in monitoring and reporting on land-cover and land use. It also involves representation from provincial government and non-governmental organizations.

Canadian Land Cover Initiative (CLCI)

The CLCI is an open initiative to facilitate consensus on national land cover standards and to integrate land cover mapping initiatives. It is supported by federal agencies involved in monitoring and reporting on land cover and land use. It also involves representation from provincial government and non-governmental organizations.

Forest Burned Area Mapping

The Canadian Forest Service and the Canada Centre for Remote Sensing are collaborating to develop methods to provide consistent, national-level burned area maps at fine and coarse spatial resolutions, to be used as input for carbon budget modelling. National burned forest estimates require consistency and reliability to minimize budget errors in the national carbon model. The initiative will enhance the level of national mapping information in relation to change detection and more specifically to burned forest mapping, and therefore increase the accuracy of estimates of greenhouse gas emissions from burned forest.

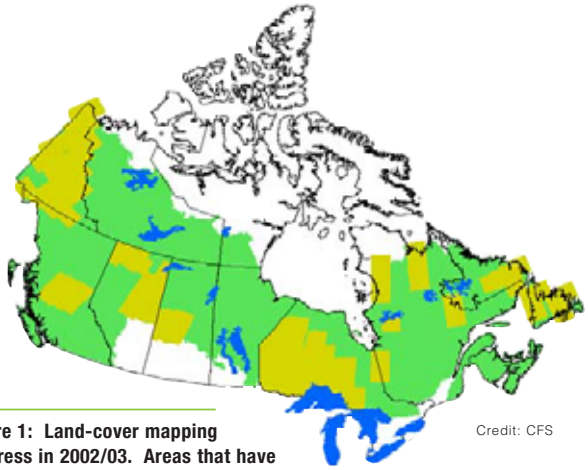
Earth Observation for Sustainable Development of Forests

The Canadian Forest Service, through the Canadian Space Agency's Government Related Initiatives Program, is using space-based Earth observation technologies to create products and data for the national forest inventory, forest carbon accounting, and the public, and for monitoring the sustainable development of Canada's forests. The Earth Observation for Sustainable Development of Forests initiative is working in partnership with the provinces, territories, universities and industry to develop a land-cover map of the forested area of Canada with the long term goal of producing not only land-cover maps, but maps of change over time and biomass.

Research programs are also a component of forest Earth observation and will develop and improve techniques for land-cover mapping, change monitoring, biomass estimates and automated processing to aid in production. Research is being conducted in partnership with the provinces, territories, universities and industry.

www.pfc.cfs.nrcan.gc.ca/eosd

Data produced will support the National Forest Carbon Accounting Framework and will also be used to extend Canada's new National Forest Inventory. The National Forest



Credit: CFS

Figure 1: Land-cover mapping progress in 2002/03. Areas that have been mapped (yellow) are shown against the forested area (green) of Canada

Information System will be used to integrate and synthesize applicable data and data products and make them accessible to users through the web.

Land Cover Mapping

Land cover mapping of the forested areas of Canada began in the 2002/03 fiscal year. Progress made is shown in Figure 1. A regional implementation plan was initiated during this period in Alberta, Newfoundland and Labrador, Ontario, Quebec, Saskatchewan and the Yukon.

The Canadian Space Agency and the Canadian Forestry Service are leveraging their efforts through regional initiatives with support from territorial and provincial partners. In many cases, Earth Observation for Sustainable Development of Forests is building upon ongoing provincial and territorial land-cover projects, which are likely to continue in future years.

Distribution of data is also a priority. An Internet map server has been developed with the capability for sharing land-cover classification products amongst partners and the Canadian public. A further objective is to link this data distribution system for the derived products to the National Forest Information System. Metadata will also be available through the GeoConnections Discovery Portal.

Significant Earth Observation for Sustainable Development of Forests land-cover mapping achievements in 2003 include:

- Classification and labelling of 99 Landsat images
- Implementation of a data distribution system
- Integration of the project's land cover legend with Agriculture and Agri-Food Canada land use/cover legend
- Initiation of discussions or signing of agreements with provinces and territories to participate in the program, specifically British Columbia, Manitoba, New Brunswick, Northwest Territories, Nova Scotia and Prince Edward Island

Research

Significant Earth Observation for Sustainable Development of Forests research achievements in 2003 include:

1. Land Cover:

- Methodological adjustments to ensure operational integrity including the integration of provincial information into the project's classification;
- Updated land cover mapping processes manual;
- National accuracy assessment trial initiated to test the planned accuracy assessment approach;
- Spatial analysis for the comparison of land cover maps from various sources.

2. Change Monitoring:

- Creation of a focused prototype system;
- Development of a two-date burn mapper by the Canada Centre for Remote Sensing to detect burns on the 5-year project repeat cycle and exploration of use in clearcut mapping;
- Initial development of methods to combine evidence of change;
- Continued investigations of Landsat and RADARSAT synergies for change monitoring (RADARSAT-1 and RADARSAT-2).

3. Biomass:

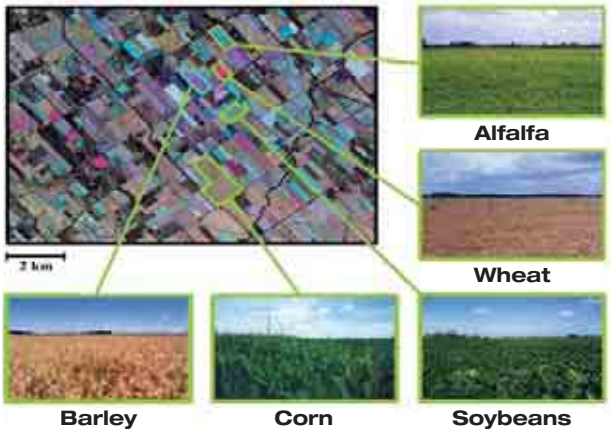
- Documented and presented results of biomass mapping method on five completed pilot regions and implementation and adaptation of biomass mapping method on new pilot regions;
- Built and improved biomass regressions methods for expansion to non-inventoried and non-merchantable forest areas including an assessment of the impacts of environmental drivers;
- Assessed reflectance modelling to improve cover type and structure estimation from Landsat Thematic Mapper for biomass mapping and for application in non-inventoried areas;
- Assessed RADARSAT-Landsat synergism for biomass estimation in non-inventoried areas;
- Continued development of a method to map biomass from Landsat Thematic Mapper specifically addressing compatibility with the project's land-cover mapping methods;
- Developed strategic planning for national implementation.

4. Automated Processes:

- Migrated additional automated processing software and scripts from Unix to PCs (Windows 2000 and Linux) and construction of automated processing tools (product generation, ingestion of products into data storage and distribution system);
- Continued maintenance and improvements of Atmospheric Correction and Enhancement software;
- Developed and implemented a data storage and distribution system for the project using GRID architectures, mobile agents, and high bandwidth connections. The System is an extension of MacDonald Dettwiler's Catalogue User Data Ordering System.

Agriculture

Federal, provincial and territorial Ministers of Agriculture have pledged to meet the many challenges and opportunities facing the agriculture and agri-food sector by jointly developing a comprehensive Agricultural Policy Framework (APF). Working together under the Framework, governments and industry are accelerating efforts to reduce agricultural risks to water resources, soil, air and bio-diversity. Federal, territorial and provincial governments have committed to develop and implement this comprehensive plan for accelerated environmental action fully covering all Canadian farms, to achieve measurable and meaningful environmental goals.



Aerial simulation of RADARSAT-2 cross polarization data, used for crop identification and monitoring

In order to meet Agriculture and Agri-Food Canada commitments under the Framework, action plans are being implemented by the Ministry in collaboration with provincial and territorial partners. These plans include: the National Agri-Environmental Health Analysis and Reporting Program, a National Land and Water Information System, research funding to improve farming systems and practices for risk reduction, the Environmental Farm Plan, the National Carbon and

Greenhouse Gas Accounting and Verification System, and the Green Cover Canada Program. Information about agricultural resources and management practices is key to supporting these Framework action plans. This information must be relevant, accurate, repeatable and timely. Agriculture and Agri-Food Canada is thus engaged in assessing and demonstrating the usefulness of Earth observation data in meeting these national initiatives. Such demonstrations will lead to Earth observation data becoming an important component for Agriculture and Agri-Food Canada in achieving its commitments under the Framework.

On-going Studies

Under the Agricultural Policy Framework, Canada is committed to reducing the environmental impact of agriculture, in part through improved cropping systems with reduced and efficient application of fertilizers and pesticides. Large-scale research studies have been established by Agriculture and Agri-Food Canada, private industry and producer organizations at several sites across the country. These studies are investigating the application of Earth observation data for deriving crop and soil descriptors and for delineating field management zones to aid in the variable management of fertilizers and pesticides.

Delineation of Management Zones Using Multispectral and Hyperspectral Imagery

Studies conducted by scientists at Shaunavon and Indian Head, Saskatchewan, evaluated the combined use of satellite imagery and grain yield information for identifying management zones in the field. The scientists concluded that using a Normalized Difference Vegetation Index derived from Landsat-7 plus mapped grain yields to delineate zones showed promise. For a hummocky field near Shaunavon, the methodology successfully delineated two stable zones of different fertilizer response. Thus at this site, there would be an advantage to applying fertilizer at different rates to each zone. At Indian Head, the three zones delineated did not represent different fertilizer responses. Research is continuing to further refine this methodology.

Retrieval of biophysical crop and field descriptors

In 2002/03, Agriculture and Agri-Food Canada initiated the development of applications of advanced Earth observation sensors, through the Canadian Space Agency's Government Related Initiatives Program. These airborne data projects simulate data from future space projects and ensure user communities are prepared to make operational use of data from missions. The project (Retrieval of biophysical crop and field descriptors in order to develop procedures for delineating homogeneonus field sub-units for crop management) complements the work being conducted in Saskatchewan and adds several new objectives. Collaborators under this project include the Canada Centre for Remote Sensing, York University, Université du Québec à Chicoutimi, McGill University, University of Valladolid and Noetix Research Inc. The objective of this research was to analyze multi-temporal airborne polarimetric synthetic aperture radar and Compact Airborne Spectrographic Imager hyperspectral data for: (1) extracting crop biophysical and field descriptors; (2) defining strategies for best combining the descriptors and the precision required for effectively monitoring crop growth conditions and; (3) developing procedures for delineating major homogeneonus field sub-units for crop management.

The project exploited multiple dates of airborne hyperspectral imagery and airborne polarimetric synthetic aperture radar imagery which had been collected over the Ottawa Experimental Farm. The airborne hyperspectral data was used to develop modelling approaches in order to determine and predict several crop biophysical descriptors such as leaf area index and leaf chlorophyll concentration. Hyperspectral reflectance images were used to invert radiative transfer models and to implement algorithms for extraction of chlorophyll content and leaf area index, and to delineate field management zones. Derived chlorophyll maps revealed the location of nitrogen treatments applied to the field. Correlations between predicted and observed leaf area index were strong with coefficients of determination (R2) of 0.82 (corn), 0.92 (wheat) and 0.96 (soybean). The correlation between the Water Band Index and measured total leaf water content was also significant (R2 of 0.58). The hyperspectral imagery was also used to produce soil and crop segmentation maps using a k-means unsupervised clustering.

Processing, calibration and quality assurance of the airborne synthetic aperture radar data was addressed during the first phase of this project. The result was a guide to end-user diagnostics for assessing polarimetric synthetic aperture radar data quality. Segmentation maps were also produced using multiple polarizations and a Fuzzy k-means approach. As well, the relationship between total effective volumetric moisture for the canopy and multi-polarized backscatter was explored. Results indicated a strong correlation between linear and circular cross-polarizations, and the variable total effective volumetric moisture.

Improved forecasting for the processing vegetable sector

Researchers in Eastern Canada are developing remote sensing approaches for the evaluation of crop biomass and phenology, in conjunction with modelling tools. The objective of this work is to value the potential of new technologies in achieving a better knowledge of crop status in terms of growth (yield potential) and development (maturity dates). Vegetation indexes and leaf area index were derived from multispectral satellite data at a resolution of 20 x 20 m or finer. This information was computed for

the commercial fields of interest and used to adjust model predictions. From this adjustment, a better forecast of yield potential and optimal maturity date was obtained.

The second Agriculture and Agri-Food Canada workshop on agricultural remote sensing applications was held in Ottawa January 27-28, 2003. During the first day of the workshop, experts in remote sensing and applications shared their perspectives and experience on the usefulness of remote sensing in agriculture. Day two included updates on remote sensing activities at Agriculture and Agri-Food Canada, followed by the formulation of action plans to identify and integrate future Earth observation activities within the department.

New Projects

In 2003/04, several multi-year Agriculture and Agri-Food Canada projects under the Canadian Space Agency's Government Related Initiatives Program will continue to develop methodologies and applications of Earth observation data in support of the Agricultural Policy Framework and the sustainability of the Canadian agricultural resource base.

Wither the Weather: measuring the impacts of precipitation anomalies on vegetation and soil

The purpose of this project is to enhance the capability to monitor climatic effects on agriculture in an objective manner so that a resilient agricultural industry that responds appropriately to short and long term climate variability can be sustained. The soil moisture component of the project, led by Agriculture and Agri-Food Canada, will develop and test methodologies to estimate surface soil moisture from Earth observation data, and to investigate options for extrapolating surface soil moisture to the root zone. Statistics Canada will lead the second component of the project, which will develop the methodology to apply US National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) data to Eastern Canada.

Assessing and Managing Agricultural Sustainability

This second project will develop methodologies to use Earth observation data to provide some of the information needed under the Agricultural Policy Framework implementation plans. The project will develop a land use and agricultural management practices inventory to meet the needs of the Framework's environment chapter. The project will also set up the procedures for updating the inventory using both field and Earth observation information. The project will also demonstrate the potential of Earth observation data to map frozen soil. Knowledge of the extent of frozen soil under a snow cover will help in predicting and reducing spring water contamination by nutrients and for managing manure spread during the fall. The intent is to make the information derived from these methodologies accessible through the National Land and Water Information System.

Retrieval of biophysical crop and field descriptors in order to develop procedures for delineating homogeneonus field sub-units for crop management – Phase 2

The objective of the second phase of this project is to extend and further validate the methodologies developed in year one. Analysis of the Compact Airborne Spectrographic Imager hyperspectral data will extend to developing and testing methodologies to estimate the percentage of green cover, crop biomass and yield. The field segmentation methodologies will be further developed, and the correlation between the zones segmented using the synthetic aperture radar polarimetric imagery and field descriptors will be assessed. Estimates from a process-based growth model will be compared to crop descriptors derived from the polarimetric analysis.

Significant achievements in 2003 include:

- Development and validation of methodologies for delineating field management zones for variable rate applications, using both optical and radar data
- Validation of methodologies to derive leaf area index, leaf chlorophyll and leaf water content from hyperspectral data
- Compilation of a guide for end-user diagnostics for assessing polarimetric synthetic aperture radar data quality
- Assessment of the sensitivity of backscatter from multiple polarizations to total effective volumetric canopy moisture
- Demonstration of the use of Earth observation derived vegetation indices and leaf area index estimates for improving forecasts of yield and maturity date
- 2nd Agriculture and Agri-Food Canada workshop on agricultural remote sensing applications held in January 2003

Habitat

Developed by the Canadian Space Agency, the Canadian Wildlife Federation, the Canada Centre for Remote Sensing and the Canadian Wildlife Service, with assistance from corporate

sponsors, “Space for Species” is a Web-based learning program that brings science and technology to life. The program is an excellent example of how space can be used both in an environmental context and as a tool to inspire youngsters and engage their interest in science and technology. Through Space for Species, young students can explore the role of satellite telemetry, remote sensing, field biologists, astronaut observations, weather satellites and RADARSAT images in wildlife conservation. All these "eyes in the sky" provide a panoramic view of wild wayfarers.

RADARSAT enables the assessment of the health of important waterfowl habitats, from Canada’s Prairie pothole region to the Pantanal wetlands of Brazil. Its data are used to monitor the effects of clear-cutting forests in Alberta’s Rocky Mountain foothills, to estimating ringed seal populations by counting breathing holes made in ice, to identifying fish habitats in Cambodia’s Mekong watershed, and to mapping coastal habitats around the world for the sake of environmental monitoring, emergency preparedness, and the establishment of marine protected areas. Species tracked under the program include eider, caribou, peregrine falcons, polar bears, and leather-back sea turtles.

Through the program, children create migration maps, record climatological and habitat data, and keep their own field notes as part of a tracking journal, science project, or even a recovery plan. They can explore the role of scientific inquiry in conservation, and get acquainted with Canadian astronaut Bob Thirsk, and an array of other experts, while learning about careers in fields where space and species meet.
www.spaceforspecies.ca

The North

Canada is the world’s second largest country in terms of square kilometres. Most of our landmass is made up of Northern lands that are sparsely settled and in many cases poorly mapped. The North, while rich in resources and potential, lacks infrastructure and the means to develop its resources efficiently. Space has a critical role to play in increasing our information of the North and augmenting our ability to develop Northern resources. RADARSAT covers the Arctic in one day and the rest of Canada every three days. It transmits cloud-free radar images of the ice cover to two Canadian receiving stations. It is worth noting that the Canadian Ice Service is Canada’s largest single user of RADARSAT data, and that mapping safe ship routes through Northern waters in spring and autumn relies on information from space. In 2003, Canada began receiving and using ENVISAT Advanced Synthetic Aperture Radar data to complement RADARSAT-1 data for use in ice management and mapping.


Credit: NOAA

Ice forming in the Eastern Great Lakes


Credit: Canadian Ice Service

Canadian Coast Guard icebreakers use near real-time RADARSAT-1 data to navigate ice infested Northern waters

The Canadian Space Agency signed a significant agreement with Geomatics Canada to provide fundamental geospatial information in support of Northern development beginning in 2003, with a project end date in 2005.

Under the aegis of Global Monitoring for Environment and Security (EU/ESA), a joint initiative of the European Commission and the European Space Agency designed to establish a European capacity for the provision and use of operational information for global monitoring for the environment and security, a Canadian team led by C-CORE of St. John’s, Newfoundland has been awarded an ESA contract for “Northern View”, a project to better use space assets in support of Northern issues. "Northern View" brings together a team from Canada (C-CORE, Canada Centre for Remote Sensing, Natural Resources Canada, the Canadian Ice Service, the Canadian Polar Commission, Cryosphere System in Canada, Environment Canada, Hickling, Arthurs & Low, MacDonald Dettwiler and Associates, Noetix Reseach, and RADARSAT International), Finland, Norway, Sweden, the United Kingdom and Germany to focus on Northern issues.

“Northern View” will have both short-term and long-term planning horizons. It is the long-term vision of “Northern View” to establish a service centre to provide value added services required by organizations and individuals concerned with policy, development, and environmental preservation of the Earth's northern regions. This service centre will effectively be a "one-stop shop" for key areas of interest to northern stakeholders.

This long-term vision, however, will be built on the foundation of existing organizations and services that can provide benefits in the short-term. The objective of the 20-month project is to demonstrate to key organizations the utility and effectiveness of using Earth observation data for northern monitoring, particularly in support of policy development, and to establish links with other northern stakeholders that might benefit from Earth observation -based information. The first service offerings will be in the areas of oil spills and discharge monitoring, glacier and snow cover monitoring, and sea ice and iceberg monitoring.

Finally, Parks Canada and Natural Resources Canada work with the Canadian Space Agency to provide 3-D land cover and land type change maps, 3-D climate change information and 3-D virtual visits of some of Canada’s northernmost parks.

Northern Ontario Engineering Geology Terrain Studies are

available for the part of the Canadian boreal forest region south of latitude 51° N. Each study includes a 1:100,000-scale terrain map that was based almost entirely on the interpretation of air photographs with limited field checking. The legends of the maps contain information on surface material type, landform, topography (relief) and drainage conditions. These maps provide useful information concerning the landscape for forest management and civil engineering.

The vast area of boreal forest north of 51° N latitude, for the most part, has no equivalent maps of the terrain conditions. Such maps would be expensive to create using traditional air photo interpretation and field investigations because of the large aerial extent and limitations of access. As a result, a project was undertaken by the Ontario Geological Survey, and the Canada Centre for Remote Sensing, with ACG Space Technologies Corporation as prime contractor, to prepare a series of satellite-based terrain maps for a 250,000 square kilometre area of the boreal forest region in Northwest Ontario.

The purpose of this provincial and federal mapping program was to produce a series of 1:100,000 standardized, satellite-based engineering terrain maps that are now published as a provincial map series. Engineering geology terrain maps were created using the integration and interpretation of various types of remotely sensed imagery, digital elevation models and their derivatives and appropriate geological depositional models. The published image map series produced from a combination of Digital Elevation Model and Landsat Thematic Mapper imagery can provide a base on which to interpret and overlay engineering terrain units, resulting in considerable savings in time and cost when compared to traditional air photo methods. The terrain maps may be used to plan forestry roads and other civil engineering works in support of forest harvesting programs in the region.

Significant achievements in 2003 include:

- Canadian Space Agency-Natural Resources Canada agreement to develop northern geospatial information using RADARSAT and Landsat-7 data
- Northern View project kick-off
- Parks Canada-Natural Resources Canada initiative to improve ecosystem management and outreach programs using Earth observation data
- Canada Centre for Remote Sensing project with the Ontario Geological Survey to produce 60, 1:100,000 satellite-based terrain image maps of northern Ontario

Space-based Wide Area Surveillance and Support

Project Polar Epsilon is a new initiative by the Department of National Defence's Directorate of Space Development, to exploit space-based information obtained from existing or emerging commercial satellites to contribute to wide area situational awareness. Capabilities are being developed that will provide high quality cueing, and possibly classification and motion detection information, for targets over the surface and subsurface approaches to Canada, over Canada's Arctic region, and in foreign littoral areas where Canadian Forces may be deployed. Although all space assets are being evaluated for inclusion into the Polar Epsilon Concept of Operations, Canada's RADARSAT-2 is considered the key sensor. Accordingly, much effort is being expended in algorithm development to innovate its utility for a sovereignty and surveillance mission. In particular, algorithms and tools for Coherent Change Detection, target classification, near-real time acquisition and processing of data, cross cueing, mission planning, and increased probability of detection are being developed. As an innovative and transformational project, a new procurement approach named spiral development is being developed, such that as capabilities are demonstrated, a means will be in place to leave the interim capability with the user. Polar Epsilon is taking the approach that partnership development early on is the best way to achieve interoperability with interested government departments and allies, and this network of partners is expected to expand throughout the project.

Climate Change, Atmospheric Research and Modelling

Space science activities in Canada contribute significantly to Earth and Environment projects, particularly in the area of climate change and atmospheric research. These activities are carried out through strong partnerships with the Canadian scientific community, industry, and government laboratories, as well as through cooperative programs with international partners. These partnerships provide support to the researchers and scientists in academia and government laboratories. They also provide opportunities for graduate students, in both science and engineering, to pursue studies in a wide range of space-related areas.

New and on-going missions

Scisat-1: Atmospheric Chemistry Experiment

Canada has played a significant role in atmospheric research, particularly in ozone research. This work continues with

the launch of Scisat-1 in August 2003. Scisat-1 carries the Atmospheric Chemistry Experiment mission, which consists of a Fourier Transform Spectrometer and the Measurements of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation (MAESTRO) instrument. Both instruments are designed to gather information on the chemical processes occurring in the ozone layer, approximately 8 km to 50 km above the Earth's surface.

The principal goal of the mission is to investigate the chemical processes that are involved in the distribution of ozone in the atmosphere. This mission will work in conjunction with other instruments and missions planned by NASA, ESA, and other international partners over the next decade to gain a better understanding of the chemistry and dynamics of the atmosphere that affect the Earth's protective ozone layer. The analysis of the large amount of data that will be collected will lead to a more informed assessment of international environmental policies such as the Montreal Protocol on Substances that Deplete the Ozone Layer.

The overall objective of the Atmospheric Chemistry Experiment is to improve our understanding of the depletion of the ozone layer, focusing close attention on Canada and the Arctic. The measurements obtained by the Fourier spectrometer and MAESTRO instruments will be combined with data gathered by ground-based, balloon-based and other space-based projects in order to obtain the best possible information to predict future trends relating to the ozone layer and its depletion.

MAESTRO was developed, in co-operation with the Canadian Space Agency, by the Meteorological Service of Canada, the University of Toronto, and EMS Technologies.

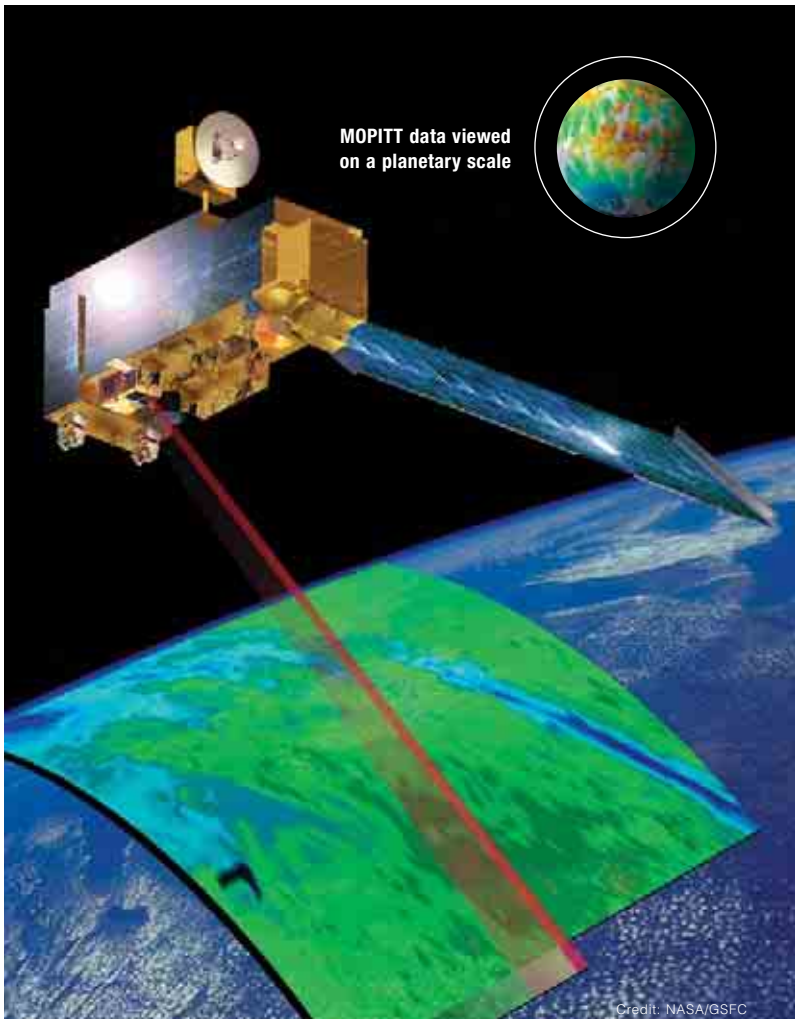
MAESTRO's primary scientific goal is to provide high-resolution data on the atmosphere and precise profiles of ozone concentration. Other goals include measuring the amounts of organic and inorganic particles under polar ozone holes and near large tropospheric pollution sources, such as active volcanoes. The troposphere is the portion of the atmosphere that lies between the Earth's surface and an altitude of approximately 15 km. It consists of water vapour, gases, and vertical winds that account for much of our weather.

Comparing the data gathered by MAESTRO with that from the Atmospheric Chemistry Experiment will help scientists determine the levels of aerosol in the atmosphere, which is crucial to understanding why and how fast the ozone layer is depleting.

www.space.gc.ca/asc/eng/csa_sectors/space_science/atmospheric/scisat/background.asp

MOPITT on NASA's TERRA

Canada's Measurements of Pollution in the Troposphere (MOPITT) instrument is flying aboard NASA's Terra spacecraft, measuring the global distributions of carbon monoxide and methane in the troposphere. MOPITT is Canada's first major instrument to measure pollution of the Earth's atmosphere from space. It is also the Canadian Space Agency's largest contribution to the NASA's EOS.



Canada's MOPITT instrument provides unique global data on pollutants in the lower atmosphere

Several years' worth of scientific data has been gathered, allowing carbon monoxide monitoring on a global basis for an extended period of time. NASA has compiled the data in a time-simulation that portrays carbon monoxide levels around the globe over a period of eighteen months. MOPITT-derived information, combined with those relating to high atmosphere winds and changes, clearly show large-scale transport of pollutants from continent to continent and strong seasonal and hemispherical variations in source strengths. MOPITT continues to provide unique information about carbon monoxide levels globally and plans have begun to develop MOPITT-2, to ensure this valuable information is available for years to come.

OSIRIS on Sweden's Odin

Odin is a Swedish-led international satellite mission involving Canada, Finland and France that is addressing a number of important issues in astronomy and atmospheric sciences. The two instruments designed to achieve the scientific goals of the mission are the Canadian Optical Spectrograph and Infrared Imager System (OSIRIS) and the Swedish Sub-Millimetre Radiometer. The Canadian Space Agency is contributing the OSIRIS instrument, which will provide scientists with detailed data relating to ozone depletion, especially at high latitudes.

OSIRIS is collecting a unique set of data and producing maps of ozone concentrations every 1.5 km of altitude in the stratosphere and the mesosphere. These altitude maps are produced daily, providing greater and more detailed data than previously possible. Work is in progress to confirm the new maps through detailed comparison with data collected by other ground or space-based sensors.

Odin carries the Canadian Optical Spectrograph and Infrared Imager System (OSIRIS) which provides detailed data on high-latitude ozone depletion.

This scientific venture will have a major impact on the atmospheric science community in Canada, allowing it to develop the capacity to play an even greater role in future projects dealing with the scientific, environmental, economic and social aspects of the atmospheric ozone problem.

International Living With a Star and Canadian GeoSpace Monitoring

The international solar terrestrial science community has come together to study Sun-Earth relations and "space weather", the phenomenon created by the interaction of solar plasma with the upper atmosphere. This collective enterprise is called International Living With a Star. Through science and cooperation, the project endeavours to stimulate, strengthen, and coordinate space research to understand the governing processes of the connected Sun-Earth System as an integrated entity. Canada plays a key role as lead for ground segment activities in this effort involving over 40 countries over 14 years. Recent work has indicated that space weather may be one cause of global warming.

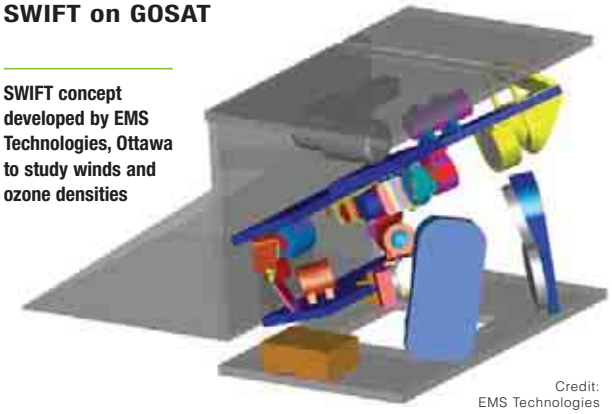
Space data enhances our understanding of solar-terrestrial relations, which impact satellite communications and climate change.

Canadian GeoSpace Monitoring is motivated by the recognized need for greater fundamental understanding of planetary environments that are affected by short and long term variability of our star: the Sun. The Sun and Earth form a tightly coupled system, with solar variability driving effects on space weather and climate, the creation of harsh radiation environments and the generation of the aurora. This program seeks to understand this fundamental solar-terrestrial coupling and its influence on our planetary environment.

The overarching scientific goal of Canadian GeoSpace Monitoring is to understand the transport of mass and energy across multiple scales throughout the entire solar-terrestrial system. Results from this program will enable significant advances to be made in developing and improving space weather prediction and empirical space environment models, and will provide valuable deliverables for the Canadian space industry. Canadian GeoSpace Monitoring science will be central to understanding the exogenic contribution to terrestrial climate change, particularly during the current period of rapid changes to the magnetic environments of both the Sun and the Earth. The primary scientific objective is to elucidate the fundamental processes that cause and control:

- convection within and energy injection into the global magnetosphere;
- magnetotail instabilities and flows;
- auroral particle acceleration;
- energization, transport and loss of energetic magnetospheric particles;
- injection, transport, and loss of low energy magnetospheric particles.

SWIFT on GOSAT



SWIFT concept developed by EMS Technologies, Ottawa to study winds and ozone densities

Credit: EMS Technologies

Initial feasibility studies or Phase A activities are in progress at the Japan Aerospace Exploration Agency (JAXA), ESA, and the Canadian Space Agency for the potential flight of the Stratospheric Wind Interferometer For Transport Studies (SWIFT) instrument on board JAXA's Global Change Observing Mission-A1 (GOSAT). This instrument will provide global profiles of winds (with an accuracy of 5 m/s) and ozone densities (with an accuracy of 10 percent) within an altitude range of 20 to 45 km.

SWIFT will further the understanding of the stratosphere in an important area, namely the link between dynamics and chemistry that occurs through transport of chemical species, especially ozone. It will also provide a unique characterization of the dynamics of the tropical stratosphere, and will improve the quality of stratospheric analysis products in the tropics, where they are currently very deficient. Furthermore, the provision of wind data in the lower stratosphere could enhance the performance of medium-range numerical weather forecasts. In the longer term, this mission will open a way to establish expertise in direct measurements of stratospheric winds from space. Formal approval for Canadian participation was sought in 2003.

Canadian Contribution to the Global Precipitation Measurement Mission

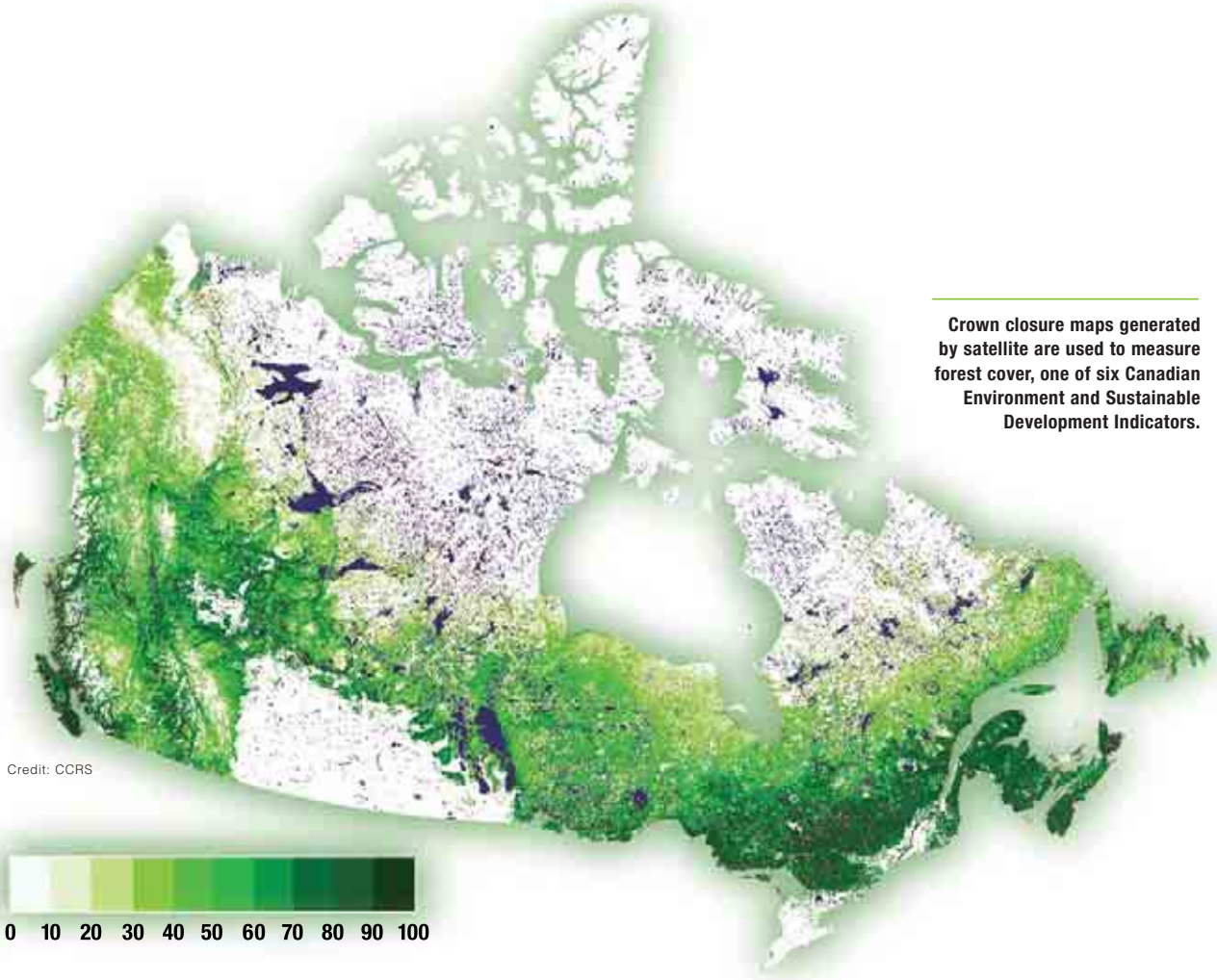
The Global Precipitation Measurement mission is an ambitious international initiative aimed at measuring precipitation over the world. The proposal is built around a NASA/JAXA core satellite, which would fly around 2008 and carry a dual-frequency precipitation radar as a follow-on to the Tropical Rainfall Measuring Mission, as well as passive microwave radiometers on a variety of platforms and other possible international contributions.

A Canadian science team with wide participation from university and government scientists and led by a scientist from the Meteorological Service of Canada, has proposed a Canadian contribution to this mission. The science proposal envisages that Canada would contribute to improving the capability of the precipitation radar on the European satellite, which would form part of the Global Precipitation Measurement mission. The proposed enhancement is aimed at increasing the sensitivity of the radar of the European instrument in order to measure snow and light precipitation, which are important in middle and high latitudes, as well as improving the ability of the radar to detect shallow precipitation systems also common in these latitudes. The proposed enhancement is currently undergoing phase-A studies in parallel with ESA.

The Canadian science team has suggested a preliminary definition of a Canadian science program, which would include retrieval algorithm development for radar and passive microwave measurements with a focus on middle and high latitudes, an extensive Global Precipitation Measurement validation and algorithm validation program, assimilation of its data in Canadian numerical weather prediction models and use of Global Precipitation Measurements for validation of numerical weather prediction precipitation forecasts, and generation and application of derived products. The validation program would be built around numerous current and planned Canadian networks and measurement facilities, including the Meteorological Service of Canada's radar, hydrometric, and surface weather networks, and university facilities such as the mesonetwork in the Montreal area funded by the Canadian Foundation for Innovation and other partners.

Significant achievements in 2003 include:

- Launch of Scisat-1
- Formal invitation to develop MOPITT-2
- Decision to prolong Odin/OSIRIS mission by one year
- Canadians leading ground segment research for International Living with a Star
- Phase A studies for Canadian contribution to the Global Precipitation Measurement mission and SWIFT



Crown closure maps generated by satellite are used to measure forest cover, one of six Canadian Environment and Sustainable Development Indicators.

Climate Change and Ecosystem Impacts

Climate Change and Ecosystem Impacts is a project within the Natural Resources Canada - Earth Science Sector program "Reducing Canada's Vulnerability to Climate Change". This project will improve algorithms to derive higher level products such as surface reflectance and temperature, and will develop and produce time series of Earth observation-based indicators for albedo and surface radiation budget, vegetation phenology/growing season length, burned area, leaf area index, crown closure, evapo-transpiration, net primary productivity and net biome productivity from existing and new satellite sensors.

Project objectives are:

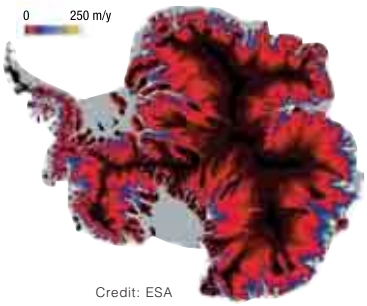
1. To improve existing and develop new algorithms for processing and applying Earth observation data, and to develop new Earth observation-based environmental products and information on the status and trends of Canada's ecosystems regarding climate variability and change; with emphasis on vegetation, radiation, carbon cycle and water resources and their interaction with climate on various time scales from days to years;
2. To develop and demonstrate a capability founded on Earth observation data that will provide current, timely and quantitative information and trends on the Canadian landmass to meet government, public, and educational needs for environmental information for the benefit of the public and private sectors of Canada and in response to the international commitments of the Government of Canada;
3. To stimulate and support technology transfer so that marketable Earth observation data handling systems can be developed for operational uses of Earth observation data, and to disseminate new knowledge among industrial and educational stakeholders.

A major new feature of this project will be on the development of long-term Climate Change and Ecosystem Impacts trends from Earth observation using improved and new algorithms, while the research activities in previous years were mainly focused on single-year data. The temporal trends information will be built upon historical and newly available observational capabilities (multi-spectral observations from new sensors and spectral bands), advanced computing and data storing resources, improved calibration techniques, and the most recent developments in the atmospheric physics, radiative transfer theory, and ecosystem modelling.

The work is conducted in cooperation with the Canadian Forest Service, Environment Canada, Statistics Canada, the National Round Table on the Environment and the Economy, Fisheries and Oceans Canada and Agriculture and Agri-Food Canada. Results of this project will contribute to the development of Environment and Sustainable Development Indicators which have been recommended by the National Round Table to be published by Statistics Canada annually and incorporated into the federal budget statement by the Minister of Finance. The project research team also has close ties with Canadian universities through various national projects and programs such as the Mackenzie GEWEX Study and Fluxnet-Canada, as well as internationally with U.S. and European scientists and projects. Linkages with provincial and municipal level users will be provided through Natural Resources Canada's Program "Reducing Canada's Vulnerability to Climate Change". Significant scientific and technique advances and contributions have been made by this project over the last three years, with a total of over 100 peer-reviewed papers published.

Significant achievements in 2003:

- Completing the development of image-based haze suppression methodology of particular use for archival optical images and large-area as well as time series analyses;
- Completing a consistent land cover map for North America, in collaboration with the United States Geological Survey;
- Completing and applying a representative fine resolution data set at the national level encompassing 35 Landsat scenes transformed into detailed land cover types maps;
- Developing a methodology for producing land use maps for Canada by fusing satellite-derived information with census data collected by Statistics Canada;
- Improving leaf area index retrieval using a new algorithm;
- Developing a Crown Closure product (a forest biophysical parameter) based on leaf area index, clumping index, and land cover, to form the basis of a national environmental indicator;
- Demonstrating the feasibility to use medium resolution satellite imagery for mapping severe insect defoliation in boreal forests;
- Contributing Canadian component of the Global Burned Area 2000 data product led by Environment Canada;
- Developing an approach for systematic mapping of surface reflective properties and albedo from multiple satellite observations;
- Integrating Earth observation-derived products with models and surface observations to obtain spatial fields of evapotranspiration and net carbon uptake, thereby demonstrating the vital role of satellite earth observation in climate change and carbon cycle research.



Credit: ESA

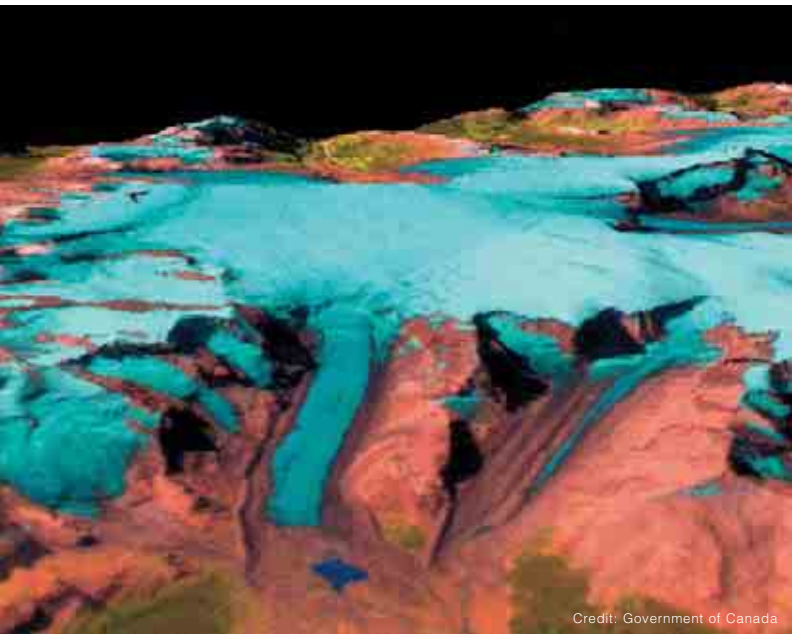
"Ice rivers" threading their way across the Antarctic Ice Sheet. Much of Antarctica is only readily observed from space.

Cryosphere and its Response to Climate Change

Climate Research Branch scientists led an intensive two-week airborne and ground field experiment from February 15-28, 2003 in the Prince Albert region of Saskatchewan to provide validation data for assessing Snow Water Equivalent products from the new Advanced Microwave Scanning Radiometer launched on the EOS Aqua satellite in May 2002. Two flight line networks were flown with the Canadian National Research Council's Twin Otter aircraft fitted with Meteorological Service of Canada microwave radiometers. The first series of flight lines covered both the agricultural area between Prince Albert, Regina and Yorkton and the boreal forest region north of Prince Albert (the BERMS study area). Extensive coincident ground-based measurements of snow cover properties (depth, Snow Water Equivalent, structure) were conducted along calibration flight line segments by Climate Research Branch staff with assistance from staff and students from the Universities of Waterloo, Regina and Sherbrooke. The second series of flights were conducted over a localized study site, with coincident intensive ground sampling and data acquisition from the Meteorological Service of Canada's ground-based microwave radiometers to investigate the effects of vegetation on the satellite retrievals, and to look at scaling issues.

CRYSYS, led by the Meteorological Service of Canada, is hosted and funded by Canadian agencies and universities. One of the main objectives of CRYSYS is to develop capabilities for improved satellite-based measurement, monitoring and understanding of cryospheric variables over a range of spatial and temporal scales. An overview of the CRYSYS project and science goals can be obtained online at www.crysys.ca. CRYSYS activities also contribute to the "Cryosphere and its Response to Climate Change".

In 2003, 14 research projects were supported in Canadian universities with topics ranging from application of RADARSAT data to glacier dynamics in the high Arctic, to multi-sensor mapping of snow cover. The annual science meeting (Montreal, March 23-25, 2003) attracted a total of 62 participants, with over 20 graduate students. Efforts continued in 2003 to expand Canadian cryospheric data holdings at the Canadian Cryosphere Information Network developed at the University of Waterloo in partnership with the Canadian Space Agency and the private sector (Noetix Ltd., Compusult Ltd., and SGI). The other major focus of Cryosphere Information Network activities was continued development of web-based interactive data display capabilities for near-real time monitoring of Canadian cryospheric conditions.



Modelling of Canada's cryosphere based on space and in-situ data

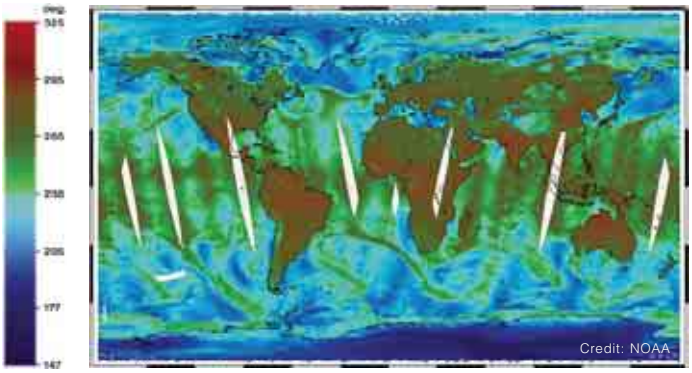
Significant achievements in 2003 include:

- CRYSYS support of a Global Land Ice Measurements from Space regional centre for the Canadian Arctic Islands at the University of Alberta has resulted in the quantification of the response of glaciers to climate change over the entire Queen Elizabeth Islands, and detailed estimates of Canadian Arctic glacier contributions to sea level rise (an estimated 1.45 mm rise in global sea level, or ~15 percent of the total contribution of glacier melting to sea level changes over the period 1959-99);
- Research into computer-aided identification of Synthetic Aperture Radar sea ice information at the University of Waterloo contributed to the commercial implementation of a rapid algorithm for determining co-occurrence probabilities in PCI Geomatica©. The improvements in sea ice classification methods are being incorporated into ice forecasting operations at the Canadian Ice Service;
- Comprehensive two-week airborne and ground field experiment in February 2003 in the Prince Albert region of Saskatchewan to validate satellite-based snow cover information over agricultural and boreal forest regions;
- Research at the Institut national de la recherche scientifique (Université du Québec), Eau, Terre & Environnement demonstrated the utility of RADARSAT data in an integrated river ice management system for the St. François River;
- Development by the University of Sherbrooke of a new physically-based approach for extracting snow water equivalent information over boreal forest regions;
- Development by the Meteorological Service of Canada of consistent passive microwave Snow Water Equivalent time-series information from the Scanning Multi-channel Microwave Radiometer and Special Sensor Microwave/Imager sensors which allows investigation of spatial and temporal variability in Snow Water Equivalent over many regions of Canada from 1978;
- Development by Meteorological Service of Canada of a 19-year gridded monthly snow depth and Snow Water Equivalent dataset for North America the data have been used extensively for evaluating model output and satellite retrievals.

Numerical Weather Prediction

The operational numerical weather prediction systems at the Canadian Meteorological Centre in Dorval, Québec are one of the cornerstones of weather and environmental prediction program. Numerical weather prediction models are launched twice a day to provide forecasts for time ranges from a few hours to 5-10 days ahead. Launching the models requires sophisticated data assimilation systems to combine information from a wide range of measurements including weather balloons (radiosondes), ships, buoys, surface weather stations, aircraft, and satellites. The Canadian Meteorological Centre, in common with most other major numerical weather prediction centres around the world, uses a three-dimensional variational data assimilation system which was implemented in 1997. One of the major drivers of this technique is to make better use of measurements from satellites. Radiance measurements from the Advanced Microwave Sounding Unit instruments (which provide information on the three-dimensional temperature structure of the atmosphere) aboard the U.S. NOAA Polar Operational Environmental Satellites (POES)

have been assimilated directly into Canadian Meteorological Centre operational numerical weather prediction systems since 2000. A major upgrade to the treatment of many types of data, including the Advanced Microwave Sounding Unit-A radiances, was implemented in December 2001, leading to substantial improvements in forecast performance.



Ocean temperatures collected by satellite are used for numerical weather prediction

Recent observing system experiments (in which the operational numerical weather prediction systems were re-run numerous times, each with a particular class of data withheld) showed that satellite measurements are now the most important source of data for Canadian Meteorological Centre models in the southern hemisphere, and the impact of satellite data is now a strong second to the international radiosonde network in the northern hemisphere. In 2003, the capability was developed to directly assimilate radiances from the Advanced Microwave Sounding Unit - B instrument on the POES satellites, as well as some channels from the atmospheric sounder on the U.S. geostationary meteorological satellites (GOES), both of which provide three-dimensional information on atmospheric humidity. The new data were assimilated into the operational global numerical weather prediction system in June 2003. Tests showed a clear improvement in the three-dimensional humidity field used to launch the model forecasts as well as to precipitation forecasts.

Ouranos

Ouranos, a consortium on climatology and adaptation to climate change, was launched last year. Its mission is to develop, structure and undertake a collective project to analyze and search for solutions to climate change adaptation issues in the North American context. In addition to greenhouse gas emission reduction, the creation of Ouranos constitutes an additional means of addressing climate change and a tool for adaptation to new regional situations stemming from global warming.

A partnership that is truly unique and without precedent in Canada, Ouranos involves over 250 persons in multidisciplinary research teams from universities, governmental and para-governmental organizations, in disciplines that have traditionally worked apart: climate sciences, statistical analysis, characterization, impact and adaptation studies. The merging of isolated teams of scientists under Ouranos will pull in relevant scientific data and information needed by decision makers to plan responses to the rapidly evolving climate situation.

Ouranos is funded by several federal departments and agencies, as well as departments and agencies of the Quebec government. The Université du Québec à Montréal, McGill University, Université Laval and the Institut national de la recherche scientifique are also members of the Consortium.

www.ouranos.ca

Disaster Management

RADARSAT-1 data are regularly acquired for covering natural and technological disasters. A data acquisition campaign called 'RADARSAT-1 Disaster Watch Program' was introduced early in the satellite operations. This was done as part of the RADARSAT-1 Background Mission for collecting and archiving data routinely over disaster occurrences and disaster prone regions. As a result, a wealth of reference imagery is now available for delivery when a disaster strikes and space data are solicited to assess damage and provide relief to those affected. More recently, the Disaster Watch data have been delivered to the International Charter 'Space and Major Disasters'.

Disaster Watch

RADARSAT-1 is among the world's premier satellites used for delivering remote sensing data on an operational basis. This has been achieved on the one hand because of the all-weather, all-time imaging capability of the satellite, and on the other due to the organization of the satellite data policies and program procedures, which favour quick data acquisition planning, payload tasking, data reception reporting and data handling. The operational nature of the RADARSAT-1 program was well recognized in the design of the satellite resource that could be offered to the user community for emergencies and search and rescue purposes. Data acquisition planning over disaster sites has therefore been done as part of the baseline RADARSAT-1 data collection called 'Background Mission', without interference with user requests. This data collection constitutes the Canadian Space Agency's CSA's Disaster Watch Program.

RADARSAT-1's data policies were the first to incorporate

guidelines for planning urgent data requests and managing the resulting conflicts in the planning routines. These guidelines are now being used as standards by other programs. Emergency data acquisition planning receives very high priority, second only to the spacecraft health and safety in the RADARSAT-1 data acquisition planning procedures. Emergencies caused by natural and technological disasters also require reference imagery pre-dating the disaster in order for the authorities to assess the effects and determine the extent of the damage caused by the disaster. The Disaster Watch Program was introduced soon after the commissioning of the satellite in 1996 precisely for the purpose of building a database of reference imagery.

The RADARSAT-1 mission planners search for information on a disaster happening or an impending disaster, and if the imaging opportunities are available, they immediately plan data acquisition over the selected site. The data received are stored directly in the archives. A variety of natural and man-made disasters, ranging from floods, earthquakes, and volcanic eruptions to fires and oil spills have been covered. The table below gives the number of these occurrences covered in 2002/03 and the rate of planning success.

Event	April 02-March 03	April 03-July 03
Floods	270	14
Earthquakes	64	9
Volcanoes	35	9
Landslides	35	3
Storms	61	4
Fires	68	0
Oil Spills	34	1
Others	60	3
TOTAL	627	43
% planned	68.90%	72.09%

Hurricane Watch

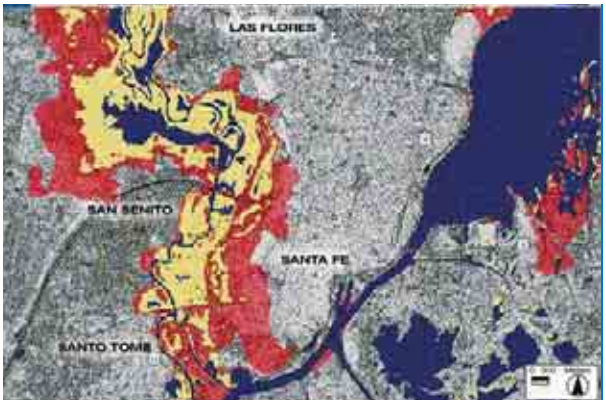
Over a period of 4 years, from 1998 to 2002, RADARSAT-1 ScanSAR Wide beam coverage planning was carried out jointly by the Canadian Space Agency and the Canada Centre

Hurricane Isabel viewed by RADARSAT-1 on September 18th, 2003 about to make landfall near Cape Hatteras, North Carolina

for Remote Sensing in support of NOAA activities related to hurricanes in the West Atlantic basin. The coverage planning period coincided with the hurricane season of August through October and targeted the Caribbean Sea, Gulf of Mexico and the U.S. East Coast. The procedure took into account the hurricane track predictions posted on the web before the planning was performed, as late as 29 hours prior to imaging by using the emergency data acquisition timeline in the RADARSAT-1 planning system. The RADARSAT-1 coverage planning was prompted by some earlier observations derived from radar imagery that were associated with storm features, such as strong convection, rain bands, boundary layer rolls and hail. The RADARSAT-1 data based observations were validated against aircraft data. The results so far have shown that synthetic aperture radar provides high-resolution ocean surface wind information, which reveals patterns in the boundary layer, especially in the eye of the storm and in the outlying rain-free areas. Though certain other storm structures observed on the C-band radar imagery require further investigation, it is thought that synthetic aperture radar could evolve into a real-time tool for this application.

International Charter 'Space and Major Disasters'

The International Charter is the first instance of joint operations by several space agencies to task their space and ground resources collectively for delivering data in situations of emergency. The International Charter idea was born during the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) in 1999. ESA and the French Space Agency (Centre national d'études spatiales) decided to establish a Charter of cooperation for a unified response to natural and technological disasters. The Charter is the expression of a collective resolve to put space technology at the service of rescue authorities in the event of a major disaster on a free-of-charge basis. Canada signed the Charter in October 2000. Since then, the Indian Space Research Organization, NOAA and the Argentinean Space Agency (Conae) have become Charter members. Japan and China are actively pursuing membership in the International Charter.



In May 2003, RADARSAT-1 data was used to monitor flooding in Santa Fe, Argentina

The Charter has been activated a number of times to cover floods in France, Canada, Russia, Austria, Germany, Indonesia, Morocco and Argentina, landslides in Slovenia, Italy and Russia, earthquakes in El Salvador, India, Afghanistan, Turkey and Algeria, volcanic eruptions in Italy, Congo and Montserrat, oil spills off the coasts of Ecuador, Lebanon, Denmark, Yemen and Spain, forest fires in France, and finally wind storms in India and Mexico.

United Nations Action Team on Disaster Management

The decision to establish the Action Team was taken pursuant to the agreement of the Committee on the Peaceful Uses of Outer Space at its 44th session. The agreement gave rise to the establishment of several action teams with the voluntary participation of the UN member states to implement the recommendations of UNISPACE III.

The mandate of the Team relates to the "implementation of an integrated, global system, especially through international cooperation, to manage natural disaster mitigation, relief and prevention efforts through Earth observation, communications and other space-related services, making maximum use of existing capabilities and filling gaps in worldwide coverage." Canada, China and France were elected as the three team co-chairs.

The Action Team is now in the final phase of its work. Practical solutions to the problems hampering the use of space technologies will be proposed and recommendations for implementing a disaster management system will be made. These recommendations along with those of the other action teams will be taken to the UN General Assembly for consideration.

The RADARSAT-1 emergency and disaster-related data acquisition planning and data delivery over the past seven years of satellite operations have helped the Canadian Space Agency assume a lead role in international disaster management activities. The International Charter 'Space and Major Disasters' is being increasingly accepted as a model of operational use of space technologies for disaster response and is likely to influence also the concept of a global system covering the entire disaster management cycle, from risk and response to recovery, which is being investigated by the UN Action Team.

The Canadian space sector is continually pursuing new missions and avenues of research to identify promising space technologies. Two critical areas of development are hyperspectral technologies and small-satellite SAR technologies, both of which offer innovative solutions to terrestrial challenges.

New sensors

RADARSAT-2

RADARSAT-2 is a significant technological evolution from RADARSAT-1. Its spatial resolution will be more than twice as high as RADARSAT-1's, its launch mass is reduced by 500 kg and its on-board recording capabilities are significantly improved. Once launched, RADARSAT-2 is expected to significantly improve our ability to monitor resources due to its enhanced resolution and multiple polarizations, particularly useful for crop monitoring. The launch is currently planned for late 2005.

	RADARSAT-1	RADARSAT-2
Mass at launch	2750 kg	2280 kg
Design life	5 years	7 years
On-board recording	Tape	Solid State
Location	S/C Ranging	GPS
Frequency	C-band (5.3 GHz)	C-band (5.405 GHz)
Spatial resolution	10 to 100 meters	3 to 100 meters
Polarisation	HH	HH, HV, VV, VH
Look direction	Right-looking	Left and right-looking

Artist's impression of RADARSAT-2

RADARSAT-2 is critical to ensuring long-term data continuity in C-band for RADARSAT users.

The Canadian Space Agency, in collaboration with the Canada Centre for Remote Sensing, initiated a series of activities early in 2001 that will continue into the first years of RADARSAT-2 operations. The program's objectives are to help the Canadian Earth observation community (academia, industry, and government departments) master the concepts, develop the tools, and explore the potential of RADARSAT-2 data. The Canadian Space Agency's Government Related Initiatives Program sponsored two separate initiatives to encourage development of RADARSAT-2 products in relation to forestry and nearshore ice, in cooperation with the Canadian Forest Service, the Canada Centre for Remote Sensing, Natural

Resources Canada, Environment Canada, the Canadian Ice Service, C-CORE and Noetix.

In 2003, the Canadian Space Agency established the Advanced Mode Utilisation Office, which creates a single point of contact for RADARSAT-2 users of the federal government and integrates the development of new applications. The Office disseminated information through workshops and symposia, acquired polarimetric data to prepare for RADARSAT-2 and provided technical support to the RADARSAT-2 Program.

The Canadian Space Agency also launched the Science and Operational Applications Research program, in cooperation with RADARSAT International and the Canada Centre for Remote Sensing. It will explore operationally and commercially viable solutions to current issues and problems relating to use of RADARSAT-2 images. The program will provide limited RADARSAT-2 data to key clients, partners and research organizations, and arrange for RADARSAT International to provide 400 free scenes to international users. An additional 800 scenes will be processed at the Canadian Space Agency's expense for research users.

Significant achievements in 2003 include:

Establishment of Advanced Mode Utilisation Office

Establishment of Science and Operational Applications Research program.

CloudSat

The CloudSat mission will provide the first global survey of the synoptic and seasonal variations of cloud vertical structure, and frequency of occurrence. This in turn will allow the first global three-dimensional cloud maps, which is a significant improvement over existing capabilities. CloudSat seeks to overcome shortcomings in the treatment of clouds in climate models and the lack of information needed to accurately characterize cloud processes or validate climate models. The satellite launch is planned for November 2004. Canada is contributing key radar components to the Cloud Profiling Radar of NASA's CloudSat mission.

Artist's impression of Cloudsat

Significant achievements in 2003 include:

Hardware development completed and delivered for integration.

HYDROS

The proposed HYDROS mission will measure global soil moisture and freeze-thaw zones over the Earth with a three-day revisit time. The mission is a proposal under NASA's Earth System Science Pathfinder program, and is currently in phase 0/A. Provided it receives support at the Critical Mission Review in 2007, the mission will be launched in 2010.

In Canada, participation has included: Canadian Space Agency support to hardware development; Canada Centre for Remote Sensing support to field campaigns and the data

The HYDROS satellite will monitor global freeze-thaw dynamics and soil moisture from space

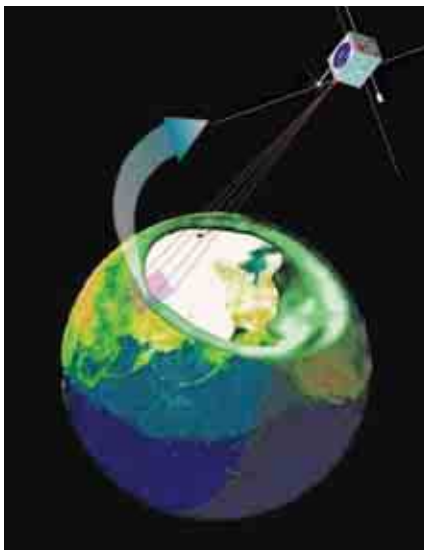
reception and processing facility; and Meteorological Service of Canada support for the development of an operational data assimilation system.

Significant achievements in 2003 include:

- Completed two synthetic aperture radar processor studies
- Completed antenna design study to reduce risk on antenna and feed systems
- Cost estimates developed and updated
- Confirmation of partnership and negotiation of mission implementation calendar with NASA

Enhanced Polar Outflow Probe (ePOP)

The enhanced Polar Outflow Probe (ePOP) mission is a Canadian small satellite that will carry eight instruments (six Canadian, one American and one Japanese) to study polar ion outflow and plasma instability over the Earth's polar cap. The mission is a space environment experiment exploring the transitional region between the atmosphere and geo-space (~1000 km altitude). This mission will contribute significantly to Canadian and international knowledge of solar-terrestrial relations. It is scheduled for launch in 2006 together with the CASCADE communications payload on the CASCADE Smallsat Ionospheric Explorer (CASSIOPE) satellite. Formal approval for the mission was sought in 2003.



Artist's impression of Canada's enhanced Polar Outflow Probe (ePOP), which will monitor solar-terrestrial relations

Significant achievements in 2003 include:

- Project documentation completed
- Formal approval for the mission sought

New Technologies

The Canadian Space Agency is continually pursuing new avenues of research to identify promising space technologies that offer innovative solutions to terrestrial challenges. Two critical activities currently being pursued are the development of hyperspectral sensing and applications technologies and the development of low-cost, small-satellite synthetic aperture radar systems.

The Advanced SAR Workshop is a bi-annual event organized by the Canadian Space Agency to review the progress of advanced synthetic aperture radar technology. The fifth Workshop was held in June 2003 at the John H. Chapman Space Center, jointly organized by the Canadian Space Agency and the Canada Centre for Remote Sensing. Extending over three days, the workshop provided a complete overview of synthetic aperture radar technology development. In all, 94 speakers and over 180 participants from 15 different countries participated in the event.

Hyperspectral Technology Development

Hyperspectral technology development in Canada has been in progress for nearly twenty years and it has resulted in many notable achievements. Among these are a series of advanced airborne hyperspectral imagers, such as the Fluorescence Line Imager, the Compact Airborne Spectrographic Imager and the Shortwave infrared Full Spectral Imager. As a result of this work, airborne hyperspectral instruments are now flown routinely to collect data in support of public and private sector information needs. The next step in this development program is an operational space borne mission. The Canadian Space Agency is currently conducting mission concept studies in preparation for launch of a hyperspectral earth observation satellite. The mission will build on Canadian industry's experience and expertise in remote sensing, and make new capabilities available for a wide variety of users that will provide economic, social, and environmental benefits to Canada and the world.

Artist's impression of HERO

The Canadian Space Agency completed in March 2003 a Phase A study for a Canadian hyperspectral mission, the Hyperspectral Environmental and Resource Observer, which would enable public and private sector users to access data from the world's only operationally-focused hyperspectral mission. It would also provide Canadian companies with an opportunity to showcase their expertise in a significant fashion. Combined with the smallsat bus program, Canada could take a lead role in spectral imaging by flying a small hyperspectral sensor in support of an operational mission.

The Canadian Space Agency has now begun a Phase A2 study:

- To develop three scenarios:
    1) A Stand alone Canadian mission;
    2) A Canadian mission to which another country contributes;
    3) A foreign mission to which Canada contributes as a component supplier or partner.
- To pursue critical technology development, allowing Canadian companies to participate regardless of retained scenario.

Significant achievements in 2003 include:

Alternate system concepts have been considered for a small satellite mission to respond to consolidated user requirements

Baseline mission requirements generated

Payload concepts progressed, optical design developed, data handling and payload specifications developed

Shortwave infrared cameras incorporating Rockwell (U.S.) devices compared to SOFRADIR devices (Itres contract)

Work on algorithms and dedicated electronics and system design

Hyperspectral Applications Development

The Canada Centre for Remote Sensing is leading a collaborative pre-competitive research effort to develop new techniques in the processing, visualization, and analysis of hyperspectral data by focusing on the development of calibration and data pre-processing methods, procedures for extracting information, and related information products. The Hyperspectral Applications Development Program at the Canada Centre for Remote Sensing is strongly focused on issues of concern to the Earth Sciences Sector: sustainable development of natural resources, northern development, and a clean environment. It is currently focusing on the development of algorithms and related information products in:

- Exploration geology
- Environmental monitoring and assessment
- Forestry
- Precision farming
- Wetlands
- Geobotany

www.ccrs.nrcan.gc.ca/ccrs/misc/issues/hypersp_e.html

Membrane Synthetic Aperture Radar antenna under development at EMS Technologies, Ste-Anne-de-Bellevue, Québec.

Last year, the Canadian Space Agency initiated a number of hyperspectral applications development projects under the Earth Observation Application Development Program which culminated this year, including:

- A.U.G. Signals Ltd. used hyperspectral data to develop a prototype that automatically detects and classifies minerals and provides an on-line reliability test;
- Dendron Resource Surveys developed techniques and approaches exploiting hyperspectral technology to drive models for tree species identification;
- Paterson, Grant & Watson Limited, a geophysical consulting firm, in partnership with EarthScan Limited, a remote sensing consulting business, developed geophysical and remote sensing software modules to aid in mineral exploration and geologic mapping, particularly in characterizing ore environments;
- PCI Geomatics developed capabilities for visualisation and processing of hyperspectral data, and its integration with other data; they also developed atmospheric correction of hyperspectral data capabilities within the Geomatica platform;
- Viasat Geotechnologies worked with hyperspectral and polarimetric radar data to give the telecommunications industry tools to improve the design and implementation of wireless communication networks.

SmallSat Synthetic Aperture Radar

The Canadian Space Agency has worked with industry since 1996 to develop new technologies in support of Canada's synthetic aperture radar program. In particular, the Agency has sought to support work enabling lower cost systems by reducing the mass and stowed volume of the antenna. This work has evolved into a technology development program focused on demonstrating the feasibility of a low-cost, lightweight synthetic aperture radar that could fly on a small satellite. The work to date has focused on L-band, though future work is expected to be done in C-band.

SmallSat Synthetic Aperture Radar development activities are currently focusing on the construction of a large engineering model of a deployable membrane antenna and the development of payload electronics for a 400 kg mission that could fly as early as 2008. The mission, if approved, could use the smallsat bus under development within the Canadian Space Agency for the CASSIOPE mission. It could either fly as a single mission, or in tandem with another satellite.

A preliminary Science Plan for a demonstration mission covers a number of applications of interest to Canada including:

- Ice/Glacier Monitoring;
- Coastal Surveillance;
- Digital Elevation Models for Polar Regions;
- Global Biomass Estimates.

Significant achievements in 2003 include:

Completion of small array demonstrator to validate electrical performance of small membrane antenna; electrical and mechanical components designed and breadboarded; small antenna tested (2.6 m x 1.7 m)

Completion of large engineering model expected by year end: mature validation of membrane antenna technology for use in low-cost SAR instrument

In order to ensure our ability to deliver and operate independent space missions, Canada must maintain an up-to-date and effective ground infrastructure and ensure programs are in place to promote and encourage ready access to space data and information.

Reception activities

Satellite Ground Segment Infrastructure

The Canada Centre for Remote Sensing operates two satellite ground stations, the Prince Albert Satellite Station in Saskatchewan and the Gatineau Satellite Station in Cantley, Quebec. Day-to-day operations are coordinated in Ottawa. The ground segment is supported by dedicated management and engineering teams, which oversee its operation and evolution. Together, the two stations are able to receive data covering the entire North American continent. Operating in a multi-mission environment, these stations receive Earth observation data from several satellites and have accumulated an archive in excess of 335 terabytes dating back to 1972. Data is made available to support near-real-time applications such as ice monitoring, forest fire monitoring and mapping, as well as non-real-time applications such as climate change and land use.

The Ground Segment Infrastructure receives remote sensing data required to generate knowledge and information critical to resource use and decision making on local, regional, national and global scales.

In addition to its primary role in providing data related to land resources and climate change contributing to sustainable land management in Canada, the ground segment also serves as the Canadian ground segment component of RADARSAT-1 in partnership with the Canadian Space Agency and RADARSAT International, and will play the same role for RADARSAT-2. The stations also serve as part of ESA's European Remote Sensing (ERS) Satellite National Station network.

Significant achievements in 2003 include:

- Completion of the ENVISAT Advanced Synthetic Aperture Radar ground segment upgrades and commencement of ENVISAT operations;
- Substantive progress on RADARSAT-2 ground segment upgrades
- Implementation of modernization plan to enhance RADARSAT-1 ground segment infrastructure for extended mission life using new RADARSAT-2 ground segment architecture;

Prince Albert Reception Station, Saskatchewan

- Development of a RADARSAT-1 contingency plan using ENVISAT radar data;
- Implementation of a Landsat-7 contingency plan using Landsat-5 Thematic Mapper™ data.

Access

The Canadian Space Agency and its partners have initiated a number of programs to improve access to Earth observation data and data products.

Government Related Initiatives Program

The Canadian Space Agency's Government Related Initiatives Program fosters the use of space-borne remote sensing information by federal government departments to enhance their efficiency and effectiveness and showcase Canadian technology. Over the course of the year, this Program was expanded to focus on multilateral initiatives supporting government-wide objectives. This has led to the creation of a large number of new initiatives that aim to integrate space data in operational mandates on an on-going basis.

The actual projects supported under the Government Related Initiatives Program are described in other sections of this document. The full list of projects includes:

1. Cryosphere and its Response to Climate Change
2. Climate Change and Ecosystem Impact
3. Earth Observation for Sustainable Development of Forests (forest mapping)
4. Wealth of Water (inland waters)
5. RADARSAT-2 Advanced Modes applications
6. Ocean's Pulse
7. This is my Canada (mapping of land cover and topography)
8. Earth observation for atmospheric and oceanographic modelling and forecasting
9. Marine surveillance for law enforcement
10. Assessing and monitoring agricultural sustainability
11. Managing impacts of precipitation anomalies
12. Real-time emergency management

Earth Observation Application Development Program

The Canadian Space Agency's Earth Observation Application Development Program supports industry initiatives to develop applications and markets. The Program encourages the use of satellite data generated by space missions in which Canada is a participant. The Canadian Space Agency's goal is to enhance the level of expertise and competitiveness of the Canadian industry while stimulating innovation.

The Program favours projects that demonstrate the ability to strategically position the Canadian Earth observation industry through the development of either commercial applications or applications to fulfill government requirements. The Program is aimed at private companies, who are nonetheless encouraged to create partnerships with potential end users as well as with research and non-profit organizations.

The Canadian Space Agency announced nine contracts in June 2003 worth over $3 million, including:

- Atlantis Scientific Inc: Monitoring Subsidence in Urban Areas Associated with Petroleum Production / Production and Editing Tools for Large Area Digital Elevation Models Derived from Spaceborne Synthetic Aperture Radar Data;
- Dendron Resources Surveys Inc: Using RADARSAT for Sustainable Development in Chile;
- Enfotech Technical Services: IceNav Virtual Marine Radar- RADARSAT Marine Radar Integration;
- Geographic Resources & Integrated Data Solutions Ltd (GRIDS): The Virtual Globe Project for Canadian Space & Airborne imagery;
- Hatfield Consultants Ltd: Decision Support Tools for Aquatic Environmental Assessment and Monitoring in the Mekong Basin;
- MacDonald Dettwiler and Associates: Generic Hyperspectral Data Scrubber/ Multi-source Image Digital Elevation Model Generator;
- MIR Télédétection Inc: Développement et commercialisation de produits sur le potentiel diamantifère intégrant la technologie RADARSAT ;
- PCI Geomatics Group Inc: Development of Enhanced SAR Visualization and Analysis Capabilities within Geomatica;
- Vantage Point International Inc: Disaster Network for Remote Observation / Multi-Acquisition Synthetic Aperture Radar Coverage Tool.

GeoConnections Discovery Portal

The GeoConnections Discovery Portal, formerly known as CEONet, provides a discovery service for satellite imagery, such as RADARSAT, as well as for related geospatial products and services. Every day, over 1200 users access the GeoConnections Discovery Portal and its underlying services. The Portal is the primary discovery mechanism of the Canadian Geospatial Data Infrastructure. The RADARSAT catalogue and browse data of RADARSAT International are accessible worldwide through GeoConnections. Access to RADARSAT and other Earth observation data as well as in-situ data allows the Canadian value-added industry to develop new products and services using RADARSAT data and market these internationally.

The Public Agency Content and Connectivity and Canadian Geospatial Data Infrastructure Development Network programs have facilitated the establishment of partnerships to support the continued growth of Canadian Geospatial Data Infrastructure access services. Ongoing partnerships include:

- Provincial agencies (Newfoundland and Labrador, Ontario);
- Federal agency (Fisheries and Oceans Canada);
- National programs (Forestry – National Forest Information System , Geoscience – Canadian Geoscience Knowledge Network);
- Regional programs (Atlantic Coastal Zone);
- Private sector (Compusult, Cubewerx, DM Solutions, Galdos, 3i, Holonics, MacDonald Dettwiller and Associates, Open GIS Consortium, PCI).

The GeoConnections Discovery Portal was released this year and the underlying software was made available free of charge to all GeoConnections partners. The suite of access services is expanding from "discovery" to visualization, data access and value-added services. Communications and training material in support of the new services are being developed in cooperation with the Technology Advisory Panel and the GeoConnections Secretariat.

Access presentations and training sessions continue for new stakeholder communities, at major conferences, and in cooperation with industry programs.

The GeoConnections Discovery Portal is accessible at: ceonet.ccrs.nrcan.gc.ca.

National Forest Information System

In conjunction with GeoConnections, the National Forest Information System project is furthering its mandate of making Canadian forestry information available online, in architectural alignment with the Canadian Geospatial Data Infrastructure. In 2003/04, an operational National Forest Information System will complete server deployment in all provinces and territories, enhance the public National Forest Information System web site, and develop a number of integral geospatial web services in consultation with, and for use by, the larger Canadian Geospatial Data Infrastructure community. These services will enhance peer infrastructures and enable new applications, as well as demonstrate the will to collaborate and consolidate development across the Canadian Geospatial Data Infrastructure. The National Forest Information System enables sustainable forest management practices in Canada with readily accessible, integrated and consistent forestry information for federal, provincial, territorial and municipal governments, as well as industry and the Canadian public.

Fourth Canada-USA Framework Data Project

In late June, representatives from GeoConnections and the U.S. Federal Geographic Data Committee met in Ottawa to evaluate proposals from the fourth Canada-USA framework data request for proposals. These joint framework data projects are designed to stimulate cross-border cooperation through the development and use of a common geospatial data framework that involves multiple organizations integrating and sharing framework data among different users. This year's selected project is for the Gulf of Maine and involves multiple Canadian and U.S. government agencies and private companies. It will result in an integrated framework of the sea floor of the Gulf of Maine to be used by those interested in commercial and recreational fishing, marine sanctuaries and protected areas, fibre-optic and electric cable laying, ecotourism, mining, navigation and aquaculture. The project will further our scientific and technical understanding of the complexities, challenges and efforts required in developing and utilizing framework data to address a common issue over one continuous piece of geography shared by Canada and the U.S.

Many of Canada's space programs are undertaken in partnership with foreign space agencies and nations. Canada has traditionally played a lead role in establishing multilateral programs and enjoys a privileged relationship with ESA, as its only non-European cooperating member. Bilateral cooperation with the United States, Japan, India and others allow Canada to leverage its space technology investments to mutual benefit.

Artist's impression of Envisat

Committee on Earth Observation Satellites (CEOS)

The Committee on Earth Observation Satellites (CEOS) was created in 1984 in response to a recommendation from a Panel of Experts on Remote Sensing from Space, under the aegis of the Economic Summit of Industrialized Nations Working Group on Growth, Technology and Employment. This Group recognized the multidisciplinary nature of space-based Earth observation and the value of coordinating international mission plans.

Canada, through the Canadian Space Agency, is a charter member of the Committee, along with France, India, Brazil, the United States (NASA/NOAA), ESA and Japan (JAXA). The Canada Centre for Remote Sensing is an Associate member. There are presently 20 CEOS members and 18 Associates.

Canada's main contribution to CEOS continues to be as an active leader and member of Working Groups established to help CEOS meet its primary objectives.

The CEOS Ad hoc Disaster Management Support Group supports natural and technological disaster management worldwide by fostering improved use of existing and planned Earth observation satellite data in selected hazard areas: drought, earthquake, fire, flood, ice, landslide, oil spill, and volcanic hazards. The recommendation from the Working Group on Disaster Management Support has led to the formation of the Integrated Global Observing Strategy Geohazard theme. The Canada Centre for Remote Sensing is a core participant in this Geohazard theme. The Working Group supports the work of the United Nations Committee on the Peaceful Uses of Outer Space in pursuit of decisions taken at UNISPACE III, under the United Nations International Strategy on Disaster Reduction and the International Charter 'Space and Major Disasters'.

At the CEOS 15th Plenary in Kyoto, the Strategy of the Working Group on Training and Education and its 3-year action plan were adopted. The Canada Centre for Remote Sensing is coordinating an effort to make CEOS agencies' educational and

training materials more accessible and visible to the international Earth observation training world.

In June 2003, the Canadian Space Agency hosted the synthetic aperture radar sub-group of the Working Group on Calibration and Validation.

Canada-European Space Agency Collaboration

The first Canada-ESA cooperative agreement was signed in 1979 and was renewed in 2000 for another 10 years. Canada is the only non-European country to participate directly in European Space Agency programs. The agreement provides the framework for Canadian companies and other organizations (universities, research institutes and various government departments) to collaborate in space-related activities with their European counterparts. In terms of industrial benefits, over $350 million in contracts have been awarded to Canadian companies through European Space Agency programs over the lifetime of this cooperative agreement.

Canada currently participates in the following ESA programs:

- Earth observation: ENVISAT, Earth Observation Preparatory Program, Global Monitoring for Environment and Security , Infoterra/TerraSar;
- Satellite communication: ARTES-1, -3, -5 and ARTEMIS;
- Satellite navigation: GalileoSat Definition Study;
- Planetary exploration: AURORA

In addition, Canada participates in the General Support Technology Program and contributes to the mandatory General Budget.

ENVISAT

ENVISAT is the follow-on to the European Space Agency's earlier Earth observation satellites, ERS-1 and ERS-2, to which Canada made significant contributions. ENVISAT provides data and information required to further the understanding, modelling, and prediction of environment and climate change. ENVISAT's two main sensors are the Advanced Synthetic Aperture Radar and the Medium Resolution Spectral Imager. The radar will likely play a key role in ensuring C-band data continuity for Canadian RADARSAT users.

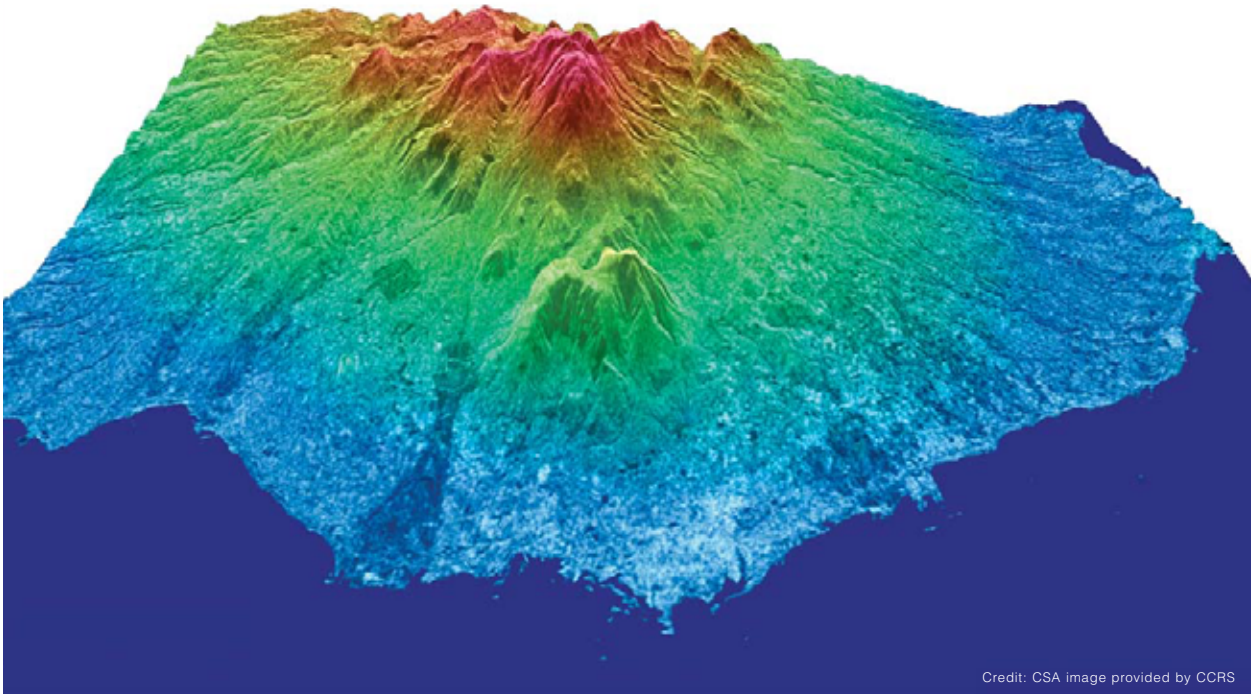
Canadian end users will also benefit from Canada's involvement in ENVISAT. The Canada Centre for Remote Sensing concluded a data distribution agreement with ESA to distribute radar data to Canadian government departments. www.envisat.esa.int.

Earth Observation Envelope Program

ESA's Living Planet Program has been introduced to address the Agency's overall future Earth observation activity after the ENVISAT program. It consists of two main components: the research-oriented Earth Explorer missions and the operational service-oriented Earth Watch missions. These missions are implemented via two programs: the Earth Observation Envelope Program and the Earth Watch Program. The Earth Explorer missions are completely covered within the Earth observation Program. Details on the Agency's Living Planet Program can be found at: www.esa.int/export/esaLP.

The first phase of the Earth Observation Envelope Program covers the 1998-2002 period, through which two Core and three Opportunity missions were selected. Planning and implementation scenarios for the second phase of the program have been formulated. Three Core missions are selected for phase A study. Canada has expressed particular interest in the SPECTRA and WALES missions.

Within the Opportunity missions of the first phase of the program, Canada proposed SWIFT as a cooperative mission between the European and Canadian Space Agencies. Through collaboration with JAXA, SWIFT was selected as one of the payloads to fly on Japan's GOSAT. Canada is well positioned



RADARSAT-1 data used to generate Digital Elevation Model (DEM) of Mt. Unzen for geo-hazard monitoring

for this type of mission given work on the Wind Imaging Interferometer, launched on board NASA's Upper Atmosphere Research Satellite in 1991. Under the European contribution to Global Precipitation Mission, the Canadian Space Agency indicated an interest to contribute a Precipitation Radar that can measure snowfalls as well as rain.

Global Monitoring for Environment and Security (GMES)

GMES is a joint European Union and European Space Agency program whose objective is to establish, by 2008, a European capacity for global monitoring of environment and security. The Program has become the focus of European development related to the use of geospatial data for resource management and monitoring. An important aspect of the program is the use of Earth observation and other data for policy and decision-making. The goals of this program are closely aligned with the goals of the federal government departments to use the results of sound science to support policy and other decision making. GMES is in the second year of a two-year Initial Period (2002-03). The report from this Initial Period will set the stage and give recommendations for the Implementation Period (2004-2008). The Final Period of the program will be the Operational Period (2009+). For this Operational Period, Europe is seeking to have an autonomous, operational system that will guarantee sustainable, long term, and coherent monitoring and the production of information products that combine in-situ measurements, Earth observation data, and the results of models.

earth.esa.int/gmes/

The European Space Agency component of GMES, implemented within the Earth Watch program, is known as the GMES Service Element. ESA approved the program in November 2001, with a total budget of 83 million Euros over the 2002-2006 period. Canada is one of the 14 participating countries. So far, a total of 10 contracts have been awarded. The C-CORE Northern View project is one these contracts.

Canada-Japan Collaboration

Canada and Japan meet annually to discuss cooperation under the aegis of the Japan-Canada Space Panel. The Earth Observation Working Group under the Japan-Canada Space Panel is chaired by the Canada Centre for Remote Sensing. Current areas of collaboration include geological hazards using synthetic aperture radar techniques. Canada Centre for Remote Sensing and Fisheries and Oceans Canada scientists are also participating as Principal Investigators in the evaluation of Japan's Advanced Land Observing Satellite in the areas of geological hazards, ocean surface and ice mapping and disaster management.

Geological hazards are considered a strategic area for cooperation for Canada and Japan. The bulk of RADARSAT data

sales to Japan is in this area. Japan has suffered the fatal effects of earthquakes, landslides and volcanoes. Developing monitoring and mapping technologies for disaster mitigation is a priority for Japan. Canada is providing RADARSAT images, InSAR software, and other image processing software. The Canada Centre for Remote Sensing cooperates with the Japan Aerospace Exploration Agency and the National Research Institute for Earth Sciences and Disaster in developing InSAR and stereo synthetic aperture radar application for geohazard mapping and monitoring that will facilitate the commercial uses of RADARSAT-1&2 and the Advanced Land Observing Satellite. Discussions are on-going on future synthetic aperture radar collaboration.

Canada – India Collaboration

In March 2003, the Canadian Space Agency and the Indian Space Research Organisation signed a Memorandum of Understanding reaffirming their pursuit of international space cooperation for peaceful purposes, while working towards economic and social development for both countries.

The Memorandum will foster the study of cooperative programs in satellite communications and satellite remote sensing as well as encouraging cooperation in the field of exploration and use of space by the private sector and academia in both countries. Both parties also signed a letter referring to the several projects and activities in which the Indian Space Research Organisation and the Canadian Space Agency have a joint interest. Such projects include: possible participation in a Moon Orbiter mission, an agreement for Launch Early Operations Phases, support of the United Nations Space Science and Technology Education Centre in India, and collaboration in the ASTROSAT/Ultraviolet Imaging Telescope mission.

Global Observation of Forest Cover and Land Dynamics

The Global Observation of Forest Cover and Land Dynamics is a panel of the Global Terrestrial Observing System and its overall objective is to improve the quality and availability of earth observations of forests and landcover dynamics at regional and global scales and to produce useful, timely and validated information products from these data for a wide variety of users.

The goal of the organisation is supported by developing prototype projects along three primary themes:

1. Forest Cover Characteristics and Changes;

2. Forest Fire Monitoring and Mapping;

3. Forest Biophysical Processes.

As part of this process, teams are assembled to execute prototype projects, develop consensus algorithms and standard methodologies for product generation and product validation in conjunction with in-situ measurements, and develop and demonstrate procedures for improved data access for the user community. These teams identify gaps and overlaps in earth observation data, ground systems, methods, and scientific knowledge from the experience gained in developing and executing Global Observation of Forest Cover prototype projects. The ultimate objective is to lead to sustained, on-going operation without the need for major funding by CEOS members.

The Global Observation of Forest Cover and Land Dynamics panel has a new Executive Director from the Canadian Forest Service, where the new secretariat will be based. The primary role of the Executive Director is to maintain external and internal communication, liaise with collaborating partners, facilitate support for the activities of the three implementation teams, and arrange annual meetings of the scientific and technical board. Support for this position is provided by the Canadian Space Agency and the Canadian Forest Service.

www.fao.org/gtos/gofc-gold/index.html

For more information on the initiatives described in this brochure, please contact:

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ACRONYMS

A

ARTEMIS Advanced Relay and Technology Mission Satellite
ARTES Advanced Research in Telecommunications Systems
AURORA ESA Space Science Mission
AVHRR Advanced Very High Resolution Radiometer (U.S.)

B

BERMS Boreal Ecosystem Research and Monitoring Sites

C

CASSIOPE CASCADE Smallsat Ionospheric Explorer
CEONet Canadian Earth Observation Network (now GDP)
CEOS Committee on Earth Observation Satellites
CloudSat NASA Earth System Science Pathfinder Mission
CONAE Comisión Nacional de Actividades Espaciales (Argentina)
CRYSYS Cryosphere System in Canada

E

E&E Earth and Environment
ENVISAT ESA Environmental Satellite
EOS Earth Observing System (NASA)
ePOP enhanced Polar Outflow Probe
ERS European Remote Sensing Satellite (ESA)
ESA European Space Agency
EU European Union
EUMETSAT European Organization for the Exploitation of Meteorological Satellites

G

GEWEX Global Energy and Water EXperiment
GMES Global Monitoring for Environment and Security (EU/ESA)
GOES Geostationary Meteorological Satellite
GOSAT Global Change Observing Mission-A1 (NASDA)
GPS Global Positioning System
GRACE Gravity Recovery and Climate Experiment
GTOS Global Terrestrial Observing System

I

I-STOP Integrated Satellite Targeting of Polluters

J

JAXA Japan Aerospace Exploration Agency

M

MAESTRO Measurements of Aerosol Extinction in the Stratospheric and Troposphere Retrieved by Occultation
MAGS The Mackenzie GEWEX Study
MERIS Medium Resolution Imaging Spectrometer (Envisat sensor)
MODIS Moderate Resolution Imaging Spectroradiometer (U.S.)
MOPITT Measurements of Pollution in the Troposphere

N

NASA National Aeronautics and Space Administration
NOAA National Oceanic and Atmospheric Administration

O

OSIRIS Optical Spectrograph and Infrared Imager System (on Odin)

P

POES Polar Orbiting Meteorological Satellite

R

RADARSAT Canadian Synthetic Aperture Radar Satellite

S

ScanSAR RADARSAT SAR Scanning Mode
SCISAT Space science satellite
SeaWiFS Sea-viewing Wide Field-of-view Sensor
SMOS Surface Meteorological Observation System
SPECTRA ESA EOEP Mission
S&T Science and Technology
SWIFT Stratospheric Wind Interferometer For Transport Studies

U

UNISPACE United Nations Conference on the Exploration and Peaceful Uses of Outer Space

W

WALES ESA EOEP Mission