JCOMM Expert Team on Sea Ice

Canada Member Report

March 2010

Introduction

1. The Canadian Ice Service (CIS) provides information about floating ice in the major navigable waters of the Canadian economic zone for the present, the future and the past. This information in intended to meet two main objectives; to ensure the safety of Canadians, their property and their environment by warning them of hazardous ice conditions; and to provide present and future generations of Canadians with a knowledge of their ice environment sufficient to support environmental science and the development of informed policies. The CIS works with the international community to foster a global awareness of floating ice for operational and scientific purposes.

Operational Support

2. Throughout the intersessional period, the CIS provided operational ice information on a 7 day-a-week basis throughout the year. In the December to May period, the main areas of support included the Great Lakes, the Gulf of St Lawrence and the east coast of Canada. From June to December, the support areas shifted to the Canadian Arctic, including Hudson Bay, Baffin Bay, the Canadian Archipelago and the Beaufort Sea. Several levels of products are issued including:

- Weekly regional scale charts for planning purposes – these cover the complete Canadian area and double as the basis for climatology. During January to March, when ice in the Canadian Arctic is historically landfast and shipping activity ceases, the frequency of Arctic regional charts is reduced to bi-weekly.
- Daily tactical scale charts for vessel routing – produced where vessels are operating in the vicinity of ice
- Daily ice hazard bulletins – text messages including warnings of hazardous ice conditions present or developing within the next 36 hours
- Daily iceberg distribution chart showing the estimated numbers of icebergs in each degree latitude/longitude square as well as the Limit of All Known Ice (copied from the International Ice Patrol when IIP is in operation)
- 30-Day Forecasts – text forecasts issued about the 1st and 15th of every month describing expected changes in ice conditions over the next 30 days
- Seasonal Outlooks – text and graphical products issued about December 1st to provide an outlook for the freeze-up and development of the ice season in southern Canadian waters, and about June 1 to provide an outlook for the

break-up and development of the navigation season in northern Canadian waters

- Seasonal Summaries – text and graphical products issued at the end of each season (summer and winter) summarizing the recently completed ice season as a brief climatological record.

The most active ice area is the Gulf of St Lawrence with approximately 1,500 ship transits during the ice season, mostly to the ports of Montreal, Sept Iles, Belledune and Port Cartier. About 20 ships routinely sail throughout the ice season between the Great Lakes Erie, Huron and Michigan. In recent years the Soo Locks into Lake Superior have been remaining open longer into the winter allowing increased winter shipping to the upper Lake. There are about 100 voyages into the Canadian Arctic each summer, including an increasing number of cruise ships, scientific expeditions and adventure cruises (e.g. small sailboats).

3. The CIS produces over ½ million ice information products annually resulting in some 2 million product deliveries. The CIS Website http://ice-glaces.ec.gc.ca continues to grow as the primary means of providing ice information products to users, receiving about 1.5 million visitors and 40 million hits per year. The CIS annually responds to about 400 telephone calls and 900 e-mail messages requesting ice information.

4. The Canadian Coast Guard (CCG), which operates the fleet of icebreakers and is responsible for marine safety, is a major partner of the CIS. Ice Service Specialists from the CIS work aboard CCG icebreakers to directly advise the captain on ice navigation and also in regional Coast Guard ice offices to support vessel traffic routing through ice-covered waters.

5. Climate change is increasingly evident in the Canadian Arctic with more ships venturing into the Arctic and remaining later and later in the fall. For several years now, vessels are routinely remaining in Hudson Bay into November, a month later than the historical end of the shipping season. In mid-season, ships are now scattered more widely across the Canadian Arctic rather than being concentrated in well defined routes. This has created a significant increase in the workload of the Canadian Ice Service which is reflected in the number of daily ice analysis charts produced increasing from 737 in 2005 to 1164 in 2009.

6. The CIS continued to ensure delivery of a service to provide arctic communities with information regarding the position and condition of local “floe edges” (fast ice edges) which are important hunting and social gathering places. Using satellite remote sensing and ancillary data, products are made automatically and placed on a web page for access by two communities to assist them in planning on-ice travel to avoid potentially dangerous situations. This service has been well received by the communities and the information is regularly consulted before trips to the ice are made. The service is actually provided by the Polar View initiative of the Global Monitoring for Environment and Security (GMES) as a cost effective way of assuring the safety of northern residents.

7. The CIS also monitors the ice cover on 134 inland lakes using satellite data for numerical weather prediction. The Canadian Meteorological Service reports that this information is now essential for weather forecasts over Canada.

Data Sources

8. The CIS relies on a mix of satellite, aircraft and surface observations. The most important data sources are RADARSAT-1 and RADARSAT-2 from which about 7,000 images are acquired annually. Envisat ASAR is used regularly with about 500 images being acquired annually. Over the past year, CIS has been receiving PALSAR L-band SAR images from the Japanese ALOS satellite via the National Ice Center. AVHRR optical imagery from U.S. satellites is of almost equal importance despite their vulnerability to cloud cover. MODIS, AMSR-E and OLS provide additional optical information. SSM/I data provide useful background information but have limited resolution.

9. Aircraft ice reconnaissance is an important source of tactical data in direct support of navigation as well as “ground truth” for satellite data. Three aircraft routinely intermingle ice reconnaissance, marine pollution and security patrols over Canada’s ice covered waters. As of June 2009, all of these aircraft were outfitted with a new Swedish Space Corporation MSS-6000 SLAR system.

10. The CIS is now comfortable with the availability of satellite SAR data for the coming years. The current mix of satellites and the advanced stage of planning for Sentinel-1 and the RADARSAT Constellation Mission provide an adequate degree of security of data availability.

Information Technology

11. The CIS continues to update its main computer system known as “ISIS”, now at Version 3.6.1 (see previous ETSI report for a more complete description of ISIS). All products are produced digitally and made available via the CIS website (http://ice-glaces@ec.gc.ca) and other means. Charts, bulletins and satellite images are sent to icebreakers by ftp using MrSID image compression.

12. Previously, it was reported that CIS and the Canadian Coast Guard had completed a joint development and implemented pen computer technology as a means of producing observed ice charts from aircraft in digital form directly on a computer. The system, known as “ICEggs”, allowed significantly decreased time and effort to integrate aerial reconnaissance charts with other data. However, the system is no longer supported by the developer and CIS and Canadian Coast Guard are examining new options.

Sea Ice Climatology

13. The “Canadian Ice Service Digital Archive (CISDA) – Regional Charts” dataset (1968 – present) is updated in real-time and available on our web site at:

http://www.ice.ec.gc.ca/App/WsvPageDsp.cfm?Lang=eng&lnid=3&ScndLvl=no&ID=11715

This dataset constitutes the climate database used in the production of the climatic ice atlases also available on our web site at:

http://www.ice.ec.gc.ca/App/WsvPageDsp.cfm?ID=11700&Lang=eng

This dataset is also used for the production of climate products in real time such as "Departure from Normal" and various "Ice Cover Graphs" comparing current conditions to normal and past years. A new tool called "Ice Graph Tool" allowing users to create their own Ice Cover Graphs is available on the web.

14. Since January 2006, all current CIS charts are available in Sigrid-3 format and the regional products are provided to NSIDC in real time.

15. CIS is currently digitizing the "Historical Chart" collection 1959-74 to be added to our climate database. The digitization should be completed in 2011.

Training

16. CIS has continued to develop its "Ice University" concept in which experts in various topics deliver ½ day modules on various science topics for delivery to all analysis and forecasting staff. Week-long sessions are scheduled twice each year, in spring and fall. The US National Ice Center is a regular participant in these sessions.

17. CIS held two Team Retreats with staff to discuss the current and potential impacts of climate change and new Government initiatives on the Ice Service programs and to postulate what the future holds in terms of new information products; services and production/delivery model in the years to come. The CIS is planning to develop and implement standards and performance programs for its ice analysis and forecast component over the next few years and to increase its focus on training.

Standards

18. The CIS undertook to produce an S-57 Product Specification for an Ice Overlay for Electronic Navigation Charts. S-57 format ice charts were produced in a semi-automated manner during 2009 but with little interest from industry.

Science

19. Evaluation of Dual Channel RADARSAT-2 for CIS Operations - After the successful launch of RADARSAT-2, a core focus of the CIS was to evaluate the spacecraft's new imaging capabilities. After a successful transition of CIS Ice and Oil Operations to RADARSAT-2's heritage modes (SCW-HH), the utility of dual channel ScanSAR, i.e. HH+HV, for CIS Ice Operations was investigated. While pre launch investigations indicated significant potential value in adding the HV channel, it was important that these findings be validated with actual RADARSAT-2 data and they be assessed first hand by CIS Operations. Also, it was recognized that the regular use of dual channel ScanSAR data by Operations could carry real costs and associated risks to the present operation. As a result, CIS completed a six month study identifying and studying the potential costs and benefits associated with the regular use of HH+HV ScanSAR data in CIS Ice Operations. The results of the study enabled CIS Operations to make an

informed decision regarding the adoption of dual channel ScanSAR in its daily ice workflow. This evaluation has resulted in several conference presentations/papers as well as a comprehensive technical report.

20. New Automated SAR products - Ice Motion - Natural Resources Canada (NRCAN) has been leading the mapping of Canada's continental shelf in support of an upcoming Canadian UNCLOS submission. CIS' role in this interdepartmental initiative is to provide ice and marine weather support to the on-ice participants. Critical to this suite of CIS products is output from an in-house developed ice motion algorithm. The CIS ice motion system operates with two overlapping and sequential Synthetic Aperture Radar (SAR) images from RADARSAT-2 and takes into account two main components of ice movement: parallel shift and rotation. The output from the ice motion system provides a set of sea ice displacements with low, medium and high levels of confidence. After the 2010 UNCLOS experiment, CIS will continue to generate sea-ice motion products on all incoming RADARSAT-2 image pairs in support of its daily operations.

21. ALOS-PALSAR Evaluation - The PALSAR sensor onboard JAXA's ALOS satellite provided CIS with an opportunity to examine the potential synergies between L-Band and C-Band SAR for ice operations. CIS in partnership with the US National Ice Centre (NIC) used both quantitative and qualitative analysis to identify the unique and complementary sea ice information PALSAR can provide. The sensor's detection of large scale topographic features coupled with its ability to penetrate through the wet snow volume in melt conditions provides valuable information not available using C-Band SARs. Through its membership in the North American Ice Service (NAIS), CIS began to operationally receive ALOS-PALSAR data in June 2009. Validation and analysis will continue as CIS gains more experience using this data in daily operations.

22. Seasonal Ice Forecasting - A multiple linear regression system has been implemented in research mode to assess its skill as guidance to CIS extended range forecasts. In addition a much simpler Optimal Filter Based Model is also being tested. Using these two models, individual and multi-model forecast guidance has been provided to CIS Operations for use in preparing their seasonal outlooks. A totally model-based 18 month forecast the Canadian east coast has also been provided to the Canadian Coast Guard for their evaluation as input to their planning process for Coast Guard icebreaker deployments. At the same time, another model based on Classical Canonical Analysis is being adapted for the Beaufort Sea.

23. Sea ice modeling - A moderate resolution (10 km) coupled ice-ocean model (CECOM Canadian East Coast Ocean Model) has been developed at the Bedford Institute of Oceanography and is currently being evaluated at CIS as a replacement for the current operational model. In preparation for migrating sea ice model operations to the Canadian Meteorological Centre, we are evaluating two state of the art ice models (CICE 4 and LIM 3) for their applicability to forecasting for CIS Operations and CMC Numerical Weather Prediction. Current research issues include: determining the effect of floe size on ice forecasts; modeling the behaviour of land fast sea ice; modeling the seasonal evolution of ice strength; and, tracking multi-year and deformed ice.

24. Iceberg modeling - A joint IIP-CIS report recommending the future operational iceberg model will be released shortly. This report is based on an evaluation of the IIP

and CIS iceberg models for predicting the drift of approximately 200 iceberg drift tracks observed along Canada's east coast. In addition to comparing the two models, four different sources of ocean current forecasts are being evaluated. Within the limitations of this preliminary study, it was found that the new CECOM ocean current forecasts were better for predicting iceberg drift than the operational CIS model, the IIP currents and forecasts available from Mercator. The CIS iceberg model has also been extended to allow it to provide ensemble forecasts of iceberg drift. It has been found that an ensemble size with 250 members is adequate to describe the variability of iceberg drift. In addition to providing an ensemble mean forecast, this system provides information on the uncertainty in the forecast iceberg position. Work is also underway to investigate the effects of sea ice on icebergs.

25. Data assimilation - In collaboration with the Environment Canada Data Assimilation Section, CIS has been developing a sea ice data assimilation system for use in sea ice analysis and forecasting and numerical weather prediction. Using a 3D variational (3DVar) approach, a variety of ice observations can be assimilated with this system including: passive microwave data from the AMSR and SSMI instruments, gridded data from CIS image analysis and daily charts and CIS lake ice analysis data. One of the crucial elements in assimilating these observations is to define the error statistics associated with each observation and the trial field as well as developing a forward model that relates the analysis fields to the observations. Initial global estimates of these have been made but the system is quite flexible in that future refinements can easily be incorporated. Several implementations are underway or nearing completion: a) an automated sea ice analysis at 5 km resolution for North America; b) a 3DFGAT (First Guess at Appropriate Time - a 3DVar variant) system has been coupled to an ice-ocean model for the east coast of Canada as described by Caya et al; c) a very similar system to b) has been developed for a coupled atmosphere-ice-ocean model that covers the Gulf of St Lawrence at a resolution of 5 km; and d) a northern hemisphere (NH) sea ice analysis system that is almost identical to a) has been developed as a step towards a new global system. In addition to the implementations discussed above, several research projects are underway. These include: development of a radiative transfer model for passive microwave data (in collaboration with the Danish Meteorological Institute): development of techniques for assimilating AVHRR data (in collaboration with MetNo); and development of techniques for assimilating active radar data. Other R&D currently underway or planned includes using displacement errors and spatially varying error statistics.

26. Historical Chart Digitization and Analysis for IPY - With the support of Canada's International Polar Year program, CIS has been digitizing its historical ice charts (1958-1968) for inclusion into its regional chart historical chart database (1968-present). The goal of this recently completed project was to extend the CIS ice chart record as far back as possible to permit longer time series analysis and a clearer indication of trends in ice concentration in Canadian coastal waters. The new database and resultant ice trends are the subject of two journal papers now under review with the hope of being published in late 2010.

International Activities

27. Under the North American Ice Service (NAIS) banner, Great Lakes ice charts and bulletins, 30-day forecasts, Seasonal Outlooks and Seasonal Summary are now produced jointly. As a NAIS partner, the National Ice Center has been providing daily ice information to the Canadian Coast Guard icebreaker Sir Wilfrid Laurier as she transits to the Arctic through the Bering Strait. – an activity that is saving considerable resources in the CIS.

Work that started in 2007 to develop a common ice chart production system for the NAIS is now proceeding in earnest. The common system has been named “Polaris” and has a target completion of December 2010.

28. The CIS has been active in the International Ice Charting Working Group that has now held ten annual meetings.

29. The CIS undertook an active role to support scientific activities during the International Polar Year. In addition to its participation in the ETSI-Polar View Ice Information Portal, the CIS provided ice information support for 10 IPY projects in Canadian waters including the Canadian Flaw Lead project that had the icebreaker CCGS Amundsen over-winter in the Beaufort Sea. Additional staff were hired and a special IPY section on the CIS web site was established. The primary focus of the CIS effort was the safety of researchers in the Canadian Arctic but a secondary goal was to provide ice information that is of “common good” to many projects so that individual projects did not have to duplicate efforts.

30. In 2008 and 2009, CIS worked jointly with the Danish Meteorological Institute to provide ice and weather information for UNCLOS seabed mapping projects in the Lincoln Sea and Arctic Ocean. These projects involved large numbers of people and several aircraft working on the sea ice for several weeks in the spring of each year. Despite difficult weather and some surprising ice conditions, the work was completed successfully and without incident. Support was also provided cooperatively with the NIC to the joint seismic operation conducted by the CCGS Louis S St Laurent and USCGC Healy in the Beaufort Sea in 2009. In this project, a seismic array was towed through the sea ice by the Louis while the Healy broke ice ahead.

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