UTILIZATION OF RADARSAT DATA IN THE CANADIAN ICE SERVICE

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Abstract

The Canadian Ice Service (CIS) is the Canadian Government Agency responsible for providing ice information over Canada's offshore areas for marine operators. The launch of RADARSAT in November, 1995, has provided a major new input to this program. Data from the on-board C-band HH-polarised SAR sensor is acquired in near real time from the Canadian Data Processing Facility (CDPF) at Gatineau, Quebec via a T1 digital link. Ice information products are then developed at the Ice Centre in Ottawa and transmitted to marine clients. The major client is the Canadian Coast Guard (CCG) who receives the imagery and derived products on board their icebreaking vessels and at the Ice Operations Offices, and displays them on Windows NT systems known as Ice-Vu.

This paper will describe the end-to-end system that has been developed for acquiring RADARSAT digital imagery, producing ice data products and transmitting them to marine clients in near real time. The process for analyzing the data and providing ice information to the Coast Guard and other marine clients will be described, and examples of SCANSAR image data and derived ice navigation products will be shown. The image quality of SCANSAR imagery as it relates to ice information extraction will be discussed as will operational benefits to the CIS.

Recently, automatic ice information extraction algorithms are being developed in order to fully exploit the data. An Ice Tracking system, which calculates ice displacements from coincident RADARSAT image pairs, is now running at the Ice Centre in an operational demonstration mode. Additionally, an ice-no ice classifier as a precursor to a fully operational sea ice classification system has been undergoing testing. These two algorithms will be described, along with a Marine Information System (MAST) which will incorporate these and other algorithms into a suite of tools for marine information analysis on a variety of data sources.

1 End-To-End Data Acquisition.

The Canadian Ice Service is the largest user of RADARSAT data and has been an active participant in the program for many years. Indeed, the design of the RADARSAT SAR instrument and the Canadian ground segment was largely driven by the known requirements for operational ice reconnaissance in the Gulf of St. Lawrence, the East Coast and Labrador Sea, and the Canadian Arctic. The CIS had been preparing to make operational use of RADARSAT data as soon as it was available, and were thus ready to take full advantage of the pre-operational data made available by the Canadian Space Agency in early 1996 [Ramsay and Weir, 1996]. The CIS has a long history of operational ice reconnaissance using optical and radar sensors including NOAA-AVHRR, DMSP SSM/I, airborne SLAR and SAR, and ERS-1.

The normal use of RADARSAT for ice reconnaissance by the CIS involves customized ordering, rapid delivery of data, in-house pre-processing (geo-coding, enhancement), interpretation and, finally,

dissemination of products. RADARSAT data are typically ordered 2-weeks to 1-month in advance based on past knowledge of ice conditions in the regions of active commercial shipping. Because of the large volume of RADARSAT data used by the CIS, they are equipped with one of only five RADARSAT Order Desks which permits direct entry of requests to the Mission Control System located at Canadian Space Agency Headquarters in St. Hubert, Quebec. The CIS primarily makes use of the ScanSAR modes of RADARSAT which provide nominal swaths of 500km (at 100m resolution - ScanSAR Wide) or 300km (at 50m resolution - ScanSAR Narrow). These modes are preferred because of the excellent geographic coverage and revisit capabilities at sufficient resolution for the interpretation of significant ice features.

Canada has two receiving stations for RADARSAT data - at Gatineau, Quebec and at Prince Albert, Saskatchewan. The CIS orders data acquisitions from these stations through a on-site node of the Mission Control Order Desk System (ODSys). All data is processed into image products at the Canadian Data Processing Facility (CDPF) at Gatineau, Quebec. An Anik satellite link is used to move signal data from the Prince Albert site to Gatineau prior to processing. The processed data is received at the Ottawa Ice Centre by means of a dedicated T1 digital connection - the Image Transfer Network (ITN). Turn-around is guaranteed under contract with RADARSAT International (RSI) to be less than 4 hours from data acquisition .

The interpretation of imagery is performed visually by experienced ice analysts on an integrated display workstation called ISIS (see Section 2). The GIS capabilities of the system are then used to produce the final "ice chart" familiar to many marine operators, in addition to a variety of other image and map products. These products are then relayed to a variety of marine customers by means of satellite, cellular phone and land line links. The major customer of CIS is the Canadian Coast Guard (CCG). All major icebreaker vessels and the Ice Operations Offices are equipped with communication and display systems (Ice-VU) for capture and display of RADARSAT and ancillary data. Out in the field, Ice-VU is used to extract information from the imagery to assist the ship's Captain in making navigation decisions.

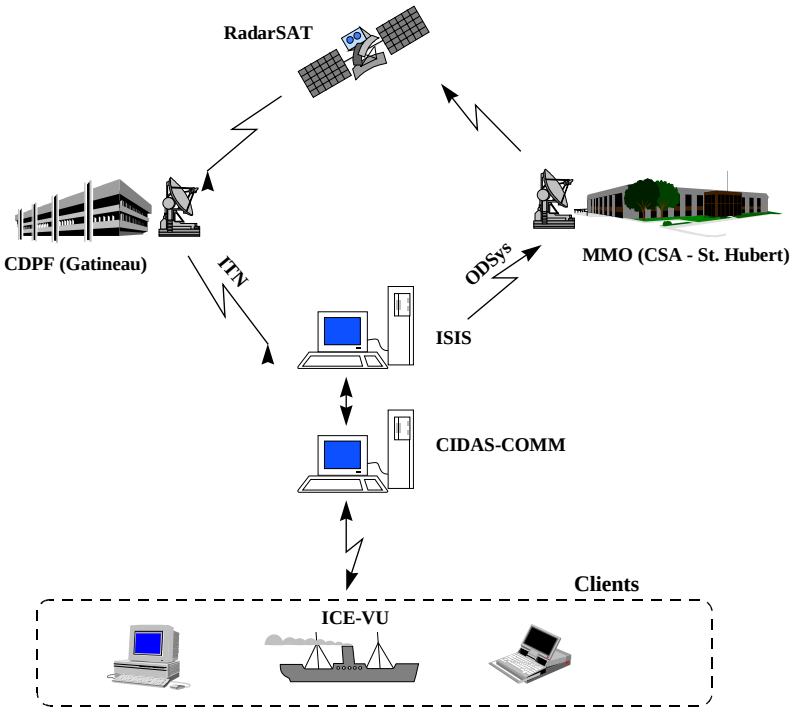

Figure1. Schematic of end-to-end RADARSAT data acquisition, processing, product preparation and delivery.

2. Ice Information Extraction

The Ice Services Integrated System (ISIS) - HP 9000 series servers and workstations - is used to process, display, and analyze RADARSAT SAR data received across the ITN. The image segments are initially 2x2 block averaged (to reduce the file sizes) and geocoded into a Lambert Conic Conformal map projection. During this processing, the file format is converted from the original CEOS to ERDAS Imagine (.img) format for internal system manipulation. The images can be individually displayed and analyzed, or "tiled" together to form a complete mosaic of the full orbital product received.

The visual interpretation of RADARSAT imagery is performed in combination with other available data sets (e.g. NOAA_AVHRR, visual airborne reconnaissance, ship reports, SLAR, ERS-2, DMSP SSMI, meteorological stations, etc.). The GIS capabilities of the ISIS system are then used to produce the image analysis charts and the final daily ice chart familiar to many marine operators. Depending on the location and season, typically 5-10 classes (stages of development and form) may be interpreted from SAR imagery when supported by ancillary data. Detail such as ridging and rafting can also be observed in optimal conditions. The RADARSAT image analysis charts and RADARSAT sub images (called “imagettes”) have become standard products available through a dial-up bulletin board system. All of the these products are made available by mandate to the CIS’s primary client, the Canadian Coast Guard. The Coast Guard Icebreakers access the charts and images using a windows NT based work station called Ice-VU. The RADARSAT imagettes are made available through a commercial redistribution arrangement with RADARSAT International Ltd.

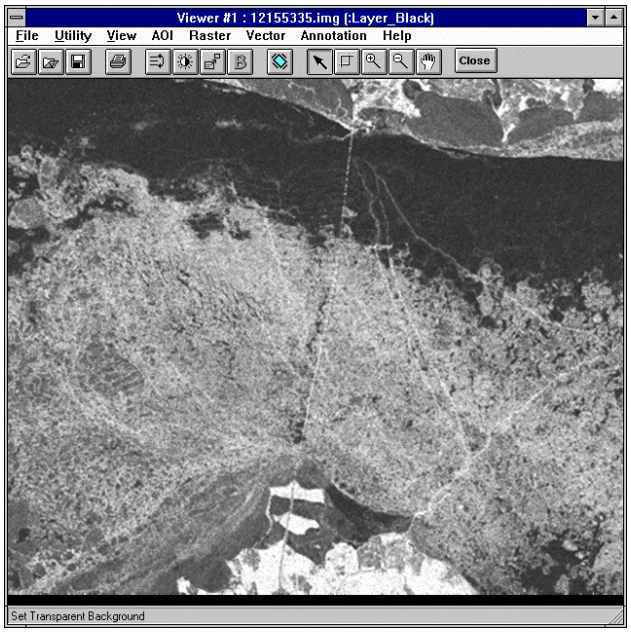

Figure 2. RADARSAT Imagette of the Confederation Bridge between P.E.I. and New Brunswick

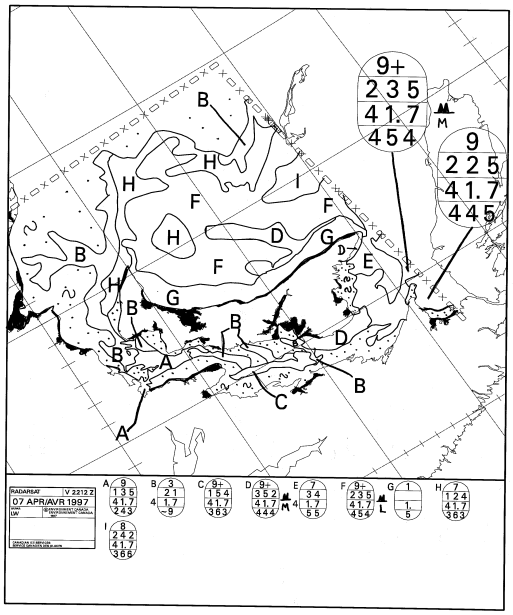

Figure 3. Image Analysis Chart

3. Operational Utility

The strength of the sensor lies in its repeat frequency and swath coverage. RADARSAT imagery is used as an important vessel management tool for the deployment of icebreakers. The data is received within hours of capture allowing Ice Operations Officers to more effectively deploy their ships to areas where ice poses a hazard. Imagery products are typically available to clients within 3 hours from data capture, and analyses

are normally available within 6 hours. During the peak winter marine navigation period from January to April 1997, an average of 85 image analysis charts and 450 RADARSAT image products were produced each month. The frequency of coverage has lead to a reduction of airborne surveillance and the flight hours saved have been directed towards tactical support to the icebreakers.

The regional coverage of ScanSAR provides the CCG with the ice information they require to design shipping routes and to balance their deployment of icebreakers between operations in the Gulf of St. Lawrence and the St. Lawrence River. The Client Services division of the CIS will acquire higher resolution non-ScanSAR modes for clients requiring more detailed surveillance over smaller areas. For instance, RADARSAT Standard and Fine beam images have been acquired over the recently constructed Confederation Bridge (between Prince Edward Island and New Brunswick) and the new mine site at Voisey's Bay, Labrador.

Although generous in geographic coverage, RADARSAT ScanSAR imagery has a trade off in image signature stability. The signatures of ice types and capability of detecting topography improve incrementally away from nadir. This is a result of changes in incidence angle (20-49 degrees for ScanSAR Wide). In the near range, sea surface signatures can often "contaminate" a scene to such an extent that reliable analysis of ice features is difficult. The problem of a steep incidence angle in the near range can be counteracted to some degree in the orbit selection process. During the ordering routine at CIS, careful consideration is given to whether the ascending or descending pass will give the optimal ice signature for an operationally sensitive location, and the data is ordered accordingly.

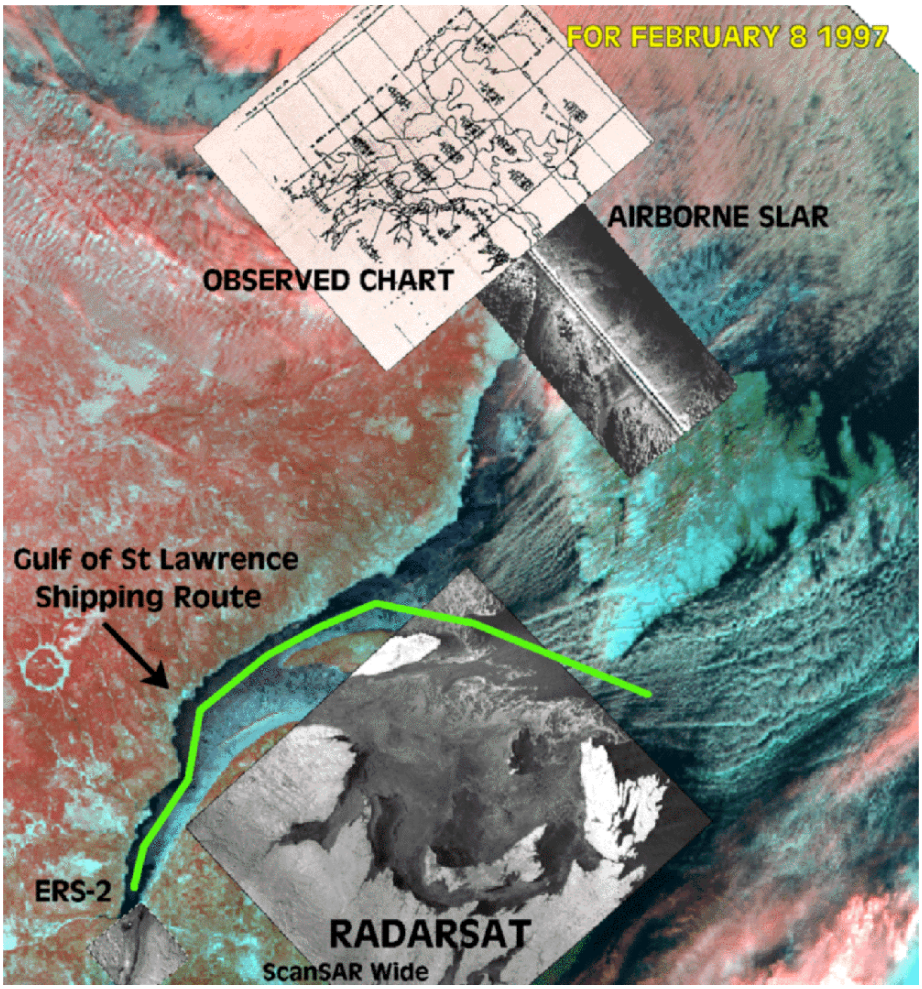

Figure 4. Composite Data Sources used to provide near real time ice information to CIS clients. Feedback from our main client, the CCG, indicates an improvement in the accuracy of our daily chart which is directly attributable to the greater availability of near real time data from RADARSAT. This has lead to improved accuracy in the provision of warnings of hazardous ice conditions.

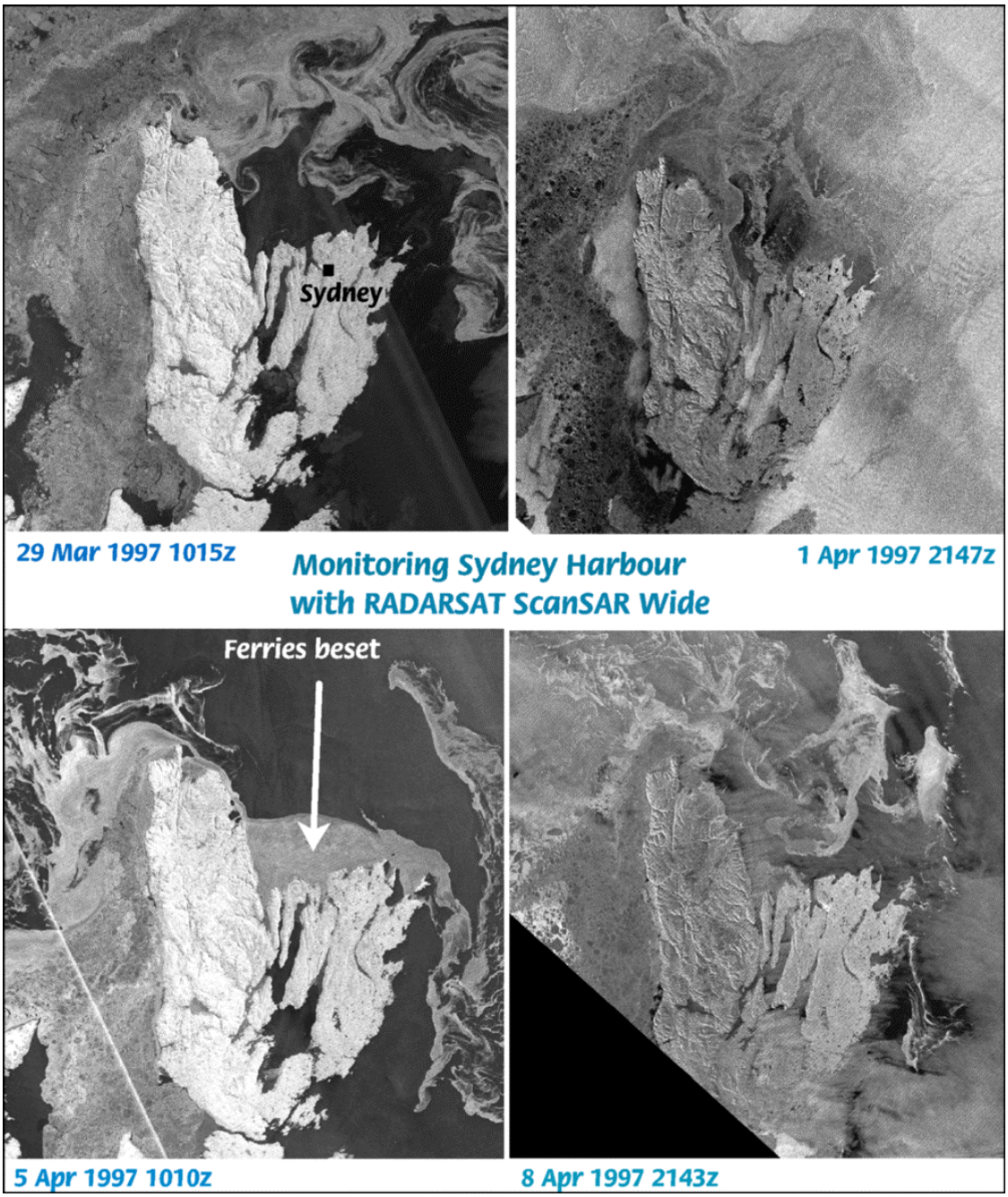

Figure 5. Ice Pressure Warnings Issued for the Cape Breton Coast at Sydney: The reliable, repeat coverage of RADARSAT was used during the winter of 1997 to provide ice warnings for the port of Sydney, Nova Scotia in support of ferry operations between Cape Breton Island and Newfoundland. This series of images illustrates the range of ice conditions encountered during the season as imaged by RADARSAT. On April 5, compacted ice in the approaches to Sydney caused several ships to be beset.

4. Image Quality and Reliability

ScanSAR imagery acquired during the commissioning and early operational phases were used operationally by the CIS, although the imagery did suffer from early artifacts in image quality (e.g., low dynamic range, residual antenna patterns, highly visible seams, nadir ambiguity in beam W3). In addition, the end-to-end reliability of the system was impacted by occasional satellite anomalies, order cancellations for calibration takes and data transmission and processing errors.

Since August 1996, both the image quality and the system reliability have improved significantly. Adjustments to processing parameters as a result of actual antenna pattern calculations for beams comprising ScanSAR, optimization of the CDPF ice applications Look-up Table (LUT), and the introduction of a user-specified Automatic Gain Control (AGC) setting option have resulted in ScanSAR imagery with consistently good dynamic range and balance. The nadir ambiguity in beam W3 remains, and instability with the Doppler centroid estimator continues to cause scalloping, especially evident over open water areas. More work needs to be done to assess whether a seasonal dependent LUT would improve image quality in the Arctic during the break-up to freeze-up transition. The completion of calibration along with continuing overall improvements in operating procedures has resulted in an end-to-end system reliability (percent of imagery acquired versus ordered) that has been around 90% since October 1996.

5. Automatic Information Extraction

Through a jointly-funded project with Canada Centre for Remote Sensing (CCRS), automatic ice information extraction algorithms have been developed in order to fully exploit RADARSAT data. An Ice Tracking system, which calculates ice displacements from coincident RADARSAT image pairs, was run at the Ice Centre in an operational demonstration mode over the Gulf of St. Lawrence this past winter. Additionally, an ice-no ice classifier as a precursor to a fully operational sea ice classification system has been undergoing testing. These two algorithms, along with a NOAA AVHRR Sea Surface Temperature (SST) extraction algorithm and an SSM/I Passive Microwave ice concentration algorithm will be incorporated into a Marine Information System (MAST) by Canadian industry. This objective of this project is to develop a suite of tools for marine information analysis to provide an automatic assist to the ice analyst to quickly extract and present sea ice information from a variety of remote sensing data sources.

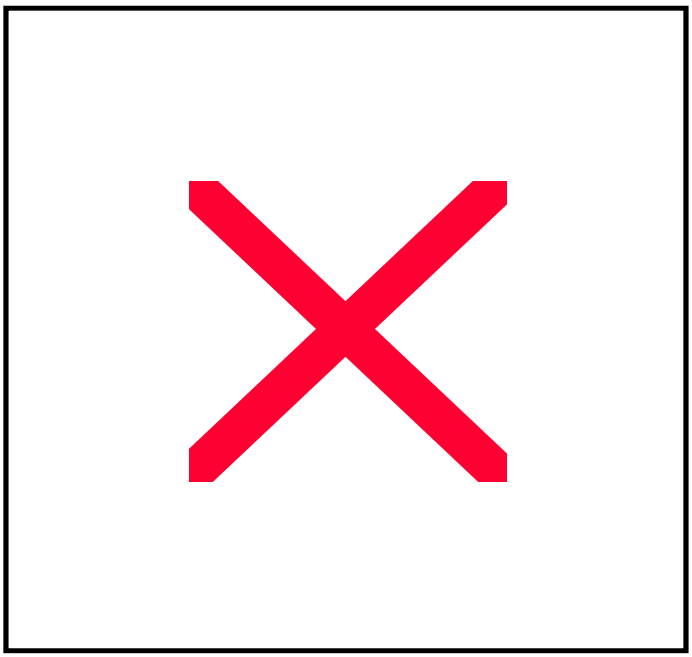

Figure 6. Ice Tracker results in Gulf of St. Lawrence.

6. Conclusions

Since January 1996, the CIS has received over 3350 RADARSAT ScanSAR scenes. In addition to the technological transition that has occurred within CIS to support RADARSAT, operational processes at the Ottawa Ice Centre, CIS field units, on board CCG icebreakers and at CCG Ice Operations Offices have been re-engineered. RADARSAT is now routinely providing data for the operational monitoring of sea ice in Canada and is being used as a valuable data source of operational marine information products to the CCG.

With over a year of operational experience, the CIS is continuing to work towards fully exploiting RADARSAT as its primary data source. Short and long term future objectives are:

- working with CSA and CCRS scientists to optimize image quality for the end users
- participation in a continuing series of field validation programs to improve knowledge of signature interpretation
- development of a digital link between the Canadian Ice Centre in Ottawa and the National Ice Centre in Washington to facilitate exchange of Canadian and U.S. processed RADARSAT data to support ice operations in both countries
- refinement and operational implementation of automatic ice information extraction algorithms and development of new ice information products from the output
- establishment of an archiving system to save data processed for CIS for its ice program
- review of the telemetry link from PASS (DTN) and of the data ingest capabilities of the CDPF with a view to optimizing the speed of end-to-end delivery
- long term planning for RADARSAT-2 and other possible new data sources such as ENVISAT

7. References

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