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Remote Sensing: A Potent Information Source for Canada's Arctic

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Almost a third of a century ago, the period of commercially and publicly accessible images from the Earth, taken from space, began with NASA's Landsat-1 satellite (then called ERTS-1). The image resolution was of reasonable quality for the time (80m) and a new perspective of the planet we live on was born. Thereafter, a wealth of new information was brought forth from all parts of the world that enabled exciting applications to be developed. This was never truer for the Arctic, when in the 1970's an unprecedented level of exploration and development was taking place. Information from the Arctic region was so sparse, that researchers and exploration companies used pictures from weather satellites with km-scale resolution to provide land detail even before the availability of Landsat-1.

The newly formed Canada Centre for Remote Sensing (CCRS) was the first foreign agency permitted to directly receive these new U.S.-owned Landsat-1 images. This marked a history of many technological 'firsts' in Canada. The development of ground receiving stations by MacDonald Detwiler and Associates of Vancouver was one of them. From this humble beginning, two receiving stations, one in Prince Albert, Saskatchewan and later one in Shoe Cove, Newfoundland, silently received satellite data for much of North America. The Shoe Cove station was eventually discontinued and replaced in 1985 by the Gatineau Satellite Station located in Cantley, Quebec.

In the 1970's, sovereignty and surveillance in the Arctic became important issues for the government. This eventually led to the development of the RADARSAT-1 mission, the most advanced civilian synthetic aperture radar (SAR) satellite at the time of launch in

November of 1995[1]. RADARSAT-1 has been in operation ever since and, at the time of writing, has completed over 40,000 orbits of the Earth. In a near-polar orbit (as most Earth observing satellites are), a convergence of satellite orbits occurs at high latitudes, where repeat visits for any particular spot on the ground is more frequent than at lower latitudes. In the Arctic, therefore, opportunities for acquiring cloud-free optical images are much greater than at lower latitudes. Cloud cover does not obscure the ground from radar imaging, so RADARSAT-1 is often described as an 'all-weather' satellite, capable of imaging day or night and throughout the dark winter months of the Arctic. Dry snow cover is also transparent to radar, thus the Canadian-built satellite is truly well suited for our northern environment.

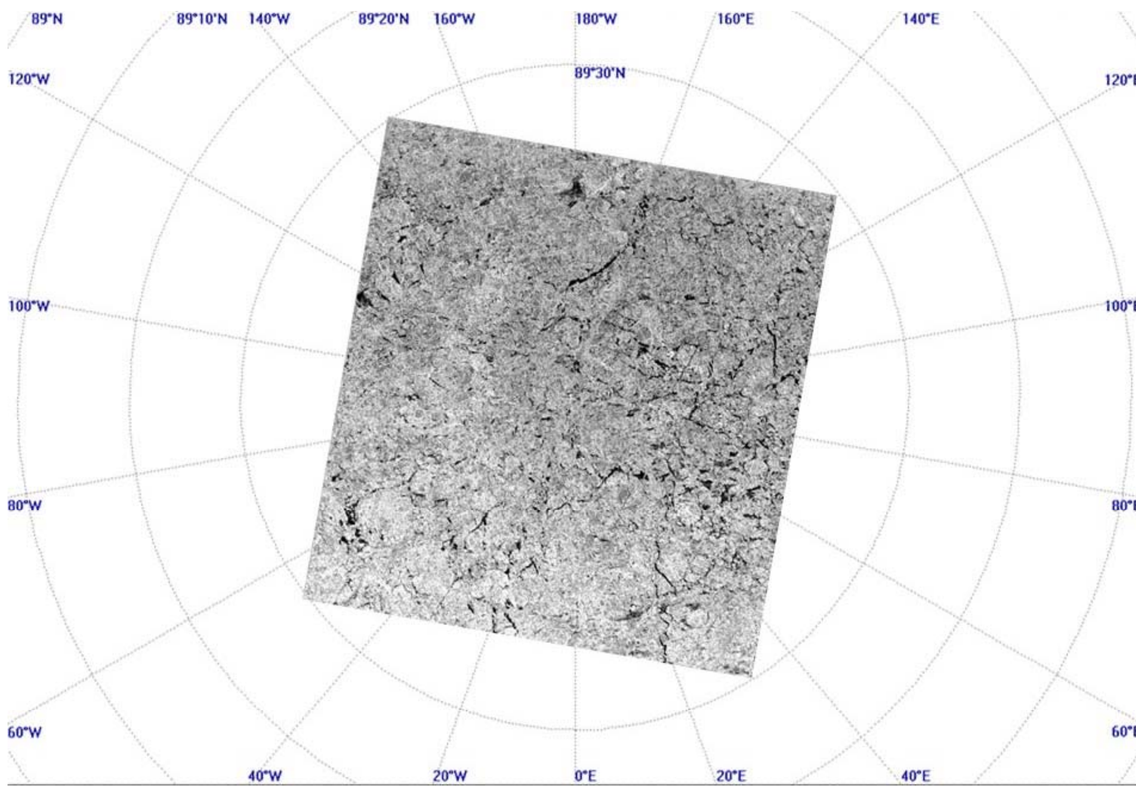

Figure 1: Eighteen images across the pole have been collected by RADARSAT-1 for various purposes since the first in 1997. The latest is a RADARSAT-1 Extended High (beam 4) image, acquired 00:30 UT on January 1, 2003. This single image covers the northernmost 30' of latitude of Arctic Ocean sea-ice where parts are still in December 31, 2002 according to the International Date Line. Cloud cover and total darkness do not impede radar data collection by RADARSAT-1. Multi-year blocks of rough ice are in bright tones, whereas narrow zones and small patches in dark tones are the current year's fractures and open water leads that have refrozen.

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[1] Further reading on the history of remote sensing in Canada can be found at http://www.ccrs.nrcan.gc.ca/ccrs/org/history/history_e.html (July 23,2003).

The CCRS ground receiving stations have collected, processed and archived data from over a dozen missions for Canada, the European Space Agency, France, Japan and the United States. Current missions include NOAA AVHRR, Landsat-5/7, RADARSAT-1, ERS and ENVISAT platforms. These international partnerships have been important for Canadians by providing data of not only the Arctic, but for all of Canada. A thirty-year archive holds an impressive, irreplaceable collection of satellite data that provides base line information to government and commercial clients. Archival data for Canada can be searched through the Canadian Earth Observation Catalogue (CEOCat[2]), an on-line image catalogue that allows browsing access to historical data. It was only recently recognized that the preservation of these past images is critical for climate change related studies that require time-series data sets. The future will tell what other applications will require these invaluable glimpses of the past. Many Landsat images older than 12 months are available to the public from GeoGratis[3] whereas NOAA AVHRR data are available soon after acquisition. About 6 Terabytes of Landsat data are received and archived annually by direct down-link over Canada, amounting to some 20-30,000 images. A more impressive volume of approximately 22 Terabytes per year of direct and recorded data collected by RADARSAT-1 worldwide is also received and archived.

In support of government issues and department programs, CCRS continues to provide reception, application development and access services on behalf of the federal government. Satellite data by itself, however, is not information and thus applications development with other government departments, universities and commercial industry has been a strong part of the CCRS mandate. These activities have been an important part of developing a strong remote sensing sector in Canada and a solid knowledge base for the public good. Another technological ‘first’ in Canada was the development of rapid “Quicklook” imagery from Landsat-1 in 1972. In later experiments, Quicklook images were sent by fax directly to ships in the Arctic as navigational aids. Today, Canadian Ice Services of Environment Canada is the largest user of RADARSAT-1, ERS and ENVISAT data in Canada and provides expert near real-time information on sea-ice

[2] http://ceocat.ccrs.nrcan.gc.ca/cgi-bin/client_acc/ceocate/holdings.phtml (July 23, 2003).
[3] http://geogratis.cgdi.gc.ca (July 23, 2003).

conditions to ships in arctic waters, to allow them to choose better and safer routing. Indeed, the economic viability of the Polaris and Nanisivik zinc-lead mines was made possible, due in part to significant cost savings in shipping of ore concentrate for export.

Other federal government users of satellite imagery include the Canadian Space Agency, Department of Fisheries and Oceans, Natural Resources Canada and Parks Canada. Parks Canada, for example, has recently completed a study on the ecological health of northern parklands using NOAA AVHRR data composites. From a 10-year data set the authors recognized a predictable relationship between the occurrence of ice-out conditions on lakes and the rapid onset of vegetation growth in early summer[4]. Impacts of annual changes and long term trends to arctic habitats affect nesting birds and grazing animals.

Resource-based industry (e.g. precious and base metals, diamonds and petroleum), relies increasingly on remotely sensed data to assist with providing information at various stages of the resource development, from exploration to environmental impact reviews, mine site planning and reclamation. Other applications in the Arctic, to name a few, include determining sea-ice conditions, creating digital elevation models, monitoring snow cover and vegetation change, studying on the dynamics of cold-climate processes and the flow of glaciers. The rapid growth of aboriginal communities in the north can be ideally and cost-effectively monitored for municipal planning and development purposes with high-resolution satellites that are often on par with the quality of aerial photography.

Today, as it has for centuries, the Arctic remains a frontier region where information is difficult and costly to obtain on the ground or from other sources. These challenges can be effectively addressed by remote sensing technology because:

- Earth observing satellites have the capability to collect data in a systematic, synoptic and repetitive manner;

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[4] Satellite Monitoring of Northern Ecosystems 2002, (Sparling, B., Wilmshurst, J., Tuckwell J. and T. Naughten). Contact Thomas Naughton, Parks Canada, email: Thomas.Naughten@pc.gc.ca

- The data are acquired in spatial reference frame and contain geophysical and thematic terrain information not available from topographic maps;
- The information is up-to-date, quantitative and impartial.

Canada was among the first nations in space with a small satellite in 1962, Alouette-1, to study the ionosphere for the purpose of furthering the understanding of radio communications in the far north. Driven by cold war policies, only the Soviet Union and the United Sates of America had developed space technologies at that time. Today Canada ranks among Brazil, China, the European Union, India, Israel, Japan, Russia, and the United States with ownership of Earth-observing satellites. Through past investments and leadership, Canada has paid dividends for our aerospace industry and the technological advancements and information have brought benefits for all Canadians. Resource exploration and development is again experiencing resurgence in the North and new concerns are being raised because it is obvious that the impact of human activities and environmental change is affecting the polar region. Satellite sensors, like never before, are poised to provide much needed strategic information for the development and monitoring of the North.

Figure 2: Looking southeast, on July 9th, 1999, across the most of the polar region with SeaWiFS (Sea-viewing Wide Field Scanner) from an orbiting altitude of 705 km (curvature of the Earth is exaggerated in this perspective).
Most of the western Arctic archipelago is cloud-free and this image includes Cape Morris Jesup (Greenland) near the lower left to the Mackenzie Delta, NWT, on the foreground right.

Receiving stations located at high latitudes are in a strategic position because direct communication with a satellite is possible during each orbit. Norway recognized this and has taken advantage of their high latitude and proximity to the pole in Svalbard. SvalSat, currently operates a farm of receiving antennae at Longyearbyen (N78°) for clients worldwide, including the United States. In Canada, for example, a receiving station at Resolute Bay, Nunavut (N75°) would be 22 degrees further north than our northernmost one in Prince Albert and have all the same relative geographic advantages that exist at Svalbard. Foreign interests have already made such inquiries, but waning support for our existing ground receiving infrastructure makes it next to impossible to respond with a Canadian commitment at this time. An investment of this kind could provide sustainable, long-term economic benefits to the north within a high technology sector.

At a time when changes in government programs occur, there is a risk of losing sight of the advantages of maintaining strong competency in core disciplines. In many areas, it can be shown that routine or operational systems of today were historically developed out of earlier support given to high-risk experiments and investigations that did not promise immediate benefits. After coming so far since the beginning of this technological era, let us not lose the solid foundation gained in the field of remote sensing at a time when more technically advanced sensors are being deployed almost annually and providing new and unique data. With our large polar landmass, Canada can continue to play an influential role in global Earth observation policies and practices and we should not let this position languish since it is critical for addressing current and future circumpolar issues.