EXTENDING ECDIS CONTENT: A PROCESS FOR PRODUCING ICE INFORMATION MIOS BASED ON S-57 ICE OBJECTS

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PREFACE

This technical report is a reproduction of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Engineering in the Department of Geodesy and Geomatics Engineering, February 2006. The research was supervised by Dr. David Coleman and Dr. Ahmed El-Rabbany.

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ABSTRACT

Some of the world's major shipping lanes run through ice-infested waters. To safely navigate these areas, mariners rely on daily ice charts produced by national governmental agencies. Most ice charts are designed to be displayed primarily on paper. Many vessels now possess Electronic Chart and Display Information Systems (ECDIS) on board that allows mariners to view Electronic Navigational Charts (ENC). Current ENC specifications allow for only one very limited description of ice conditions. New international standards specifying how detailed ice information is to be displayed in ECDIS could come into effect in 2007.

The Canadian Ice Service (CIS) produces daily paper charts to assist mariners navigate Canadian ice-infested waters. The CIS produced the charts using computer imaging and mapping software. While the electronic versions of the charts do contain detailed ice information, the format of the data must be altered in order to be able to be used with existing ENCs. Using Arc Macro Language (AML) scripting, a prototype tool was created that converts daily ice charts from an ArcInfo format file into supplemental layers (Marine Information Objects) that could be used with official ENC data. An investigation was then performed to determine which is better: to use the developed tool to create electronic ice charts or to alter the CIS chart production process so that an Ice Information MIO, not a paper chart, is the primary product. It was found that the developed tool automatically creates an electronic ice chart in at most five minutes, well below the one-hour processing time originally sought by the CIS. Since using the tool requires no changes to the current chart production system, using the tool to create Ice

Information MIOs is far more economical than altering the existing ice chart production process.

ACKNOWLEDGEMENTS

The thesis could not have been completed without the contributions of several people who have helped me during my studies at UNB and in the completion of this thesis. I am happy to acknowledge their contributions and am deeply grateful.

In the first place, Dr. David Coleman provided continuous support, advice, and patience during my entire time at UNB. His advice as my primary supervisor was extremely valuable. Dr. Ahmed El-Rabbany, my co-supervisor, regularly provided help with the project. The late Dr. Y.C. Lee was generous with his advice when I first started at UNB. Few classes challenged my mind as much as his did, and I am grateful for that.

Dr. Benson Agi gave ideas and insights throughout this project as we both worked on separate ways to solve the same problem. Dan Fequet and John Falkingham at the CIS answered the many ice-related questions I had over the many months of this project.

David Fraser gave his continued assistance with all things technical in the computer lab at UNB. Dr. Kevin Pegler freely lent his veteran tips regarding thesis writing. Dr. Garret Duffy and Shaheen Ghayourmanesh were helpful in allowing me to bounce all sorts of project-related ideas off them. Jonathan Beaudoin provided help with conceptual programming ideas, and Steven Dickie gave ideas about programming in ArcInfo.

Lastly, my father, Dr. Patrick Dias, edited this thesis. It would not be written nearly as well had I not had his input.

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

LIST OF ACRONYMS AND INITIALISMS

AAT	Arc Attribute Table
AML	Arc Macro Language
ASAR	Advanced Synthetic Aperture Radar
AMSR-E	Advanced Microwave Scanning Radiometer for EOS
AVHRR	Advanced Very High Resolution Radiometer
CARIS	Computer Aided Resource Information System
CCG	Canadian Coast Guard
CCRS	Canadian Centre for Remote Sensing
CHS	Canadian Hydrographic Service
CIS	Canadian Ice Service
CMC	Canadian Meteorology Centre
CRESTech	Centre for Research in Earth and Space Technology
DMSP	Defense Meteorological Satellite Program
E00	ArcInfo Interchange File Format
ECDIS	Electronic Chart Display and Information System
ENC	Electronic Navigational Chart
Envisat	Environmental Satellite
EOS	Earth Observing System
ERDAS	Earth Resources Data Analysis System
ESRI	Environmental Systems Research Institute
ETSI	JCOMM Expert Team on Sea Ice
GDSIDB	Global Digital Sea Ice Data Bank
GIS	Geographic Information System
GMT	Greenwich Mean Time
GOES	Geostationary Operational Environmental Satellite
GPS	Global Positioning System
GRS 80	Geodetic Reference System 1980
GUI	Graphical User Interface
HGMIO	IHO-IEC Harmonization Group on Marine Information Objects
IEC	International Electrotechnical Commission
IHO	International Hydrographic Organization
IICWG	International Ice Charting Working Group
IMO	International Maritime Organization
IOC	UNESCO Intergovernmental Oceanographic Commission
ISIS	Ice Service Integrated System
JCOMM	Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology
MIO	Marine Information Object

MLD	Multi-Look Detected
MODIS	Moderate-Resolution Imaging Spectroradiometer
NAD 27	North American Datum 1927
NAD 83	North American Datum 1983
NASA	National Aeronautics and Space Administration
NAT	Node Attribute Table
NESDIS	NOAA National Environmental Satellite, Data, and Information Service
NOAA	National Oceanic and Atmospheric Administration
NSIDC	National Snow and Ice Data Center
OLS	Operational Linescan System
PAT	Point Attribute Table or Polygon Attribute Table
PNGIS	Pacific Northwest GIS Consulting
QuikSCAT	Quick Scatterometer
RADARSAT	RADAR Satellite
S-52	IHO Special Publication 52
S-57	IHO Special Publication 57
SAR	Synthetic Aperture Radar
SLAR	Side-Looking Airborne Radar
SSM/I	Special Sensor Microwave Imager
TSMAD	IHO Transfer Standard Maintenance and Application Development Working Group
UNESCO	United Nations Educational, Scientific and Cultural Organization
WGS 84	World Geodetic System 1984
WMO	World Meteorological Organization

CHAPTER 1
INTRODUCTION

Sea ice occurs along more than 90% of the Canadian coast line [Climate Change Indicators Task Group, 2003]. Lake and river ice also cover much of the Great Lakes and the St. Lawrence Seaway. In all, up to 4 million square kilometres of Canada's navigable waterways are covered by ice [Lapointe, 2001]. In the open waters of Canada's eastern coast, roughly 40 000 icebergs appear annually [Lapointe, 2001]. Ice is present in Canada's navigable waters year-round.

Ice affects all types of mariners, including those involved in transportation and shipping, commercial fishing, offshore resource development, tourism and recreation [CIS, n.d.], the military, search-and-rescue operations, and Aboriginal peoples in their hunting and fishing patterns. The potential danger that ice poses is so great that a single iceberg report can cause tens of thousands of square kilometres of ocean to be declared unsafe for shipping [IICWG, 2004b]. Ice can cause varying degrees of damage to ships, the 1912 Titanic disaster where over 1500 lives were lost being the greatest on record. Many other ice-related accidents cause damage to ships and consequent marine pollution [IICWG, 2004b].

To assist marine navigation, many ice-affected nations have government-run ice charting agencies. These organisations, along with the International Ice Patrol, provide operational ice information to mariners. The information provided by these ice services enables year-round operations of major ports (such as Montreal, Boston, New York, Helsinki, or St. Petersburg), provides tactical ice information to national militaries, and provides logistical and safety support to offshore structures in ice-infested waters (such as the Caspian Sea and the Grand Banks). In Canada, the Canadian Ice Service (CIS) helps ensure the safe transit of 1500 ships through the Gulf of St. Lawrence each winter [IICWG, 2004b].

In 1995, standards for Electronic Chart and Display Information System (ECDIS) were adopted by the International Maritime Organization (IMO) [Hetch et. al., 2002]. ECDIS is used to assist mariners safely navigate waters. Mariners with ECDIS can use the electronic navigational charts (ENC) provided by national hydrographic offices to assist their navigation. An ENC is essentially an electronic representation of a paper chart. All information that is displayed in ECDIS adheres to standards developed by the IMO.

Throughout this thesis, references to ECDIS, ENC, and MIO are made. ECDIS is a computer system that displays navigation-related information. This information is contained in an ENC, MIOs, and positional information from navigation sensors. An MIO consist of chart- and navigation-related information that is not included in an ENC. This thesis focuses on Ice Information MIOs.

1.1 Problem

In ice-infested waters, the use of ECDIS alone does not provide mariners with sufficient information for safe navigation. Effective navigational ice information is not completely integrated within ECDIS; only three categories of ice are identified in the current (Edition 3.1) standards specified by the International Hydrographic Organization (IHO) for displaying information in ECDIS: fast ice, glacier, and polar ice [HydroService AS, c2003]. Because the required detailed ice information cannot currently be represented in ECDIS, mariners must rely on paper ice charts to facilitate navigation. A set of proposed ice objects and attributes currently exist, but the earliest time that they will become part of the IHO standards is late 2006, when the next edition of standards is released [IHO, 2005].

Paper charts do not offer as many benefits as electronic charts do. Chief among the advantages that an ENC offers over a paper chart are that an ENC can be displayed at different scales, the information presented is not limited by the page size, and data sets of different scales and resolutions can be overlaid. If all possible ice information, not just that available on paper charts but all information that is excluded from the final paper product due to page limitations, were to be available to mariners, they would be better able to make informed decision as to how and where to navigate.

The problem that this research addresses is that the CIS is not equipped to produce Ice Information MIOs that can be used with ECDIS.

1.2 Objectives

The primary objective of this research is to efficiently alter the daily ice chart production workflow at the CIS so that one of their output products is an ice coverage

Maine Information Object (MIO) based on S-57. In order for a solution to be efficient, it must be fast (relative to the current system), easy to implement (cost-, time-, and effort-wise), and accurate.

A secondary objective of the project is to develop a colour and symbol scheme for displaying ice information in an ECDIS.

1.3 Contribution

Altering the daily ice chart production workflow at the CIS to produce an Ice Information MIO will provide many benefits to mariners. With detailed ice information in their ECDIS, mariners will benefit by being able to plot safer courses through ice-infested waters. Increasing the likelihood of safe passage will have several economic benefits: travel time, insurance costs, and possibly the number of workers required could all be reduced. Less travel time means savings are found in operational costs (fuel, daily wear) and personnel costs. Because vessels will have better routing information, shipping seasons could be lengthened, thus creating further economic benefits.

Shorter trips are also beneficial to the environment as less fuel is required. Safer passage is also a benefit for the environment because the risk of accidental spillage of contaminants due to collision with ice is reduced. Another benefit of integrating detailed ice information into ECDIS is that emergency personnel may be better prepared to deploy when required.

Proposing colours and symbols to be used to display ice information in ECDIS will benefit the overall project of integrating the proposed ice objects and attributes into the existing IHO standards.

1.4 Methodology

As stated, the primary goal of this research is to alter the daily ice chart production workflow at the CIS so that one of the final products is an Ice Information MIO. Two approaches are taken in order to achieve this goal.

1.4.1 Tool Creation

The first approach to creating an Ice Information MIO from a daily ice chart is to develop a tool that translates the existing digital daily ice chart from ArcInfo coverage format to S-57 format. This approach modifies the existing workflow by appending the new tool to the end of the current chart creation process.

In order for a tool to work, two conditions must be met. The first is that it be possible to map data types between the ArcInfo vector data model and the S-57 vector data model. The second is that it be possible to map CIS ice coding values to the proposed S-57 ice objects and their attributes.

1.4.2 Workflow Alteration

The second approach to producing an Ice Information MIO based on CIS ice information is to consider and evaluate alternate means for producing daily ice charts at the CIS. The original intention of this part of the research was to fully investigate all aspects of the daily ice chart creation process and recommend workflow alterations that would improve the speed, accuracy, and cost of ice chart production. However, it was made abundantly clear to the author by Mr. Fequet, the Senior Development Technician at the CIS, that the current daily ice chart production workflow was optimized for efficiency, as the production of daily ice charts has been continuously refined and improved over several decades [Fequet, 2003]. Part of the focus of this research thus shifted from optimizing the chart production workflow to investigating, evaluating, and recommending alternate solutions for producing an Ice Information MIO in lieu of the tool being developed by the author.

1.4.3 S-52 Colours and Symbols

The approach taken to accomplish the secondary objective of this research, to propose colours and symbols to be used for displaying ice information in ECDIS, was to base all recommendations on the CIS colours and symbols standards.

1.5 Metrics

The most important factor in determining the efficiency of a new daily chart production workflow is the difference in time required to produce an Ice Information

MIO as compared to the current system. Due to the time-sensitivity of the product, any system that adds more than one hour to the production time is deemed to be unacceptable. Second in importance is the cost of implementation. This is measured as an estimate of the time that will be required to develop and implement the solution, plus the time to train ice-chart creators how to adapt to the new system. The analysis of the author's developed and alternate workflow solutions is presented in Chapter 4.

1.6 Thesis Organisation

This thesis is divided into five chapters and six appendices. The following chapter provides background information on: Canadian and international ice charting standards and methods; the existing ice chart production workflow at the CIS, including the data sources used to produce daily ice charts; digital hydrographic data and nautical charts; and previous work done in integrating CIS daily ice charts into ECDIS. Chapter 3 presents the author's tool as the developed solution for efficiently integrating CIS ice information into ECDIS. Also presented is a proposal for symbols and colours to be used in displaying ice information in ECDIS. Chapter 4 evaluates the author's developed solution in terms of efficiency, proposes alternate solutions, and compares the efficiency of the developed solution to the efficiency of both the previously researched solutions and the proposed alternate solutions. Chapter 5 presents final conclusions and recommendations. Included in the appendices are ice object definitions, programming code for the developed solution, and proposed colours and symbols for ice objects.

CHAPTER 2
BACKGROUND

This chapter provides background information on ice charting agencies (Canadian and worldwide), digital mapping hydrographic of hydrographic data, and previous work done in this field.

2.1 Mapping Ice Information

It is extremely important that mariners know current ice conditions so that they can safely and efficiently plan and navigate a route though icy waters. Many national ice charting agencies from countries in Asia, Europe, North America, Oceania, and South America exist around the world to assist mariners with this navigational challenge [IICWG 2004b]. International marine-related organisations that specify ice charting standards also exist. These include the International Ice Charting Working Group (IICWG), the International Ice Patrol, the Expert Team on Sea Ice (ETSI) of the World Meteorological Organization (WMO) and the Intergovernmental Oceanographic Commission (IOC) (collectively known as the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology, or JCOMM), the Baltic Sea Ice Meeting, and the North American Ice Service [IICWG 2004b].

2.1.1 Canada

The national ice monitoring and charting service in Canada is the Canadian Ice Service (CIS). The CIS is a branch of the Meteorological Service of Canada (MSC), itself a branch of Environment Canada, the federal government department responsible for meteorological and environmental services and regulations. The objective of the CIS is to both (a) provide reliable and timely information about ice conditions in Canadian waters for improving the safety and efficiency of maritime navigation, and (b) maintain an archive of ice conditions for environmental analysis [CIS, n.d.]. For ice-infested waters, the CIS provides on a daily basis ice and iceberg analysis charts, ice and iceberg hazard bulletins, and St. Lawrence River ice charts and bulletins. Weekly and monthly analysis charts are provided, as are 30-day ice forecast bulletins and seasonal outlook forecasts. The CIS also provides satellite and aircraft image analysis ice charts [CIS, n.d.]. Of interest to this work are the daily ice analysis charts. An example of a daily ice chart is shown below, Figure 2.1

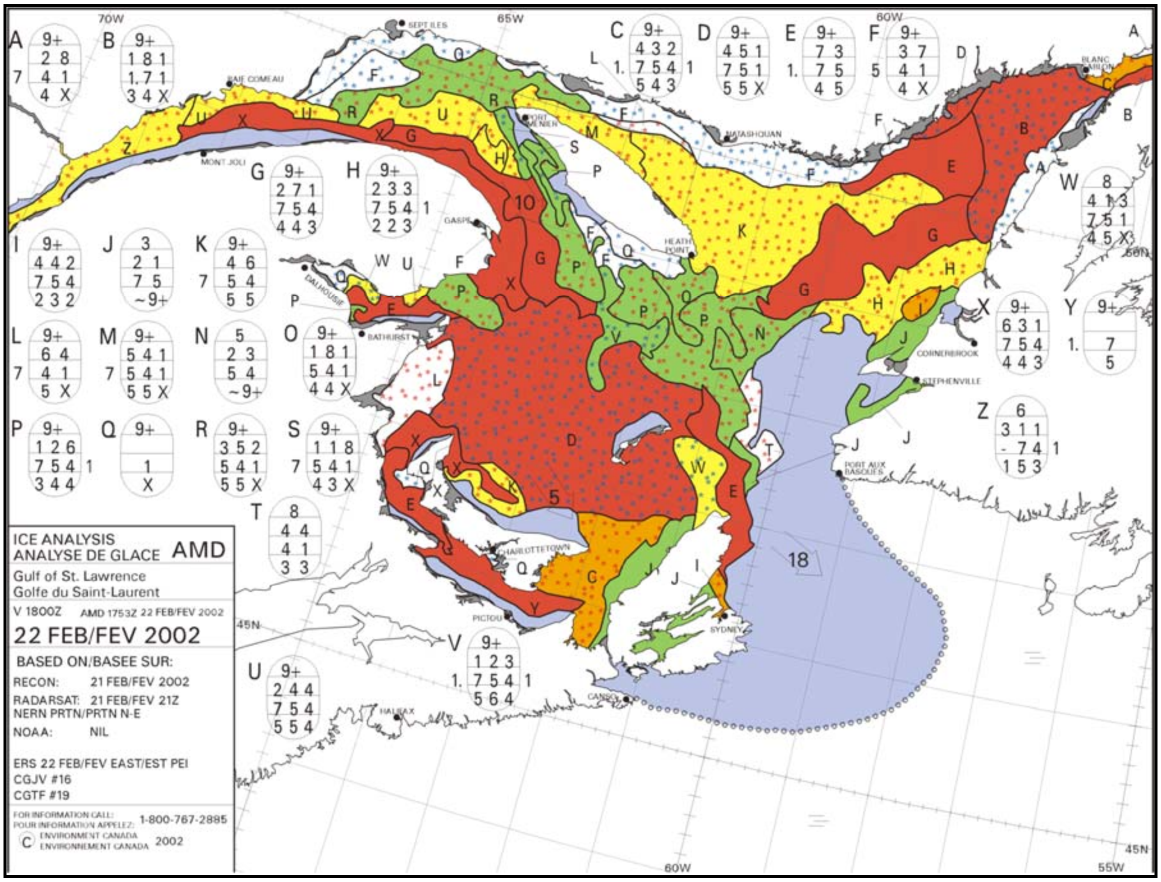


Figure 2.1. CIS's February 22, 2002, daily ice chart for the Gulf of St. Lawrence.

Daily ice charts are produced using Ice Service Integrated System (ISIS), the CIS mapping system. ISIS is comprised of mapping and imaging software [Falkingham, 2003]. Each homogenous ice area (or ice polygon) is represented on the chart by an "Egg Code". An Egg Code, many of which are seen in Figure 2.1 in the land areas (they are ovals with an accompanying letter on their outsides and numbers on their insides), describes the types of ice in that area, specifically the areas total concentration of ice, and the breakdown of the stages of development of different forms of ice [CIS, 2002]. Further details on the Egg Code are presented in Section 2.1.3. Other symbols indicate the general speed direction of ice, ice berg areas, and ship positions. The method that CIS uses to produce daily ice charts is discussed in Section 2.2.

2.1.2 Other National and International Organisations

Besides Canada, many other northern nations have mapping and charting agencies that produce ice charts for mariners. Along with the CIS, the ice mapping agencies of Denmark, Finland, Germany, Iceland, Japan, Norway, Russia, Sweden, and the United States (which has two participating agencies, the United States National Ice Center and the United States Coast Guard International Ice Patrol) formed the International Ice Charting Working Group (IICWG) in 1999 [IICWG, 2004a]. The purpose of the IICWG is to promote cooperation between the world's ice centres on all matters concerning sea ice and icebergs [IICWG, 2004a]. Other countries with national ice services that are not part of the IICWG include Argentina, Australia, China, Estonia, Greenland, Latvia, Lithuania, the Netherlands, and Poland [IICWG, 2004b]. Most agencies differ in how they portray ice of charts; however many do follow suggested standards as proposed by the World Meteorological Organization (WMO) [WMO, 2004].

The WMO is the specialised agency of the United Nations for meteorology, hydrology, and related geophysical sciences. WMO has developed standards for describing environmental conditions. Of interest to this work are its standards for ice description and ice charting. While work on colour coding ice charts goes back as early as the 1950s, only recently in April 2004 was a WMO International Ice Colour Code

Standard formally developed for the display of digital ice charts [Smolyanitsky, 2004]. Until then, use of colour in ice charts was merely suggested.

The International Hydrographic Organization (IHO) is an intergovernmental organization that supports safety in navigation and the protection of the marine environment [IHO, 2004]. Its mission is to ensure that adequate hydrographic information for worldwide marine navigation is made available through national hydrographic offices [IHO, 2004]. As IHO deals with worldwide marine navigation, harmonisation of information between nations is important. A key goal of the IHO is to have the greatest possible uniformity in nautical charts between nations.

2.1.3 Ice Chart Display Standards

Standards for displaying ice information on charts in Canada and the rest of the world have been developed by both the CIS and the WMO. Ice information is displayed on charts using both colours and symbols.

2.1.3.1 The Egg Code

In the early 1980s, in conjunction with other countries, Canada developed an ice reporting standard for the WMO [CIS 2003b]. Because of its oval shape, this standard became known as the “Egg Code”. On an ice chart, an Egg Code is placed in each homogeneous ice area. It contains the total concentration of ice in the area, plus for each age and type of ice present (the stage of development), the concentration and average floe size of is provided. Figure 2.2 shows how the information in an Egg Code is presented.

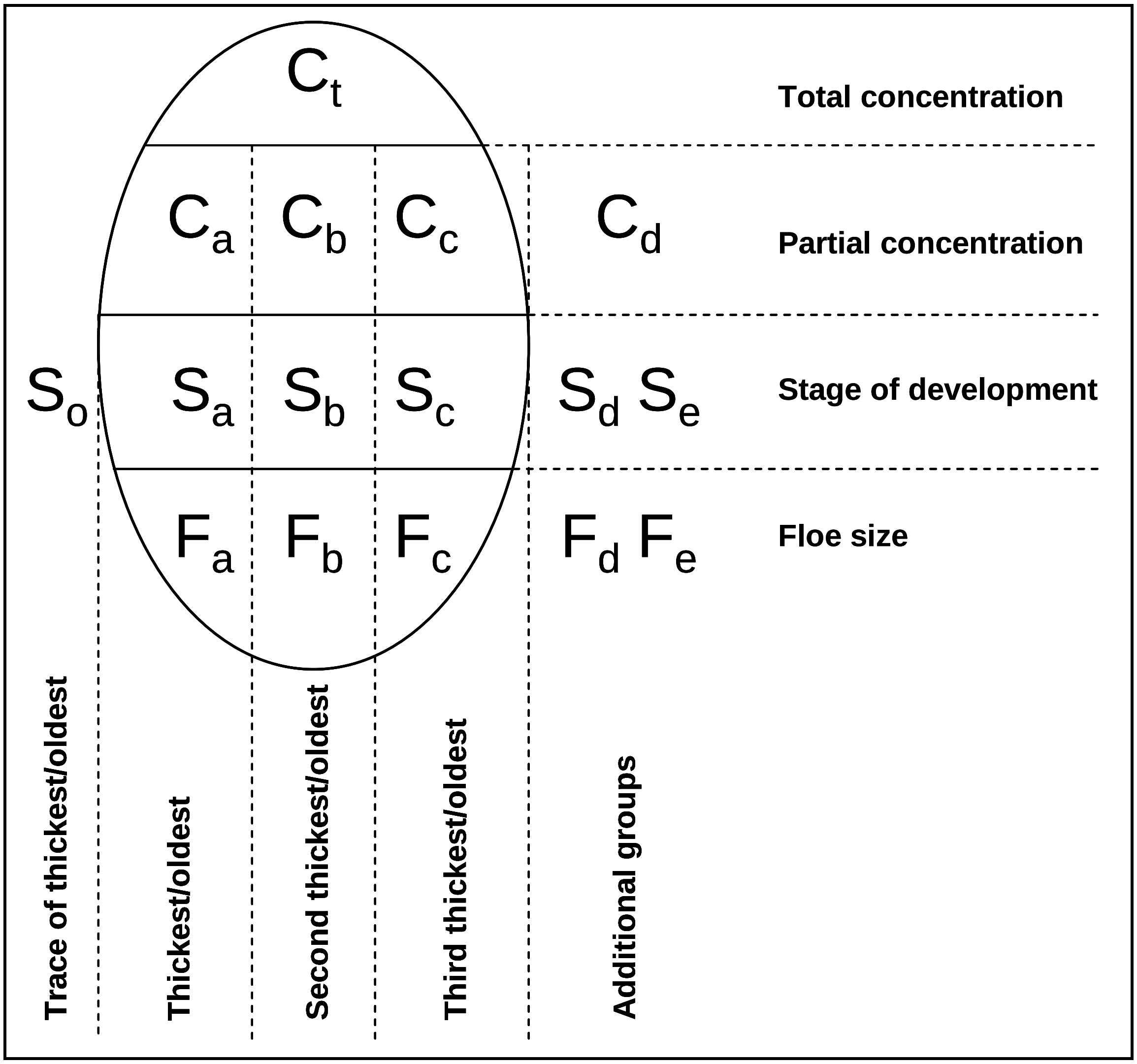


Figure 2.2. The Egg Code [after CIS 2002].

C_t is the item of most interest to mariners and is thus placed on top. It represents in tenths the proportion of the area that is covered by ice. C_a, S_a, and F_a describe the most hazardous part of the ice, that is the thickest ice (and generally oldest) in the area. C_t

should always be equal to the sum of C_a, C_b, C_c, and C_d. The stage of development is represented by digits ranging from 1 to 9, plus symbols. In general, low values represent newer, thinner ice, and high values represent older, thicker ice. There are some exceptions to the coding. The floe size is represented by digits ranging from 0 to 9. As with the stage of development coding, the value of the digit generally corresponds to the size of the floe, with some exceptions. For example, a value of 2 represents an ice cake ranging from 2 to 20 metres wide, while a value of 6 represents a vast floe ranging from 2 to 10 kilometres wide.

C_b, S_b, and F_b describe the second thickest ice in the area, and C_c, S_c, and F_c describe the third thickest. In some cases, there are trace amounts (covering less than one tenth of the area) of ice thicker than that reported in C_a/ S_a/F_a. This ice is reported in S_o. There is no need for a C_o item as concentrations that are less than one tenth are not entered into the Egg Code. Similarly, as there is only a trace amount of the ice type, entering the floe size (which would be F_o) is also not necessary. In cases where there is a fourth stage and thickness of ice present, S_d is used.

When a fifth stage of development is present, S_e is used. There is no need to include a related C_e as it can be calculated by subtracting the sum of C_a, C_b, C_c, and C_d from C_t. Internationally, a fifth stage of development is not used in the Egg Code. For this reason S_e, F_e, C_d, and F_d, are not included. As with C_e on the Canadian charts, C_d is not included because it can be inferred ($C_d = C_t – (C_a + C_b + C_c)$).

Further details and examples of Egg Code use in Canada can be found in the CIS publication, *MANICE: Manual of Standard Procedures for Observing and Reporting Ice Conditions* [CIS 2002]. A description of the WMO coding specifications is in the report from the second session of the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) Expert Team on Sea Ice (ETSI) and the tenth session of the Steering Group for the Global Digital Sea Ice Data Bank (GDSIDB) [JCOMM 2004].

2.1.3.2 Hatching and Colours

The WMO developed hatching symbology to display the total concentration of ice in an area [CIS 2002]. Different colour codes for displaying total concentration of ice and ice's stage of development were formally adopted by the WMO in 2004. The use of colour does not preclude the use of either hatching or egg codes; they can all be used simultaneously [Smolyanitsky, 2004]. Neither hatching nor colour coding replace Egg Codes as Egg Codes contain much more information than the total ice concentration and predominant stage of development. For a complete list of CIS and WMO colour and hatching codes for total concentration and stage of development, refer to Appendix I.

2.2 Current CIS Workflow

Ice charts are produced for eight different regions: High Arctic, Western Arctic, Middle Arctic, Eastern Arctic, Foxe Basin, Newfoundland, Gulf of Saint Lawrence, and

Great Lakes [Fequet, 2003]. Each chart always completely covers the same region. The areas covered by the charts are shown in Figure 2.3.

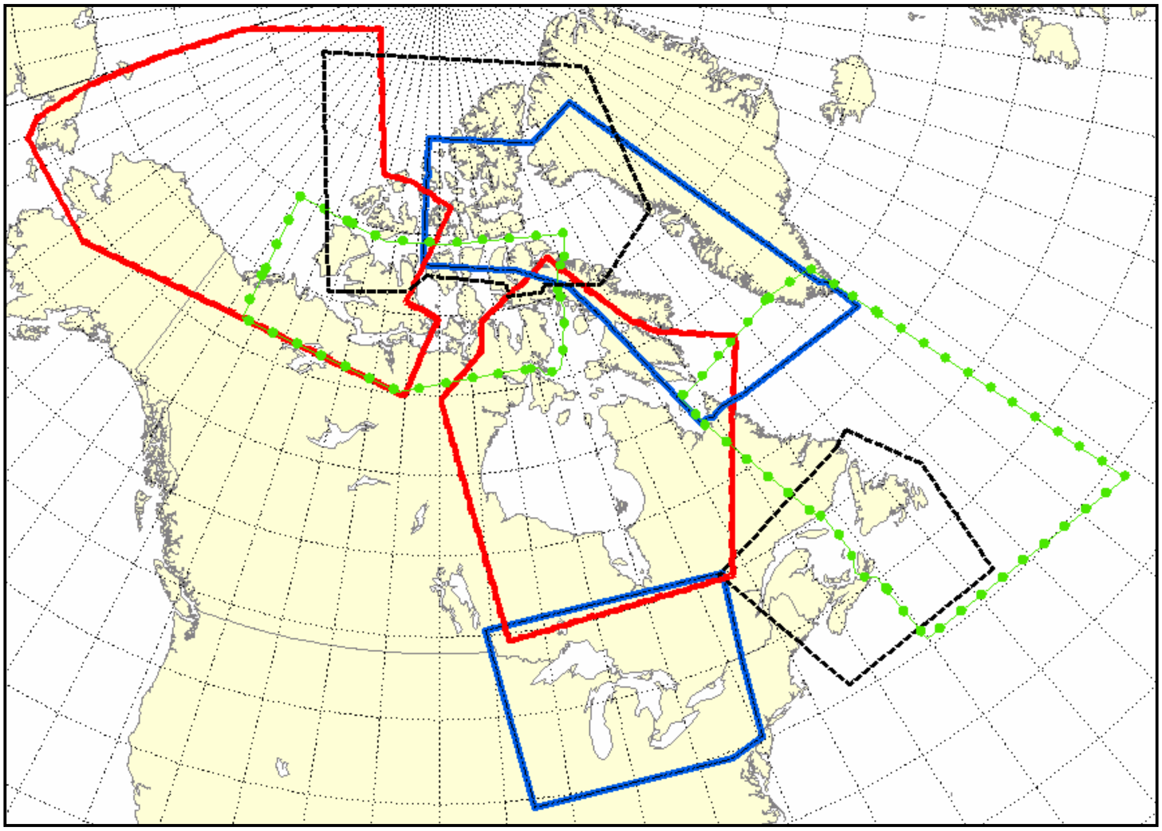


Figure 2.3. Areas covered by CIS daily ice charts. Styles and colours are used only to distinguish daily chart areas from each other.

2.2.1 Workers and Tools

The ice chart production team consists of image analysts and ice forecasters. There are five or six image analysts and six or seven ice forecasters. They produce as many as ten charts a day [Fequet, 2003]. Each chart is worked on by two analysts and three forecasters. The team works with the Ice Service Integrated System (ISIS), the CIS computer-based mapping system [Falkingham, 2003]. Both analysts and forecasters use ESRI's ArcInfo™ and ERDAS Imagine™ [Fequet, 2003] (which are integrated into ISIS), but their focuses are different; the analysts work primarily in the raster environment with Imagine, while the forecasters work primarily in the vector environment with ArcInfo [Falkingham, 2003]. A team can produce a daily chart in about five to six hours [Fequet, 2003]. Figure 2.4 shows the production workflow for how a team creates a chart.

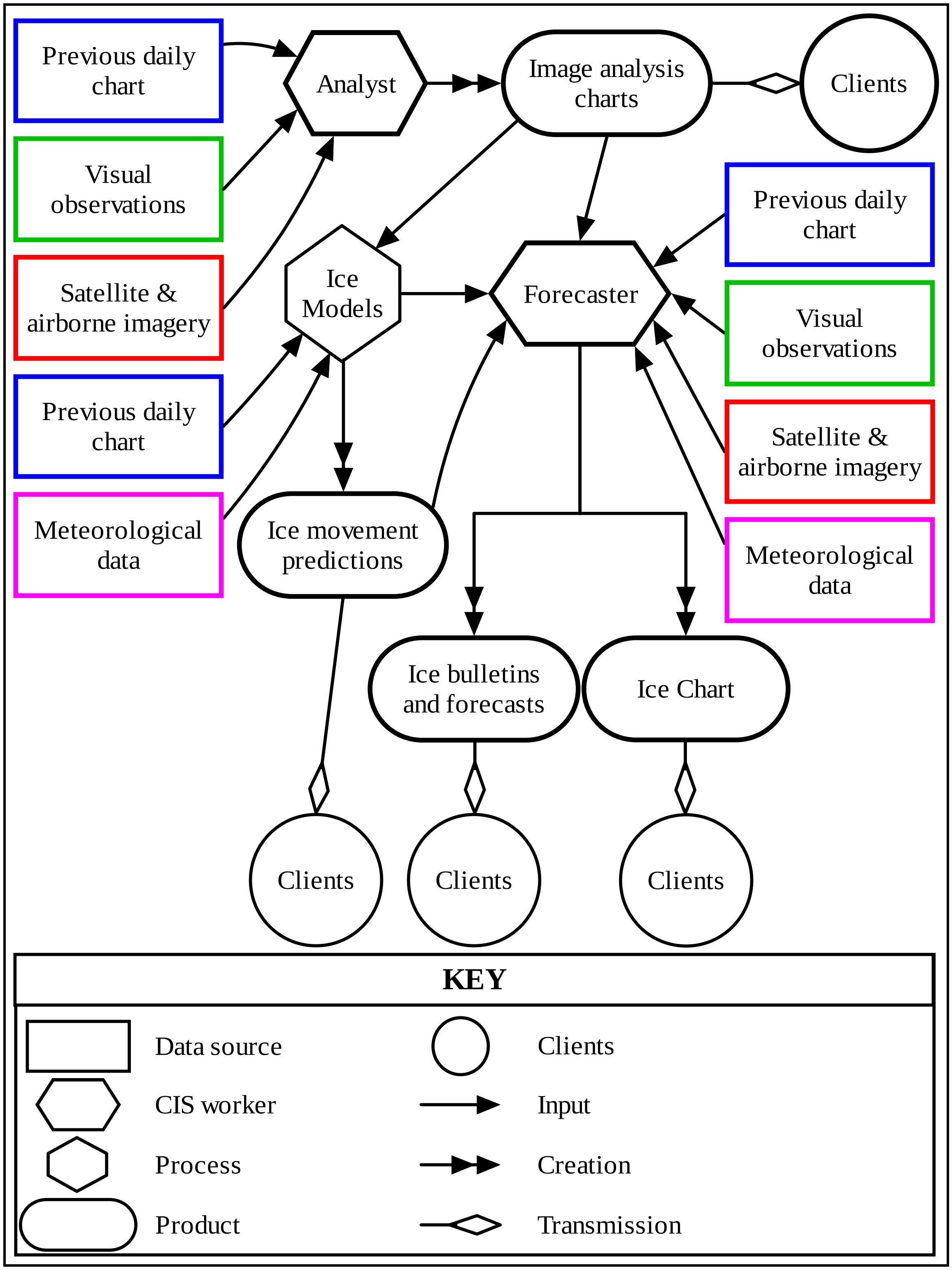


Figure 2.4. CIS daily production workflow (after Falkingham [2003]).

2.2.2 Data Sources

As Figure 2.4 shows, input data sources include space and aerial imagery, visual observations, meteorological data, and the previous day's ice chart.

2.2.2.1 Satellite Imagery

A variety of satellite imagery is collected by the CIS. The sources include both optical and microwave sensors. The sensors and satellites that imagery is collected from are described below. Following the descriptions are: Table 2.1, a summary of general information regarding each sensor; Table, a summary of how often each sensor is used in the CIS daily ice chart production workflow; and Table 2.3, which tells how well each sensor detects sea ice features.

(a) RADARSAT-1 SAR. The Synthetic Aperture Radar (SAR) receiver is the primary source of satellite imagery for ice chart creation [CIS, 2002; Falkingham, 2003] because of the reliability of its observations [Fequet, 2003]. The CIS is the largest user of RADARSAT data [Ramsay, 1997] and several images are acquired daily [Fequet, 2003]. Both ScanSAR Wide and ScanSAR Narrow modes are used [Ramsay, 1997]. ScanSAR Wide has a swath width of 500 kilometres and a resolution of 100 metres; ScanSAR Narrow has a swath width of 300 kilometres and a resolution of 50 metres [CCRS, 2004]. The longest any area will go without being imaged is three days [CCRS, 2004]. Depending on the location and season, between five and ten different ice stages of development and forms, as well as such details as ridging and rafting, can be interpreted from the imagery [Ramsay, 1997]. A sample of RADARSAT-1 imagery is shown in Figure 2.5.

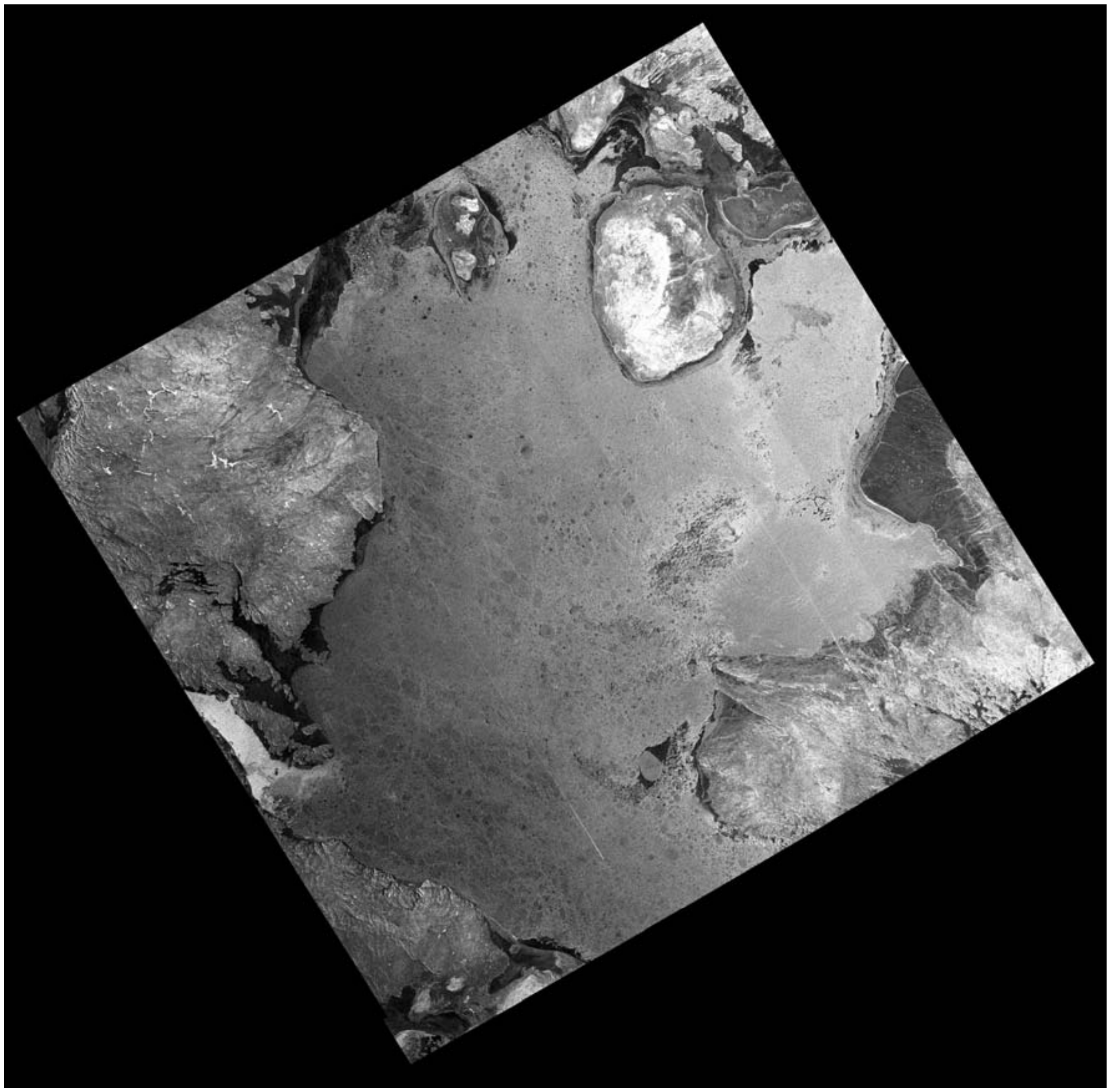


Figure 2.5. RADARSAT imagery of Foxe Basin, from May 13, 2005. Data © Canadian Space Agency (2005) and distributed by Radarsat International Ltd.

(b) ASAR. The European Space Agency's (ESA) Envisat satellite carries the Advanced Synthetic Aperture Radar (ASAR) sensor, which has a resolution of 150 metres and a swath width of 405 kilometres [ESA, 2004]. ASAR's Wide Swath Mode imagery is used as a complementary data source to RADARSAT-1 data. It is considered as a "hot backup" data source in the event of a RADARSAT-1 outage [Flett, 2004]. The CIS receives one to two images per week and uses the images daily [Fequet, 2003, 2005]. A sample of ASAR imagery is shown in Figure 2.6.

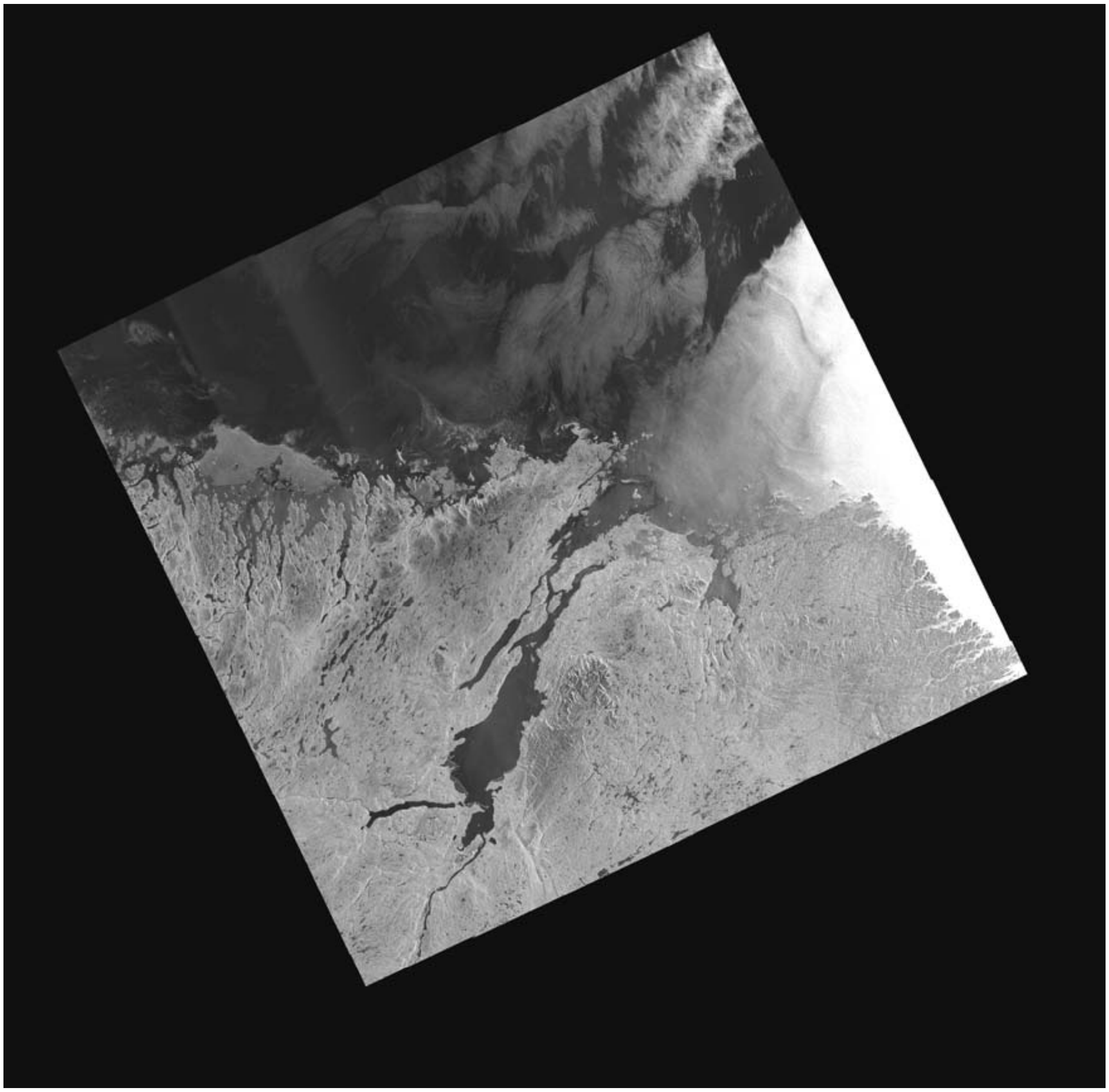


Figure 2.6. Envisat ASAR imagery of Hamilton Inlet and Goose Bay, on the Labrador coast, from May 21, 2005. Data provided by European Space Agency.

(c) AVHRR. Five NOAA satellites carry the Advanced Very High Resolution Radiometer (AVHRR) sensor, which has a resolution of 1090 metres at nadir and a 2400-kilometre swath width [NOAA, 2005]. While acquired regularly by the CIS, AVHRR data is excellent when cloud-free. Unfortunately, cloud-free conditions are not regular and thus the imagery is used infrequently [Fequet, 2003]. A sample of AVHRR imagery is shown in Figure 2.7.

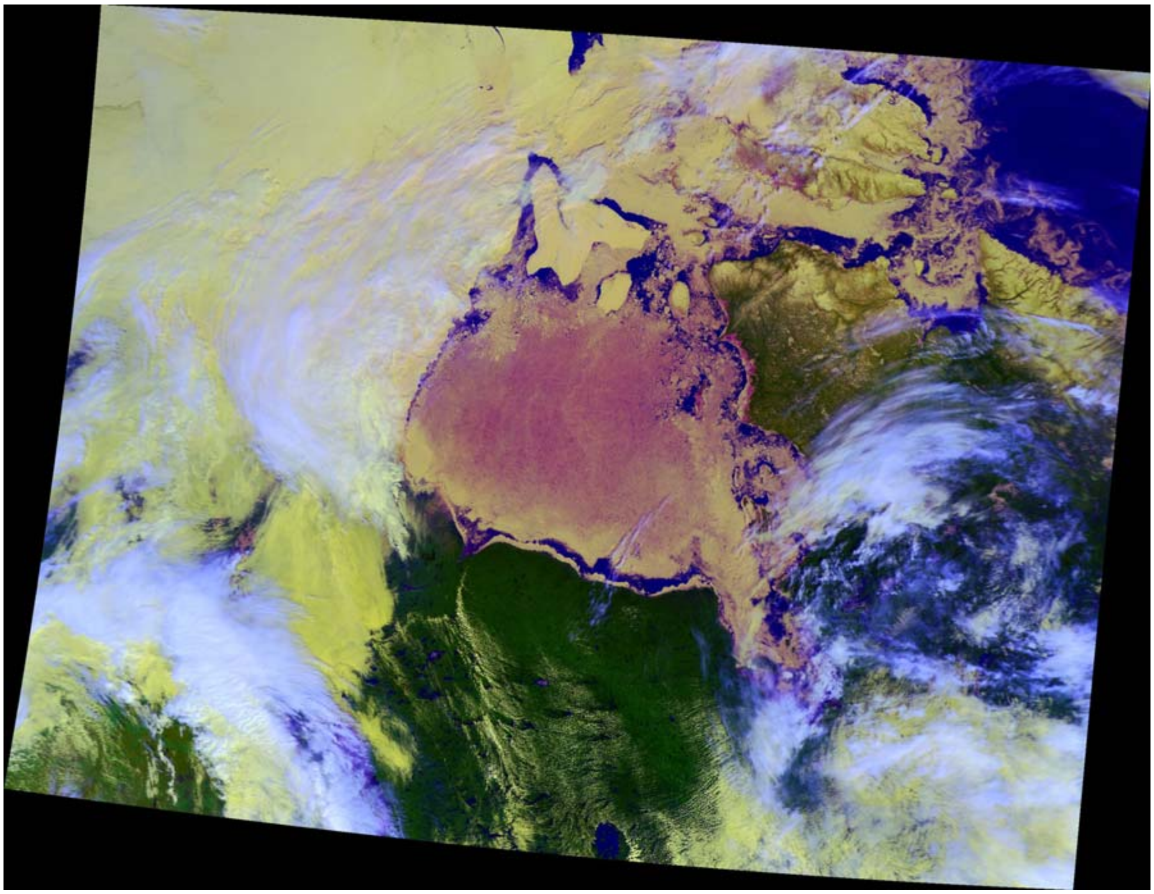


Figure 2.7. AVHRR imagery of Hudson Bay, from May 23, 2005. Data provided by NOAA.

(d) AMSR-E. NASA's Earth Observing System (EOS) Advanced Microwave Scanning Radiometer (AMSR) has a swath width of 1445 kilometres. Images are acquired by the CIS eight times per day and are used daily [Fequet, 2005]. A sample of AMSR-E imagery is shown in Figure 2.8.

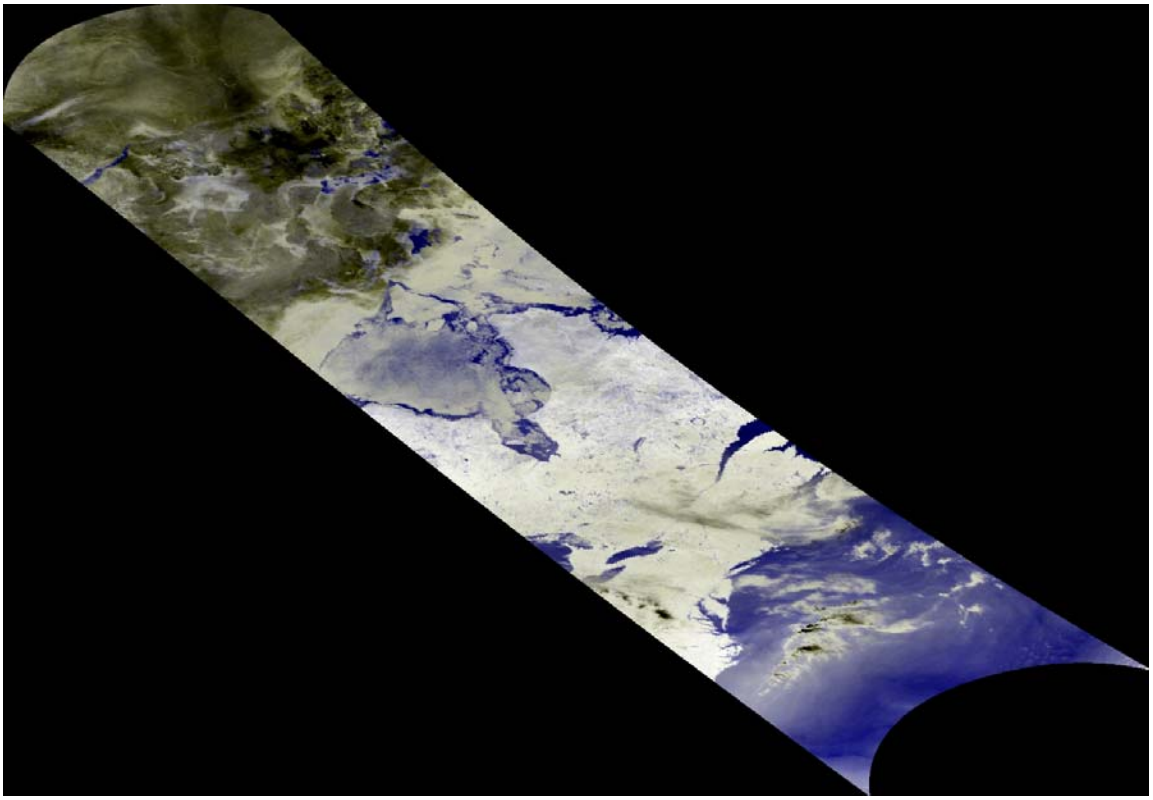


Figure 2.8. AMSR-E imagery covering Nunavut to the Atlantic Ocean, crossing Hudson Bay, Quebec, New Brunswick, and Maine, from May 23, 2005. Data provided by NASA.

(e) GOES. Imagery from NASA's Geostationary Operational Environmental Satellites (GOES) imagery is acquired hourly [Fequet, 2005] but is "not generally used" [Fequet, 2003]. A sample of GOES imagery is shown in Figure 2.9.

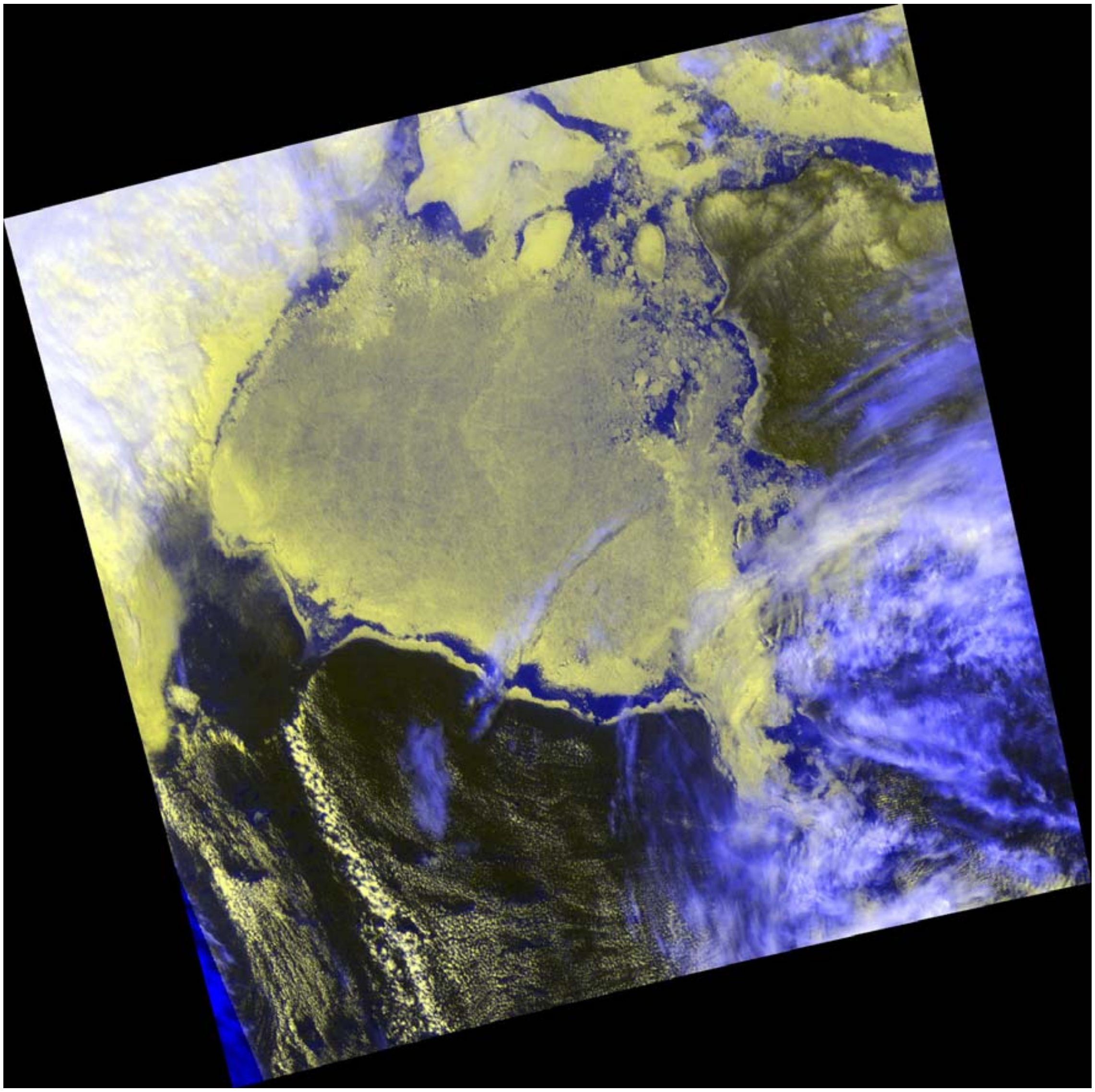


Figure 2.9. GOES imagery of Hudson Bay, from May 23, 2005.

(f) MODIS. The Moderate Resolution Imaging Spectroradiometer (MODIS) sensor is aboard NASA's Earth Observing System (EOS) Aqua satellite. It has a swath width of 2330 kilometres at nadir, and for band 7 (the shortwave infrared wavelengths of 2105 nanometres to 2155 nanometres), which is used for snow and ice detection [Hall, 2005], it has a spatial resolution of 500 metres [Conboy, 2005]. The CIS acquires and uses nongeoreferenced imagery off the World Wide Web daily [Fequet, 2004]. A sample of MODIS imagery is shown in Figure 2.10.

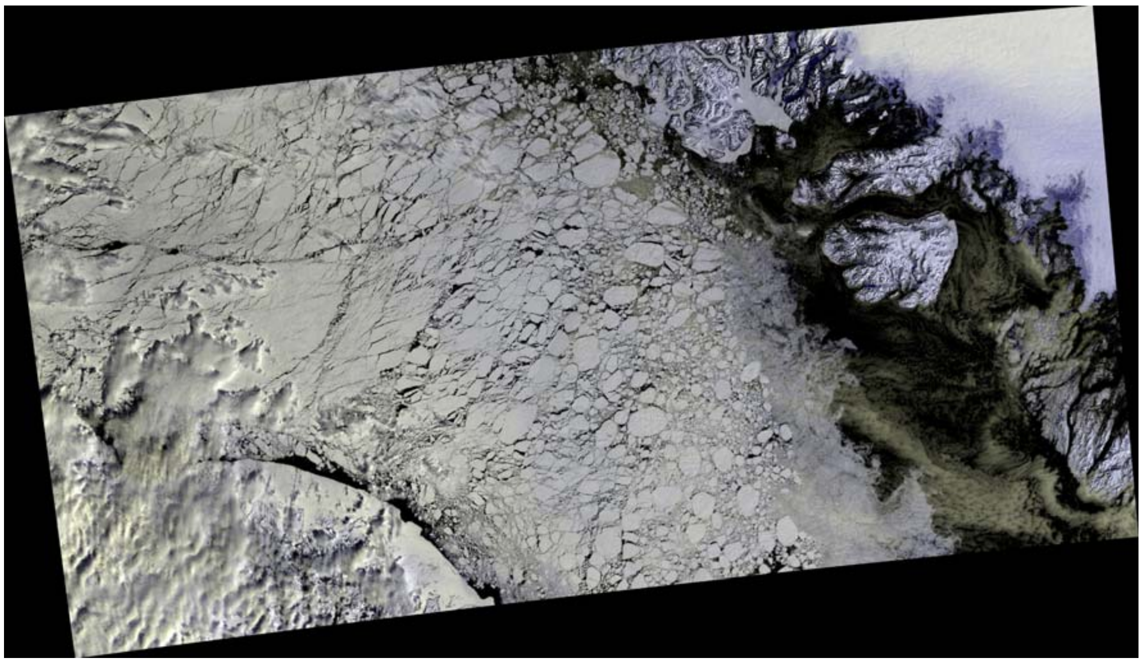


Figure 2.10. MODIS imagery of Baffin Bay, between Baffin Island and Greenland, from May 19, 2005. Data provided by NASA.

(g) OLS. The Operational Linescan System (OLS) sensor is flown aboard four Defense Meteorological Satellite Program (DMSP) satellites [NASA, 2004a]. With a resolution of 550 metres and a swath width of 3000 kilometres, it can detect snow and ice cover, ice age, and ice edges using both its visible and infrared channels [NOAA, 2004]. This imagery is used one to three times per week [Fequet, 2003]. Thirty-nine images are acquired daily by the CIS, but the use of these images is infrequent [Fequet, 2005]. A sample of OLS imagery is shown in Figure 2.11.

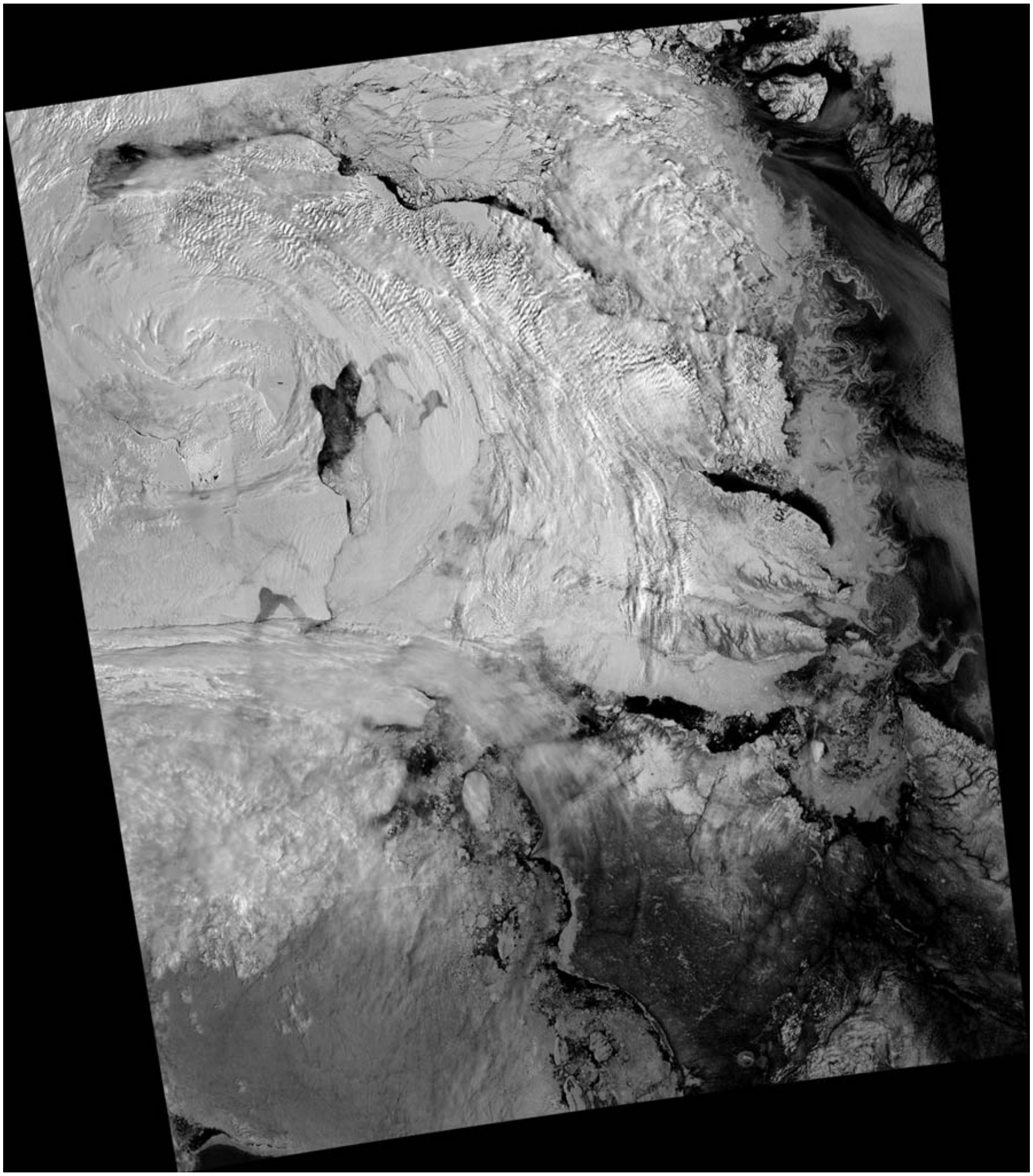


Figure 2.11. DMSP OLS imagery of Hudson Bay, Nunavut, and Quebec, from May 20, 2005.

(h) SeaWinds. The SeaWinds sensor is aboard NASA's QuikSCAT satellite. With a resolution of 25 kilometres, it collects data in a continuous, 1,800-kilometre-wide band,

and covers approximately 90% of Earth's surface in one day [NASA, 2004b]. Daily ice imagery products are generated by the NOAA National Environmental Satellite, Data, and Information Service (NESDIS) [NOAA, 2000]. SeaWinds imagery is acquired and used daily by the CIS [Fequet, 2005]. A sample of SeaWinds imagery is shown in Figure 2.12.

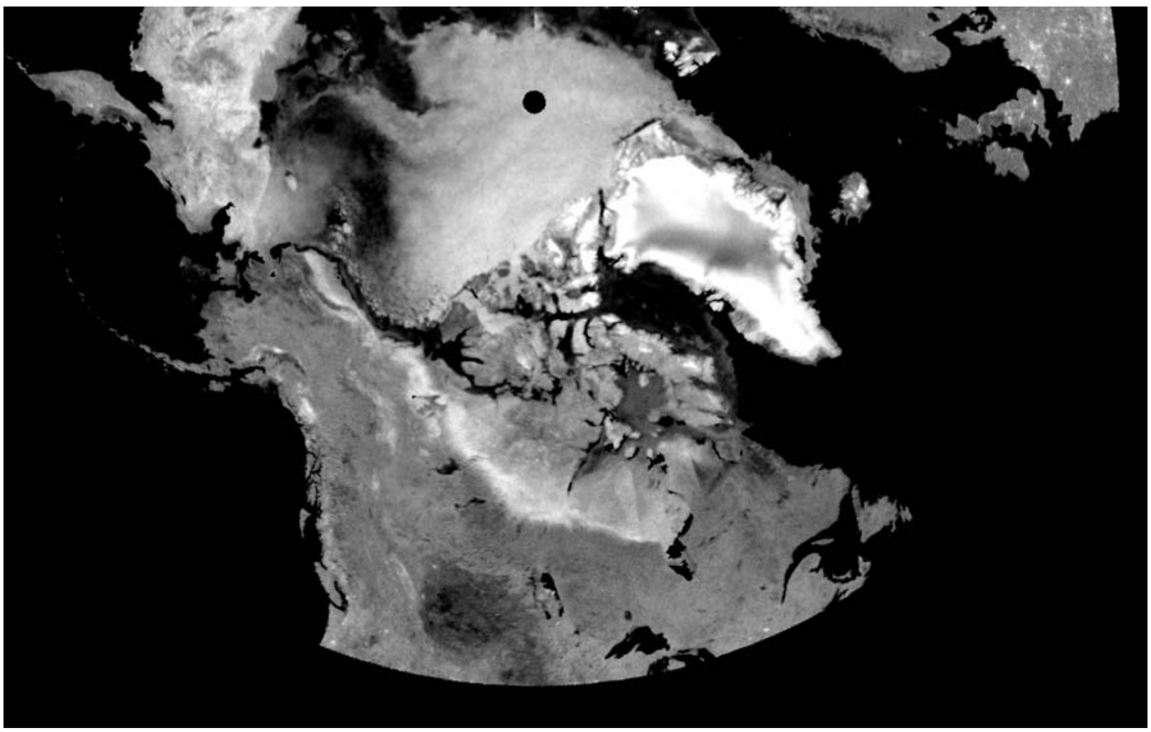


Figure 2.12. QuikSCAT SeaWinds imagery of Canada, from May 23, 2005. Data provided by NASA.

(i) SSM/I. The Special Sensor Microwave Imager (SSM/I) is a passive microwave radiometer flown aboard six NASA DMSP satellites [NASA, 2004a]. The SSM/I is designed to measure ice coverage and age [NASA, 1996]. While sixteen images are acquired daily, SSM/I images is used only one to three times per week [Fequet, 2003]. A sample of SSM/I imagery is shown in Figure 2.13.

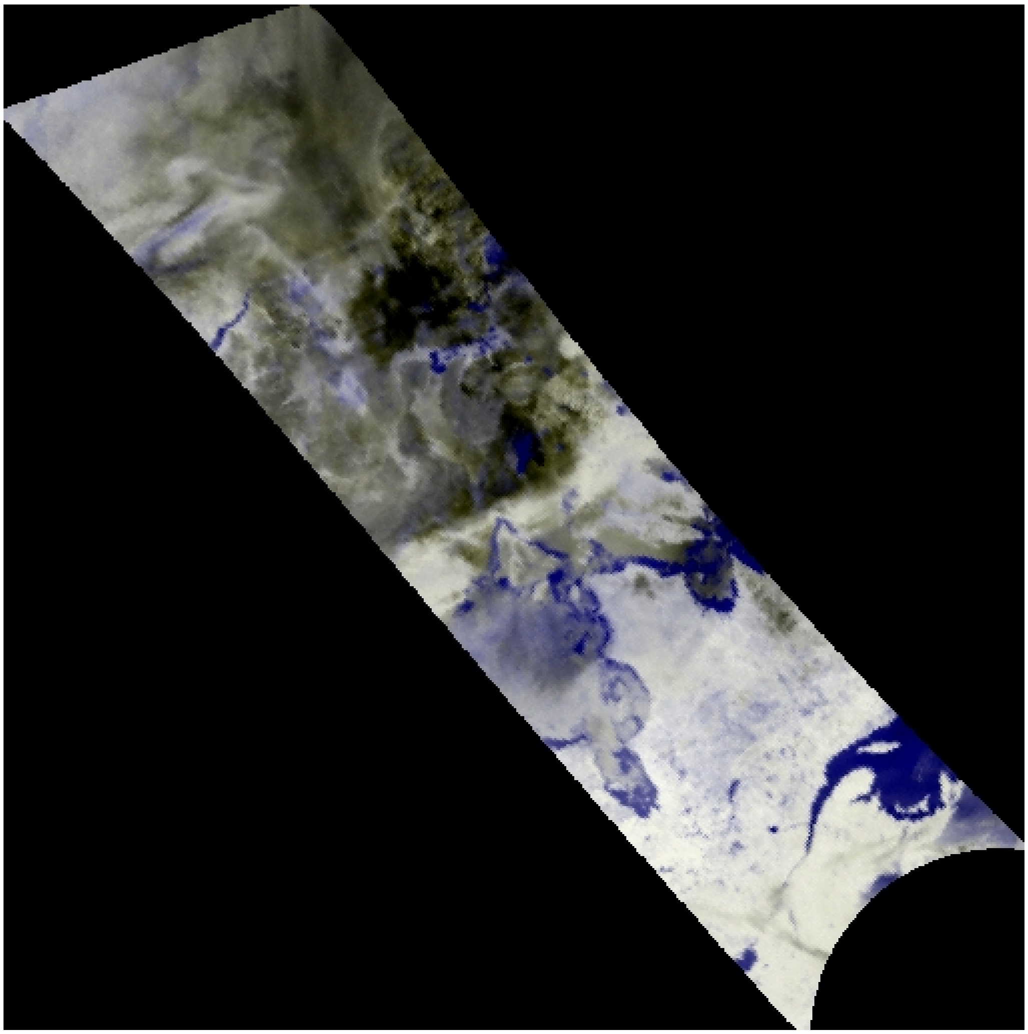


Figure 2.13. DMSP SSM/I imagery of Nunavut, Hudson Bay, Quebec, and the Maritime provinces, from May 24, 2005.

Table 2.1. Satellite sensors used by the CIS for creating daily ice charts – general sensor information.

Sensor	Satellite	Owner	Resolution	Swath Width	Band(s) / Channel(s)	Band Wavelength(s)
SAR	RADARSAT-1	CSA	100 m[1]	300 km[1]	Narrow[2]	N/A
			50 km[1]	500 km[1]	Wide[2]	
ASAR	Envisat	ESA	150 m[3]	405 km[3]	Wide[4]	N/A
AVHRR	NOAA-12, 14, 15, 16, 17[5]	NOAA	1090 m[5]	3000 km[5]	1 (VIS)[5]	0.58 - 0.68 µm[5]
					2 (NIR)[5]	0.725 - 1.0 µm[5]
					3a (SWIR)[5]	1.58 - 1.64 µm[5]
					3b (MWIR)[5]	3.55 - 3.93 µm[5]
					4 (TIR)[5]	10.3 - 11.3 µm[5]
					5 (TIR)[5]	11.5 - 12.5 µm[5]
AMSR-E	EOS Aqua	NASA	38 km[6]	1445 km[7]	N/A	10 GHz Hor.[8]
			5.4 km[6]			89 GHz Hor.[8]
			5.4 km[6]			89 GHz Ver.[8]
MODIS	EOS Aqua	NASA	500 m[9]	2330 km[10]	7 (SWIR)[10]	2105 - 2155 nm[10]
SeaWinds	QuikSCAT	NASA	25 km[11]	1800 km[11]	N/A	13.4 GHz[11]
SSM/I	DMSP missions (Air Force F08, F10, F11, F13, F14, F15)[12]	NASA	12.5 km	1400 km[11]	N/A	85.5 GHz Hor. and Ver.[8]
OLS	DMSP missions (Air Force F08, F10, F11, F13)[12]	NASA	550 m[13]	3000 km[13]	1 (VIS)[13]	0.4 - 1.1 µm[13]
					2 (TIR)[13]	10.3 - 13.4 µm[13]
GOES Imager	GOES-East series	NASA	1 km & 4 km[7]	N/A	varies	varies

Table 2.2. Satellite sensors used by the CIS for creating daily ice charts – CIS usage.

Sensor	Revist Time[5]	Importance in Chart Creation	CIS Frequency of Acquisition	CIS Frequency of Use
SAR	3 - 5 days	1	several daily[14]	always[14]
ASAR	3 days	2	1-2 per week[14]	daily[8]
AVHRR	0.25 days	3	regularly[14]	infrequently[14]
AMSR-E	3 - 5 days	4	8 per day[8]	daily[8]
MODIS	1- 2 days	4	daily[8]	daily[8]
SeaWinds	1 day	4	daily[8]	daily[8]
SSM/I	0.25 days	5	16 per day[8]	1-3 per week[14]
OLS	0.25 days	6	39[8]	infrequently[8]
GOES Imager	30 minutes	6	Hourly[8]	infrequently[8]

Data sources used for Table 2.1 and Table 2.2:

1: CCRS, 2004
2: Ramsay, 1997
3: ESA, 2004
4: Flett, 2004
5: NOAA, 2005
6: NASA, 2005
7: IICWG, 2004b
8: Fequet, 2005
9: Conboy, 2005
10: Hall, 2005
11: NASA, 2004b
12: NASA, 2004a
13: NOAA, 2004
14: Fequet, 2003

Table 2.3. Satellite sensors used by the CIS for creating daily ice charts – effectiveness for mapping ice. Three stars indicates that the sensor gives a satisfactory result at least 85% of the time; two stars indicates satisfactory results are returned at least 70% of the time; one star indicates that the sensor can be used for detection, however alternatives are better [after IICWG, 2004b].

Sensor	Total Ice Concentration	Location of Ice Edge	Ice Type	Ice Thickness	Floe Size	Ice Topography	Fast Ice	Leads & Polynyas
SAR	***	***	***	*	***	*	***	***
ASAR	***	***	***	*	***	*	***	***
AVHRR	**	**	**	*	*		*	*
AMSR-E	***	**	**	*				
MODIS	***	***	***	*	**		**	**
SeaWinds	**	**	**					
SSM/I	**	**	**	*				
OLS	**	**	**	*	*		*	*
GOES Imager	*	**	*	*				

2.2.2.2 Airborne Imagery

Aerial Side-Looking Airborne Radar (SLAR) and SAR imagery collected by the CIS serve as a base for developing each ice chart [CIS, 2002]. Chart details are then updated using visual observations made while flying the ice-reconnaissance mission [Falkingham, 2003]. SLAR is useful in bad weather because it can penetrate cloud cover (although since visual observations are also being made, the reconnaissance aircraft generally flies below the clouds). A chart is limited to the extent of the area that is imaged. The chart is only valid for the time at which the flight was taken. A sample of SLAR imagery is shown in Figure 2.14. Figure 2.15 shows an example of an ice chart made from airborne imagery and observations. Ice reconnaissance missions are flown every two to three days for each area being charted.

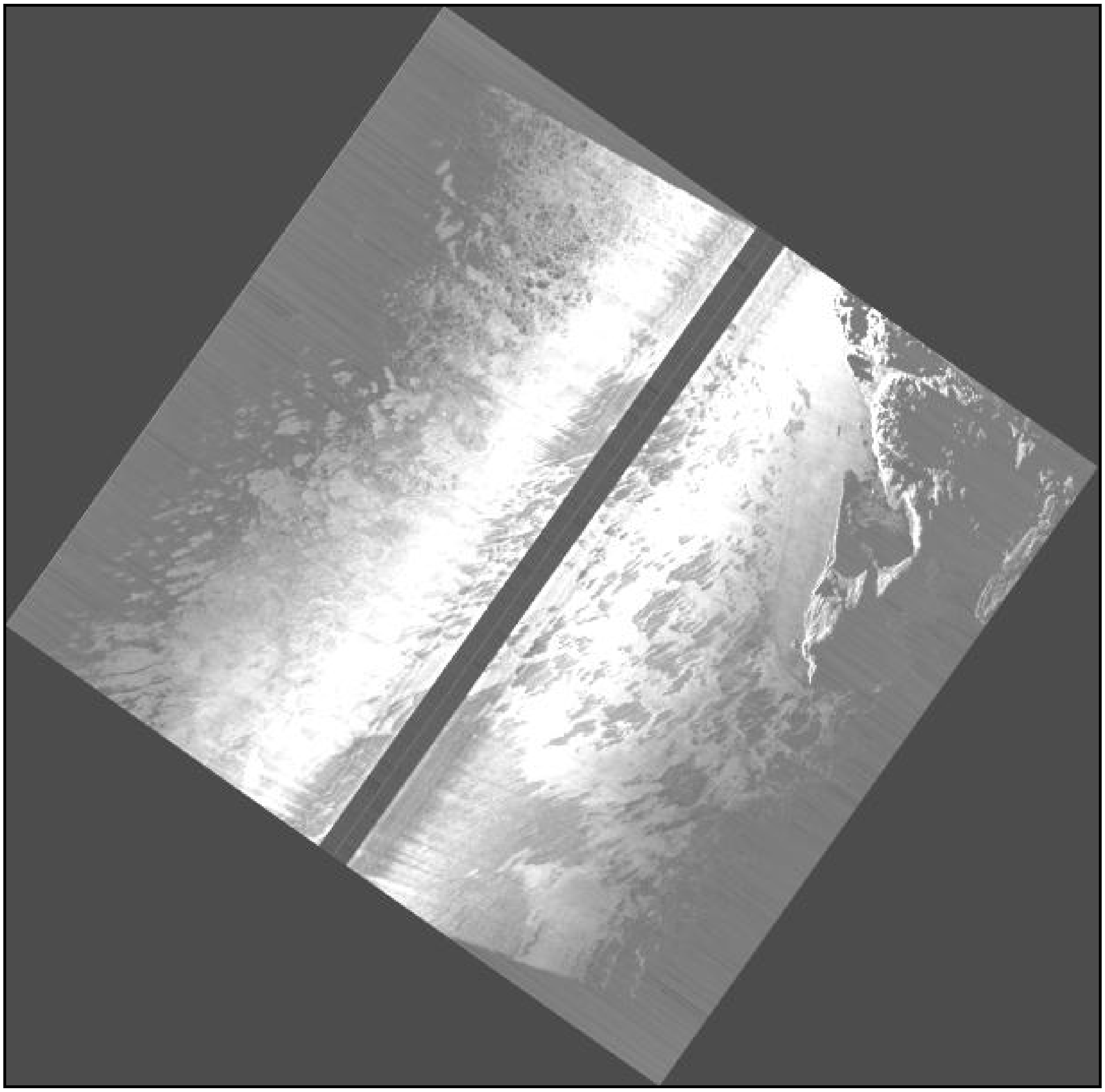


Figure 2.14. SLAR imagery of part of the Gulf of St. Lawrence, from March 4, 2003. Data provided by Canadian Ice Service.

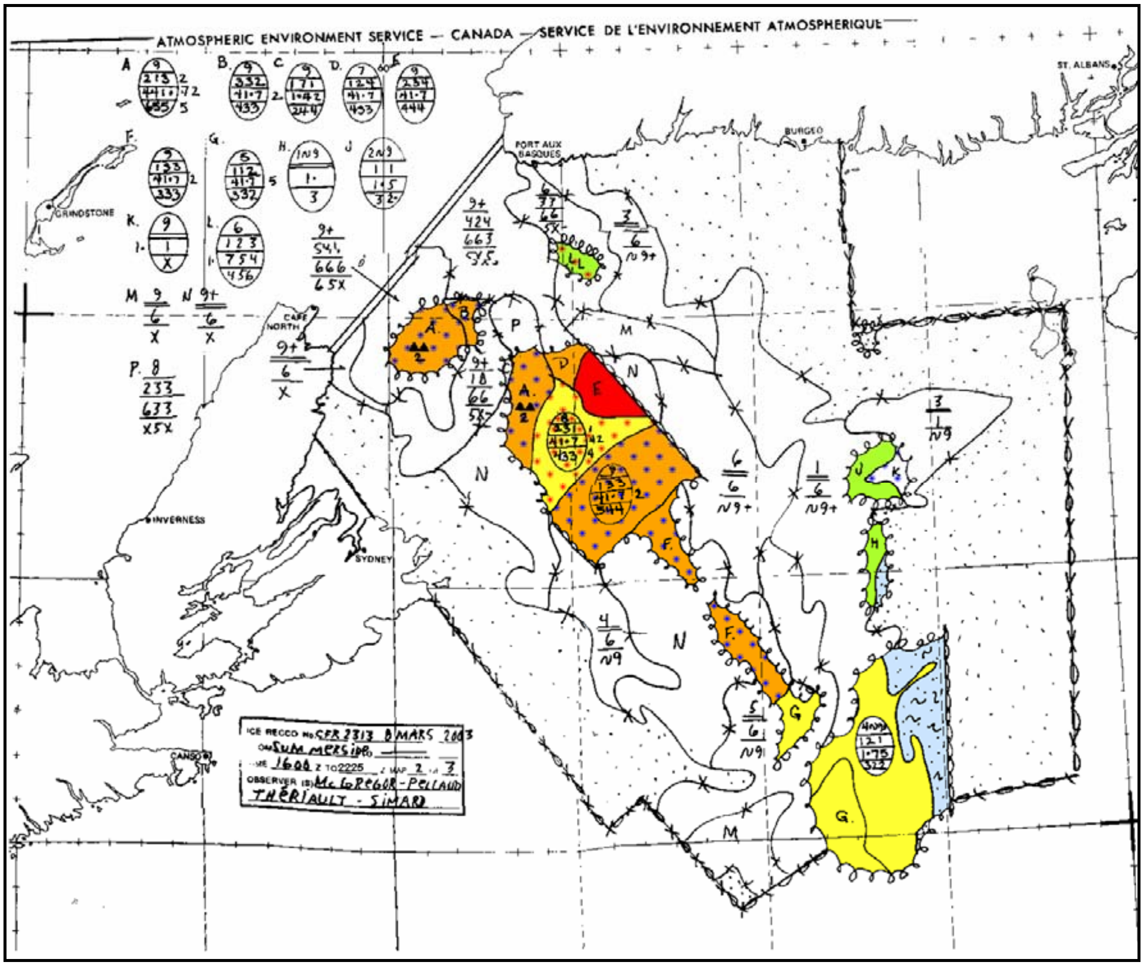


Figure 2.15. Airborne observed chart combining visual and SLAR observations.

2.2.2.3 Visual Observations

Visual observations are made from airplanes, helicopters, ships, and shore. These are used to help determine the types of ice that are seen in the imagery. Visual-only observed charts are created from helicopters and Canadian Coast Guard (CCG) icebreakers. The most important visual observations are obtained from the aircraft reconnaissance missions, as they cover much more area than the others and their observations are combined with SLAR imagery. The charts are limited to the extent of the areas that are viewed and only valid for the time at which the observations are made. Figure 2.16 shows an example of an ice chart based on observations made from an icebreaker.

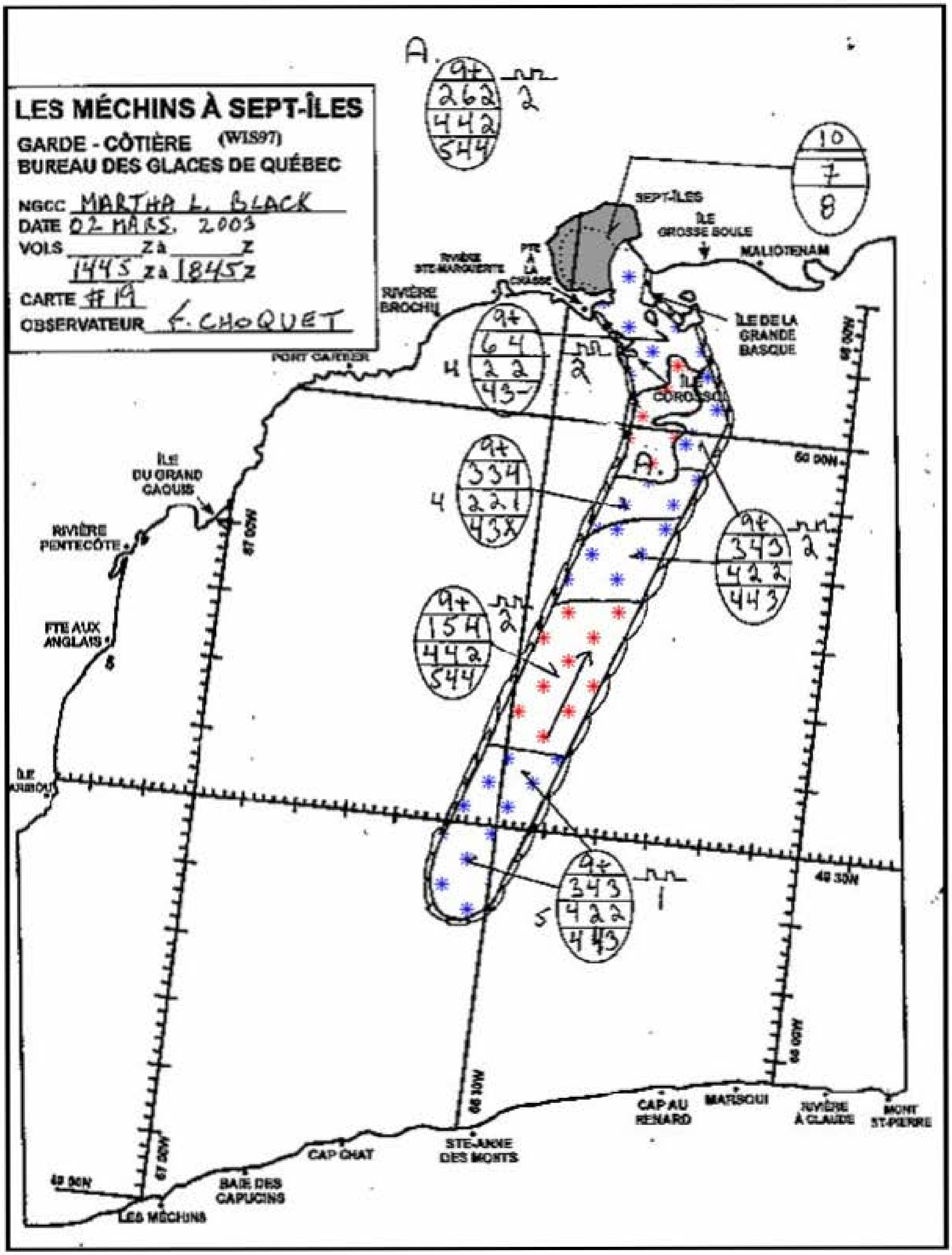


Figure 2.16. Ship-borne visual observation chart.

2.2.2.4 Meteorological Data

Meteorological data includes land observations, ship observations, and 24-hour forecasts from Environment Canada. Data is also collected from buoys [Falkingham, 2003].

2.2.3 Image Analysis

The analyst's job is to create an ice chart for each image available for the region being mapped. As seen in Figure 2.4, the image analyst uses not just the satellite and airborne imagery, but visual observations and the previous day's ice chart to help in the creation of image analysis charts. The previous day's chart is used as a starting point for creating the new chart. Visual observations are used to assist the analyst in determining the types of ice being seen in the satellite imagery [Falkingham, 2003]. The charts are only valid for the time at which the area was imaged by the satellite and are obviously limited to the area imaged. Figure 2.17 shows an example of an image analysis chart.

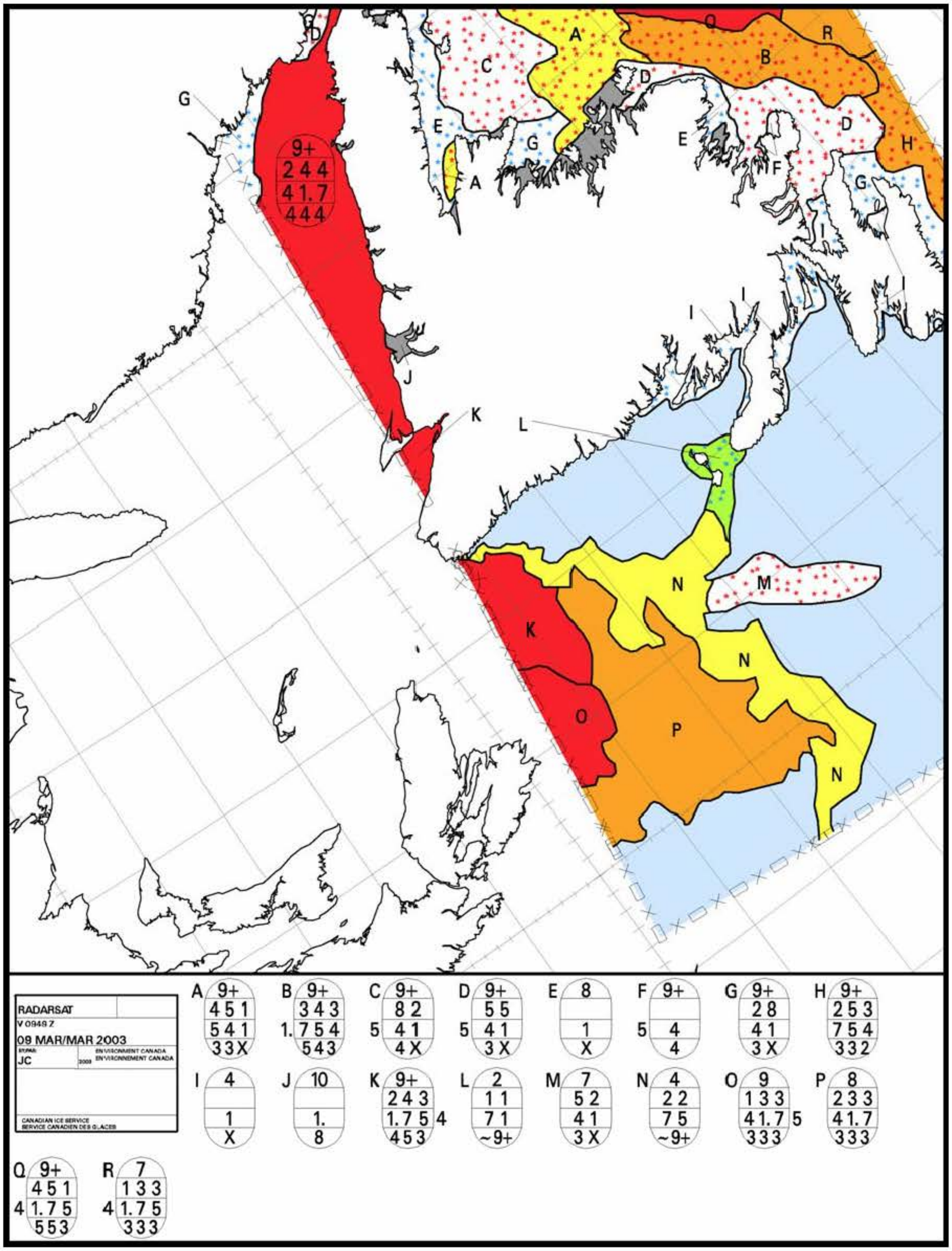


Figure 2.17. RADARSAT-based image analysis chart for the Cabot Strait.

Image analysis charts are created within four hours of data reception. As Figure 2.4 shows, the charts are used as inputs to ice models, by ice forecasters, and clients. The primary clients are the CCG ice offices and icebreakers. The CCG uses the charts to assist in decision making on ship routings and escorts. Other clients include the Canadian Meteorology Centre (CMC) (which uses ice charts in their weather forecasting models) and the Maurice Lamontagne Institute (which uses current ice conditions as an input for their ice forecasting models) [CIS, 2002].

2.2.4 Ice Models

Ice models are computer applications used to predict ice movement and development. Data from various sources (such as reconnaissance aircraft, ship reports, buoys, and satellite images) are fed into the computer application [CIS, 2003c]. The application then (possibly automatically, depending on the type of model) analyses the ice and weather conditions and predicts the upcoming conditions for up to 48 hours [CIS, 2003c]. Because image analysis charts and observation charts are often not available for the entire area that a daily chart covers, ice models are used instead. Figure 2.4 shows that ice models integrate image analysis charts, the previous day's ice chart, and meteorological data. The output of these models, shown in Figure 2.18, is a map showing predicted vectors of ice displacement and drift. For further information regarding ice models, see the CIS' Internet Web site http://ice-glaces.ec.gc.ca/App/WsvPageDsp.cfm?ID=128&LnId=5&Lang=eng.

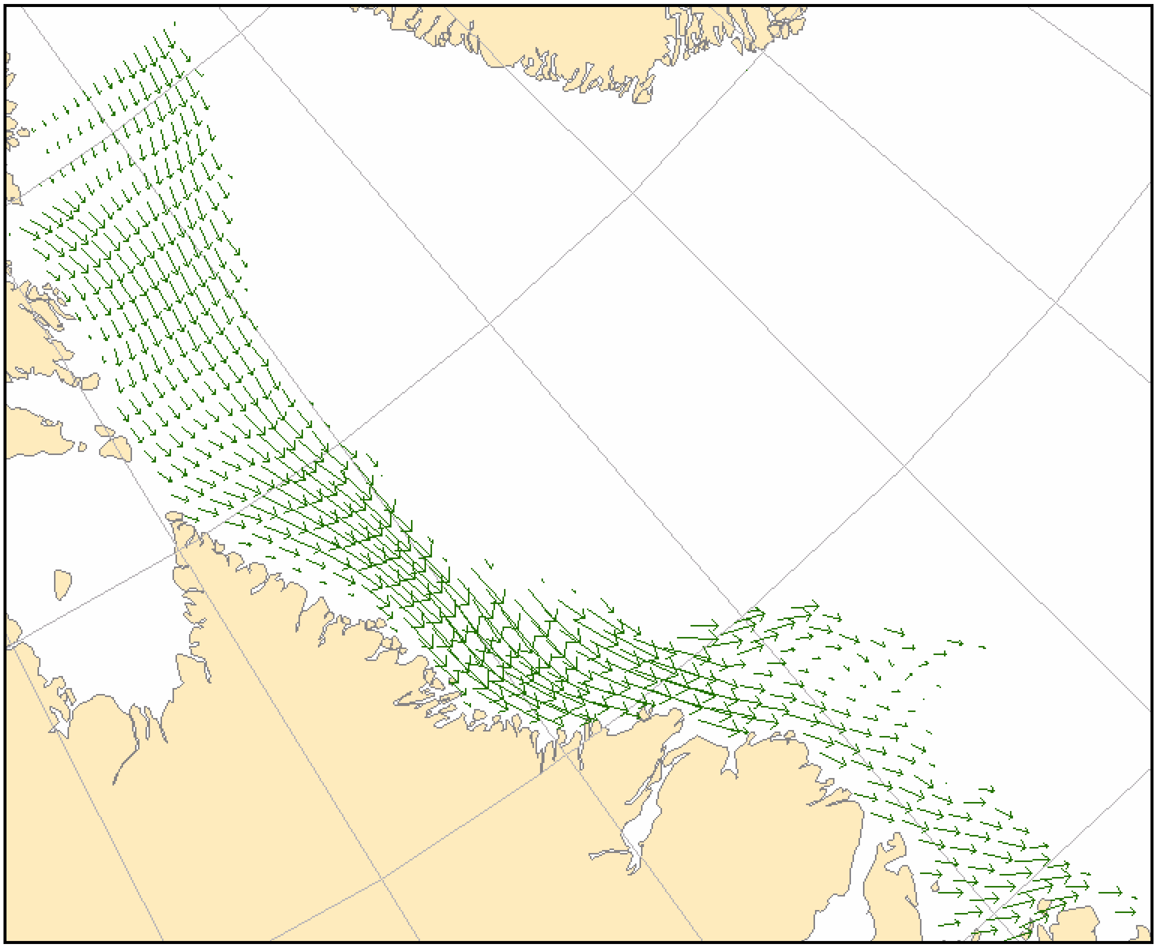


Figure 2.18. Ice trajectory map: the output of ice models.

2.2.5 Ice Forecasting

The ice forecaster’s job is to create a chart of the ice conditions for a given area at 1800 Greenwich Mean Time (GMT) [CIS, 2002]. The forecaster bases the chart on the previous day’s chart. As Figure 2.4 shows, all collected and processed data are made available to assist the forecaster. Forecasters also produce ice warnings and bulletins.

Visual observation charts and image analysis charts are only valid for the time at which the observations were made or the imagery was taken. Both of these chart types are integrated directly into the forecaster's chart; however, the chart must be valid for 1800 GMT. The forecaster uses both the ice trajectories from the ice models and his meteorological training to update the observation and image analysis charts to 1800 GMT. Because the different image analysis and observation charts are all at different resolutions, the forecaster must create a chart with a consistent level of detail [Falkingham, 2003].

The output is made available to clients by email, fax, and the World Wide Web, usually by 1600 GMT [CIS, 2002]. What is not made available to the public - but is in fact the in-house final product - is an ArcInfo interchange file (commonly referred to as an *E00* file because this is the filename extension). The daily *E00* files are used to assist in the production of weekly regional charts. Regional charts are used by mariners for planning marine activities up to several weeks in advance. They are the main climatological product issued by CIS and are used by the CMC in its meteorological models [CIS, 2002]. They are also part of the Canadian national archives.

2.3 Digital Hydrographic Data

The encoding and display of digital hydrographic data has been formally standardised by the IHO. These standards – S-52 and S-57 – deal with the systems on which data is displayed, how the data is stored and described, and what symbols and colours are used to display the data.

2.3.1 Electronic Chart Display and Information Systems

Many computer systems are capable of displaying navigational charts. An Electronic Chart Display and Information System (ECDIS) is a computer system designed to display navigational charts that complies with IMO requirements for International Convention for the Safety of Life At Sea (SOLAS) class vessels [IHO, 2003]. The IMO Performance Standards, adopted in 1995, were developed to specify how an ECDIS must work so that is can be an adequate replacement for a paper nautical chart [IHO, 2003]. The standards specify the components, features, and functions of a system in which the primary function is to contribute to safe navigation [Alexander, 2003].

Like paper charts, the main purpose of an ECDIS is to assist in route planning. However, an ECDIS is much more than just a computer display of a nautical chart. Its purpose is to allow all the same types of work that are traditionally associated with paper nautical charts (position determination, updating charts with the aid of the Notices to Mariners, and entry of observations, instructions, and notes) and to make these activities easier, more precise, and faster [Scheuermann, 1996].

An ECDIS is a real-time navigation system that integrates multiple types and sources of information and displays it for interpretation by a mariner [IHO, 2005]. It is also an automated decision aid capable of continuously determining a vessel's position in relation to land and other charted objects, including unseen hazards [IHO, 2003]. Mariners can view selected information from an ENC and data from positional and, optionally, other sensors [IHO, 1994].

An ECDIS is an integrated system of hardware, software, and data. The hardware is generally a standard workstation computer built into a console that is integrated into the ship's equipment. An ECDIS can thus obtain the ship's course from the gyro compass, the rate of turn from the turn indicator, the position from the ship's Global Positioning System (GPS) receiver, the ship's speed, and any other navigational information that can be connected to the computer [Scheuermann, 1996], such as an echo sounder or an Automatic Radar Plotting Aid (ARPA) [Hong Kong Hydrographic Office, 2005]. The software component, referred to as the "ECDIS kernel" or "function library", is what allows the user to select which information to view and at what scale [Scheuermann, 1996]. The data component of an ECDIS includes ENCs, radar information, positional information, and other sensor information.

2.3.2 Electronic Navigational Chart

An electronic navigational chart is a vector-based digital file (as opposed to a raster navigational chart) containing marine and shore features. The content, structure, and format of ENCs are standardized so that they can be displayed in both an ECDIS and an Electronic Chart System (a chart display system that does not meet with IMO SOLAS requirements) [IHO, 2003].

ENCs are issued on the authority of national hydrographic offices [Vatsa, 2002]. An ENC must be created and displayed according to the specifications stated in IHO special publications S-57 and S-52, respectively [Vatsa, 2002].

2.3.2.1 S-52 and S-57

The IHO developed technical standards for displaying and transmitting digital hydrographic data. The standards were developed by the IHO Committee on Hydrographic Requirements for Information Systems (CHRIS). IHO Special Publication 52 describes the means for how to display ENC content (colour and symbol specifications), generally on an ECDIS. These specifications are known as “S-52” [IHB, 2001].

IHO Special Publication 57 describes the standards to be used for exchanging ENC content between national hydrographic offices, commercial ENC makers, mariners, and other data users. The standards include such specifications as file, object, and attribute naming, topology, projection information, and update methods. These specifications are known as “S-57” [IHB, 2000].

Among the more general S-57 specifications, ENCs must be graticular (defined by two meridians and two parallels), have no projection, and reference the World Geodetic System 1984 (WGS 84) datum.

The original standards were adopted officially by the IHO in 1992 [IHO, 2000]. Each S-57 object has S-52 display specifications. The current edition of the S-52 standards is 4.2 (since 2002). Released in 2000, Edition 3.1 is the most recent version of the S-57 standard. The specifications of Edition 3.1 were originally scheduled to remain in place until the publication of Edition 4 in late 2006 [IHO TSMAD, 2004]. However, as of September 2005, Edition 4 has been dropped in favour of a new standard, S-100.

2.3.2.2 S-100

IHO is working on the new S-100 standard that will support a greater variety of hydrographic-related digital data sources, products, and customers than the S-57 standard currently does. Planned to be available in late 2007, S-100 is not just an incremental revision of S-57; rather it is a new standard. Web-enhanced functionality and interoperability with other geographic information systems (GIS) are two of the key enhancements under development [Alexander, 2006, and Wells, 2006].

2.3.3 Marine Information Objects

Marine Information Objects (MIOs) consist of chart- and navigation-related information that supplement the minimum ECDIS data requirements. MIOs can be displayed alongside ENC date. MIOs are additional, non-mandatory information not already covered by existing IMO, IHO, or International Electrotechnical Commission (IEC) standards [Alexander, 2003a].

In 2001, the Harmonization Group on MIOs (HGMIO) was established between IHO and IEC. Their task is to recommend additional data and display specifications that may be incorporated into future editions of IHO and IEC standards [Alexander, 2004].

HGMIO's current areas of investigation include ice coverage, meteorological data, tide and water levels, current flow, and marine environmental protection.

2.4 Displaying Ice Information in Electronic Navigational Charts

Using an ECDIS as a standalone information system would not provide sufficient information for safe navigation in ice-infested waters [El-Rabbany, 2002]. This is because the S-57 specifications allow for only a very limited manner of conveying ice conditions.

2.4.1 Current Method

Edition 3.1 of the S-57 standard defines only one object for displaying ice information, ICEARE. This is defined as being "an area of ice over land or water" [IHO, 2000]. For this one object, there are only three ways to distinguish different types of ice. An ICEARE object can have a CATICE (category of ice) attribute value of "fast ice," "glacier," or "polar ice." These three options are not very useful for an ice-charting organisation like the CIS because mariners require much more detailed information about the types of ice in the water.

2.4.2 Proposed Method

In order to display ice in an ECDIS more effectively, a new set of Ice Objects and attributes has been developed over the past decade. Collectively, these new S-57 Ice Objects, when used and displayed in ECDIS, are MIOs.

2.4.2.1 1995 to 2000

In February 1995, the Canadian Hydrographic Service (CHS) organised the "Workshop on ECDIS in Ice Infested Waters". This was the first international effort to deal with ECDIS in ice-infested waters [Scheuermann, 1999]. The output was a collection of papers and national ice service reports describing the various local ice conditions.

A second meeting was held in June 1995 at the CHS in Ottawa, Canada [Scheuermann, 1999]. Ice objects were defined by a group of experts at the "Workshop on International Standards for Ice Information in ECDIS". Following reports and reviews by American, Canadian, and German experts, as well as commercial ECDIS manufacturers, the proposed objects and their attributes became Version 1.0 of the ECDIS Ice Objects Catalogue [CIS, 2001].

The catalogue was reviewed the following May at the "Use of ECDIS in Ice Navigation" workshop in Hamburg. In addition to the experts from the original three countries, the workshop included experts from most of the Baltic nations and Argentina. The revisions became Version 2.0 of the catalogue [CIS, 2001].

2.4.2.2 2000 to Present

SevenCs, a German ECDIS company, proposed further modifications to the catalogue in June 2000 during the "Ice In ECDIS" workshop in St. John's, Newfoundland [CIS, 2001]. The results of the workshop lead Tim Evangelatos, then with CHS and funded by CIS, to complete development of Version 3.0 of ECDIS Ice Objects [Alexander, 2006]. This was the current version of the catalogue at the time of writing. It proposes eighteen Ice Objects and 34 Ice Attributes to describe them.

2.4.3 Ice in ECDIS Project

Headed by Dr. Ahmed El-Rabbany at Ryerson University in Toronto, the project involves the short-term goals of developing neural network-based tools for predicting ice motion and integrating ice information into an ECDIS [CRESTech, n.d.]. The long-term goal is to develop an integrated navigational chart system that will automatically and intelligently recommend optimal routes through ice-infested waters.

This thesis deals specifically with that portion of the work involved in integrating ice information into an ECDIS.

2.4.3.1 Previous Work

Four researchers have previously worked on the problem of creating an S-57 exchange set from a CIS daily ice chart produced with ISIS. Each began with the ESRI ArcInfo interchange format (*E00*) file that is created with ISIS.

2.4.3.1.1 2001: C. Lapointe's Report

Charles Lapointe was the first person to attempt to create S-57 Ice Objects (i.e., an S-57 exchange set) based on a CIS daily ice chart. He did this as a partial requirement for his Bachelor of Science in Engineering degree in the Department of Geodesy and Geomatics Engineering (GGE) at the University of New Brunswick (UNB). His methodology is shown in Figure 2.19. Full methodological details and analysis are in his report, "Integrating Sea Ice Information Into An Electronic Chart Display And Information System (ECDIS)" [Lapointe, 2001].

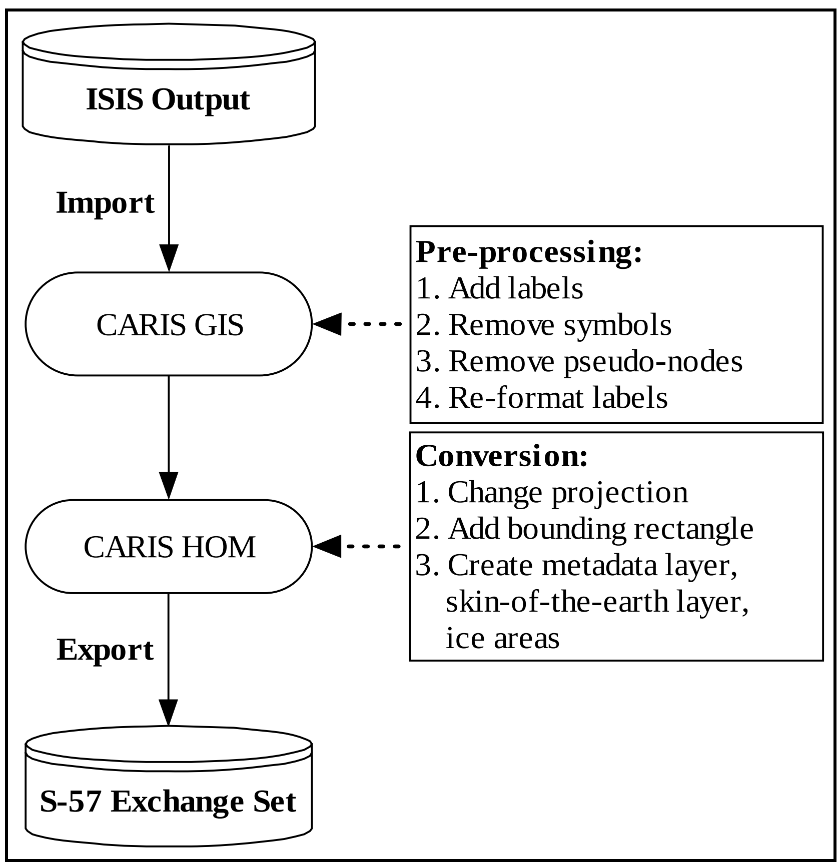


Figure 2.19. Flow chart of Lapointe's methodology (after Lapointe [2001]).

Lapointe imports the *E00* straight into CARIS GIS, where most of the pre-processing and processing is done. The pre-processing involves adding labels to non-ice polygons (polygons that do not represent ice areas), removing symbols (ice flow direction indictors, leader lines, and other cartographic symbols) and pseudo-nodes (extra nodes in a line), and re-formatting the labels. The reformatting is the only part of the process that is automated and the script ran in under fifteen minutes on an Intel® Pentium® II, 400-megahertz based system [Lapointe, 2001]. The processing was done using CARIS HOM (Hydrographic Object Manager) software. This involved changing the projection, adding a bounding rectangle, and creating a metadata layer, a skin-of-the-earth layer (a layer of non-overlapping polygons that cover the entire area of the data set), and ice areas (polygons that represent ice). If the ice objects have at one time been registered with CARIS HOM, the final step is writing out an Ice Information MIO.

Because a great deal of Lapointe's conversion process involved manual editing, the time required to perform the transformation was judged to be too long (multiple hours) [Lapointe, 2001]. Not only did this methodology exceed the one-hour processing time limit, but since it was mostly manual, the cost of producing a daily Ice Information MIO would be much greater than that of a solution that is mostly automated.

Lapointe makes several recommendations on how the CIS should alter the *E00* file that it created in ISIS. The main reason for making these alterations was to save editing time in CARIS. However, Lapointe did not remove symbology in ArcInfo prior to importing the ice chart into CARIS. Had he done so, many of the problems he encountered while editing the chart in CARIS would have been avoided, and thus altering ISIS would not be required.

2.4.3.1.2 2002: S. Diarbakerly's Work

In his paper, "On the Integration of Sea Ice Information into ECDIS," Samer Diarbakerly claims that he created an ArcInfo script that takes the output ISIS *E00* file, alters its projection information, removes multiple points from polygons (or adds points where they were missing), moves symbols to another layer, and exports the file to be used in CARIS HOM. On testing the encrypted script, however, it appears to the author that the script simply removes leader lines and builds topology. The observed and actual actions of the script are shown in Figure 2.20.

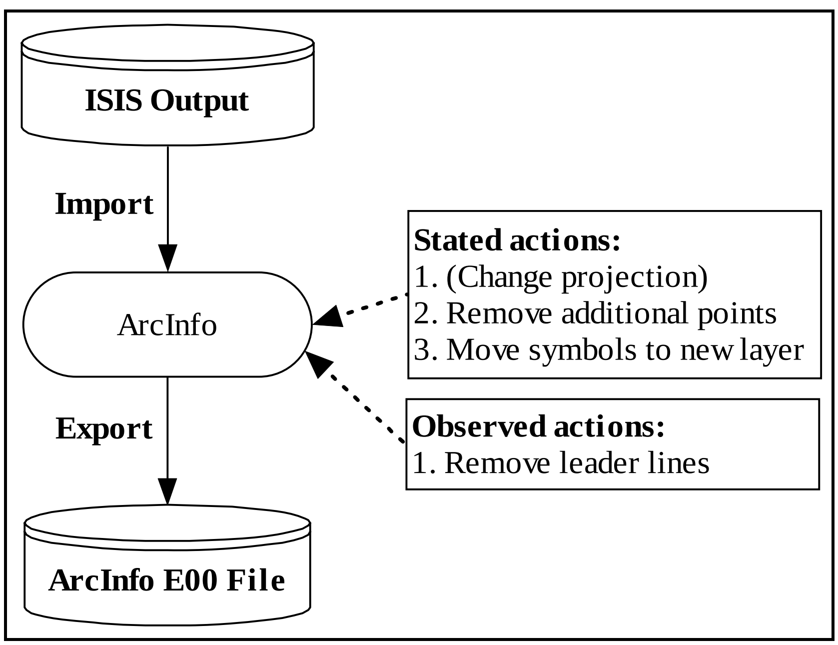


Figure 2.20. Flow chart of Diarbakerly's methodology (after Diarbakerly [2002]).

2.4.3.1.3 2002: B. Huynh's Work

As described in his report, "The Integration of Paper Ice Charts into ECDIS," Boris Huynh's work with the Geomatics Programme at Ryerson University was originally based on that of both Lapointe and Diarbakerly [Huynh, 2002]. Huynh worked on this project during the summer of 2002. He used Diarbakerly's script to remove leader lines from the ISIS output *E00* file. He then followed Lapointe's methodology for creating an S-57 exchange set.

2.4.3.1.4 2003 - 2004: B. Agi's Work

Dr. Benson Agi, also with the Geomatics Programme at Ryerson University, continued Huynh's work. Dr. Agi altered the approach in order to develop a methodology that converted an S-57 exchange set from an ISIS output *E00* file in the most efficient, consistent, and cost-effective manner [Agi and El-Rabbany, 2004]. His methodology uses CARIS GIS and CARIS HOM. Eliminating the requirement of ArcInfo is both a cost- and knowledge-saving approach when compared to using Diarbakerly's ArcInfo script to remove leader lines first. Dr. Agi's methodology is shown in Figure 2.21.

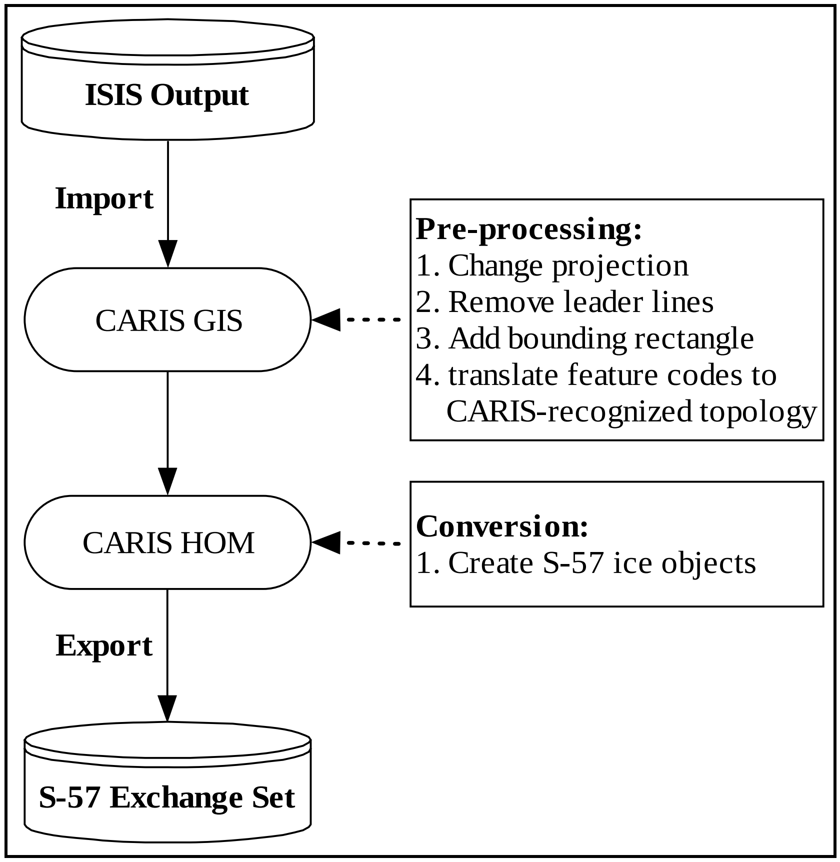


Figure 2.21. Flow chart of Agi's methodology (after Agi [2003]).

Most of Dr. Agi's process is automated. His scripts change projection, remove leader lines, creates the bounding graticule that S-57 specifications require, and translates some ISIS codes to feature codes recognized by CARIS. With most of the required steps automated, this was, until June 2004, the most efficient method for converting a CIS daily ice chart to an Ice Information MIO (as it built upon all previous work on this problem). Of the eighteen proposed Ice Objects, Dr. Agi's tool is limited to only create the SEAICE object.

2.4.3.2 Summary of Work to Date

All the previous work described has attempted to solve the MIO creation problem by primarily focusing on using CARIS. In 2001, Lapointe worked exclusively in CARIS and encountered some problems that could have been avoided had he used ArcInfo. In 2002, Huynh used an ArcInfo script developed by Diarbakerly that avoided some of the editing problems encountered by Lapointe. He then continued in CARIS in the same manner as Lapointe. Since that time, Dr. Agi worked exclusively on developing a CARIS-only solution for the purpose of cost-effectiveness.

While ESRI has no ENC-specific product like CARIS HOM, because the ISIS output is in ArcInfo interchange format, an ESRI-based solution still requires investigation.

CHAPTER 3
METHODOLOGY: DESIGN AND APPROACH

This chapter discusses how to alter the existing workflow at the CIS so that an Ice Information MIO is one of their resulting products. The solution that was developed for this project is explained, and two alternate workflow solutions are introduced. Regardless of the method that is used to create an Ice Information MIO from a daily ice chart, there is not a defined S-52 standard for displaying ice objects in an ECDIS. The final section of this chapter proposes colours and symbols to be used to display ice objects.

3.1 Developed Solution

The solution as to how to develop an efficient method for converting an ice chart to an S-57 exchange set was developed by the author. This solution begins where the ISIS output currently ends: an *E00* file.

The tool has been tested and works with data from an ice chart produced as recently as November 24, 2003.

3.1.1 Equipment and Data Sets

Developing and testing of this solution involved using an IBM® NetVista® computer equipped with an Intel Pentium III processor running at 1000 megahertz, 512 megabytes of random access memory (RAM), and Microsoft® Windows® 2000 (Service Pack 4) operating system.

The software used by the author is outlined in Table 3.1. The test datasets listed in Table 3.2 were provided courtesy of the CIS.

Table 3.1. Software Applications Used for Development and Testing

Name	**Version**	**Developer**
Access	2000 Service Pack 3	Microsoft
ArcInfo[1]	8.3	ESRI[1]
ArcView[1]	3.3	ESRI
EASY-ENC[2]	3.0	CARIS[3]
EasyEdit Lite[4]	3.0	PNGIS[4]
dKart[5] Look	4.0	HydroService AS
S-57 Checker	-	TRANSAS[6]
SeeMyDEnc[7]	2.3.18	SevenCs
Visual Basic[8] Professional	6.0 Service Pack 5	Microsoft

[1] ArcInfo, ArcView, and ESRI are registered trademarks of the Environmental Systems Research Institute, Redlands, CA, USA.

[2] EASY-ENC is a trademark of CARIS, Fredericton, NB, Canada.

[3] CARIS is a registered trademark of CARIS, Fredericton, NB, Canada.

[4] EasyEdit Lite and PNGIS are trademarks of PNGIS, Vancouver, BC, Canada.

[5] dKart is a trademark of dKart

[6] TRANSAS is a trademark of TRANSAS

[7] SeeMyDEnc and SevenCs are trademarks of SevenCs, Germany.

Table 3.2. Daily Ice Charts Provided by the CIS

File Name	Region	Date
EXPANGULF_i20010209.e00	Gulf of St. Lawrence	9 February 2001
EXPANGULF_i20010210.e00	Gulf of St. Lawrence	10 February 2001
EXPANGULF_i20010211.e00	Gulf of St. Lawrence	11 February 2001
EXPAGL_20030305.e00	Great Lakes	5 March 2003
EXPAGULF_20030318.e00	Gulf of St. Lawrence	18 March 2003
EXPAHA_20031021.e00	High Arctic	21 October 2003
EXPAMID_20031102.e00	Mid Arctic	2 November 2003
EXPANFLD_20030318.e00	Newfoundland and Labrador	18 March 2003
EXPAWA_20031023.e00	West Arctic	23 October 2003
EXPAEA_20031124.e00	East Arctic	24 November 2003
EXPAFOXE_20031112.e00	Foxe Basin	12 November 2003

3.1.2 Mapping the ArcInfo Vector Data Model to the S-57 Data Model

Before discussing decisions made and actions taken, it is necessary to understand where the data is and where it has to go. The starting point is an ArcInfo coverage consisting of points, lines, and annotations. The end point is an S-57 exchange set consisting of points, lines, and polygons. The question that must be answered is, "How do these two data models compare?" The more direct the relationship is between the two, the easier the task becomes of making the transition from coverage to exchange set.

[8] Visual Basic is a registered trademark of Microsoft, Redmond, WA, USA.

When discussing S-57, the terms “spatial record” and “vector record” are often used interchangeably. A spatial record technically is a vector, raster, or matrix record. However, only the vector record type has to date been formally defined in the current S-57 specifications [IHO, 2000]. As raster and matrix records should eventually be defined, only the term “vector record” will be used here. A vector record describes geometry. It does not have any meaningful, real-world attributes. A “feature record” describes an object and points to one or more vector records to represent it spatially.

ArcInfo has four types of geometric features: nodes, points, lines, and polygons [ESRI, 1997]. The difference between a node and a point is that a node must connect to a line; a point need not. The equivalent S-57 vector records are shown in Table 3.3.

Table 3.3. S-57 Geometric Equivalents of ArcInfo Geometry (after Cheung [1997])

ArcInfo Geometry		**S-57 Vector Record**
Point	$\Rightarrow$	Isolated node
Node	$\Rightarrow$	Connected node
Line	$\Rightarrow$	Edge
Polygon	$\Rightarrow$	Face

In Version 3.1 of the S-57 standards, true topology is not implemented. This means there are no actual faces. Only chain-node topology exists, so polygons are represented as closed loops of edges, and edges can cross each other [IHO 2000]. These topological differences do not impede this tool from converting to S-57.

S-57 has four types of feature records: points, nodes, lines, and areas. While these types of feature records appear to be just like ArcInfo's geometries, they are not. S-57 allows one edge to be part of many features (lines or areas), and one face to be part of many areas. Also, each edge need not be part of a line as long as it is part of an area. The feature point and node relate directly to ArcInfo's point and node. The feature line and area relate to ArcInfo's extended data model, specifically the route and the region. A route is a collection of one or more arcs, just as a feature line is represented by one or more edges. A region is one or more polygons, as a feature area is one or more faces. The relationship between S-57 feature records and ArcInfo features is shown in Table 3.4.

Table 3.4. ArcInfo Equivalents of S-57 Features (after Cheung [1997])

S-57 Feature Record		**ArcInfo Geometry**
Feature point	$\Rightarrow$	Point
Feature node	$\Rightarrow$	Node
Feature line	$\Rightarrow$	Route
Feature area	$\Rightarrow$	Region

To create an S-57 cell from an ArcInfo coverage, the paths shown in Table 3.5 must be taken for each ArcInfo data type:

Table 3.5. Translating ArcInfo Data Types to S-57 Data Types (after Cheung [1997])

ArcInfo		**S-57 Vector Record**	**S-57 Feature Record**
Point	$\Rightarrow$	Isolated node	Feature point
Node	$\Rightarrow$	Connected node	Feature node

ArcInfo		S-57 Vector Record	S-57 Feature Record
Line	⇒	Edge	-
Route	⇒	-	Feature line
Polygon	⇒	Face	-
Region	⇒	-	Feature area

3.1.3 Mapping CIS Chart Data to Proposed ECDIS Ice Objects

It is now clear how ArcInfo coverage features can be mapped to an S-57 exchange set. Without being able to map between the two, there could be no solution. The next necessary relationship that must be established is between ice chart data and the proposed S-57 ice objects. If ice data cannot be directly mapped to an S-57 object, again, there could be no solution.

The author compared the ISIS output coverage points and lines (and their associated attributes) with the existing and proposed S-57 object and attribute definitions. The author then matched each spatial LINE_TYPE value in the arc coverage and each spatial PNT_TYPE value in the point coverage with S-57 objects and attributes. The term "spatial" is used because many arcs and points in the ice coverage are symbolic or cartographic and do not represent any real-world objects.

Table 3.6 shows the author's mapping of each PNT _TYPE value to an S-57 object. Table 3.7 shows the same for each LINE _TYPE value. In some cases, a value may map to an object, but have no attribute value (i.e. coastline or land). This is not a problem; S-57 objects may exist with no attribute values. It should be noted that neither all

PNT_TYPE values in Table 3.6 nor all LINE_TYPE values in are CIS-documented [McCourt 2003]. The author found three undocumented PNT_TYPE values and one undocumented LINE_TYPE value [Cardinal 2004, Chagon, 2004]. A complete list of all PNT_TYPE values and their definitions is in Table II.1 in Appendix II. A list of all LINE_TYPE values and their definitions is in Table III.1 in Appendix III. The author compiled descriptions of all the S-57 objects and attributes referred to in these tables. They are in available in Table IV.1 and Table IV.2 in Appendix IV. Complete definitions of all Ice Objects can be found in *ECDIS Ice Objects Version 3.0* [CIS, 2001]. A full description of the ISIS output coverage is in *CIS Daily Chart (Sea Ice) ISIS Format Data Description* [CIS, 2003].

Table 3.6. Ice Object Equivalents of ISIS PNT_TYPE Values

PNT_TYPE	Description	Object	Attribute(s)	Value(s)
101	Bergy water	BRGARE	-	-
		SEAICE or LACICE	ICECVT	12
106	Fast ice	SEAICE or LACICE	ICECVT	2
107	Open water	SEAICE or LACICE	ICECVT	11
115	Ice free	SEAARE	-	-
117 118 120 122	Ice with Egg Code	SEAICE or LACICE	ICEACT	In EGG_ATTR
			ICEAPC	
			ICESOD or ICELSO	
			ICEFLZ	
			ICECVT	

PNT_TYPE	Description	Object	Attribute(s)	Value(s)
140	Ice area (with attributes)	SEAICE or LACICE	ICEACT	
143 144 145	Ice area (no attributes)	SEAICE or LACICE	ICEACT	
400	Land	LNDARE	-	-

Table 3.7. Ice Object Equivalents of ISIS LINE_TYPE Values

LINE_TYPE	Description	Object	Attribute(s)	Value(s)
117	Fast ice edge	ICELIN	ICELNC	2 or 5
122	Ice edge			
133	Open water edge			
140	Coastline	COALNE	-	-
141	Inland lake edge			
150	Iceberg edge (topological)	ICELIN	ICELNC	7
151	Iceberg edge (non-topological)			
162	Estimated ice edge	ICELIN	ICELNC	6
171	Crack	ICEFRA	ICEFTY	1
183	Open water lead	ICELEA	ICELTY	1 to 3
			ICELST	1
190	Frozen water lead	ICELEA	ICELTY	1 to 3
			ICELST	2
201	Radar limit	ICELIN	ICELNC	3
218	Undercast limit	ICELIN	ICELNC	1
222	Visual limit	ICELIN	ICELNC	4

3.1.4 Solution Workflow

Section 3.1.2 demonstrated how the ArcInfo data model can be mapped to the S-57 data model. Section 3.1.3 explained how the author mapped CIS chart data values to existing and proposed S-57 objects and attributes. Without both matched data models and matched data types, the conversion of an ice chart from E00 format to S-57 format could not proceed. Having ensured that the conversion was possible, the author developed the solution presented in this chapter. Figure 3.1 outlines the workflow of the author's application used in this solution.

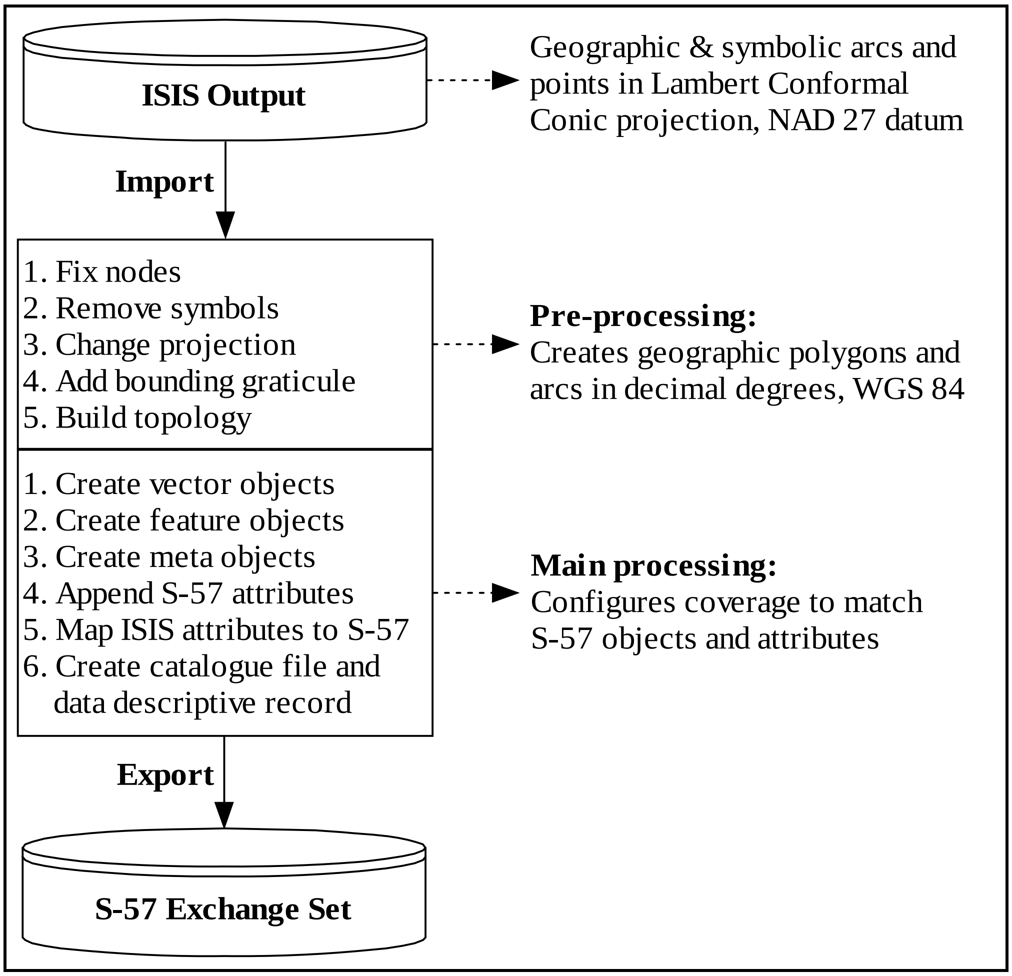


Figure 3.1. Application workflow of the developed solution.

3.1.5 Pre-processing Decision-Making

Prior to proceeding with the development of the tool, several questions had to be resolved. First, would the solution incorporate an existing GIS or would it be entirely independent? Second, would the solution be automated, interactive, or both? If the tool is to be interactive, how much will the user need to know about the input and output data sets? Likewise, if the tool is automated, how much control will the user be losing?

3.1.5.1 Selecting ArcInfo to Create an Ice Information MIO

Instead of creating a tool that is entirely independent of any external software, the decision was made to create a tool on top of an existing GIS. ArcInfo was selected as the tool's GIS engine for five reasons:

(a) CARIS was already being investigated. Dr. Benson Agi, a post-doctorate fellow at Ryerson University, was examining using CARIS software to create Ice Information MIOs from CIS ice charts [Agi and El-Rabbany, 2004]. Part of the goal of this project is to compare the results of the CARIS solution with this ESRI solution.

(b) The original data is ArcInfo's native format. The program that the CIS uses to produce the ice charts is built on top of ArcInfo. It produces charts in ArcInfo's native coverage format. Keeping the data in its original format helped ensure that there would be no corruption of the data when converting to another format. While working on the CARIS solution, Dr. Agi encountered various problems while trying to build topology after importing an ice chart into CARIS [Agi and El-Rabbany, 2003].

(c) ArcInfo includes a conversion tool. ArcInfo comes with a built-in tool, ARCS57, which converts an ArcInfo workspace to S-57 object files. While the tool is in theory simple to use, the author determined that this software would fail to convert a workspace if many (some undocumented) conditions were not met. These conditions and the implications of not meeting each condition are discussed in detail in Section 3.1.6.6.

(d) CIS already uses ArcInfo as their production software. ArcInfo is already owned and used by the CIS. It is, in fact, a major part of ISIS.

(e) The author's knowledge of ArcInfo. The author had worked and programmed with ArcInfo for several years before beginning work on this project.

3.1.5.2 Limiting Options Made Available to Ice Chart Creator

The majority of attribute values can not be edited by the user of the tool for only one reason: the current implementation is only a prototype. Many more of the attribute values could easily be made editable for the user. However, a simpler interface was all that was desired for the prototype. Adding options would only increase the time the user would spend before the tool runs. As more options would not alter the processing time, the possibility of inhibiting fully-automated processing was not a reason for limiting the options available to the user.

3.1.6 Pre-processing

The current implementation of the tool requires that the input file be in ESRI ArcInfo interchange format (*E00*). This was selected as the input format because this is how the data was received from the CIS. The Arc Macro Language (AML) scripts developed by the author for this tool are contained in Appendix V and Appendix VI. All processing is automated.

The chart contains arcs, points, and annotations. Polygon topology is not required because the daily charts are only used in-house and are strictly for printing, and as such it will never be needed. Because these charts are produced only for printing, both geographic and symbolic features are included in the same coverage [CIS, 2002].

3.1.6.1 Modify ARCS57 to Recognize Ice Objects

ARCS57, as distributed by ESRI, cannot create the proposed S-57 ice objects. As the objects do not officially exist, ARCS57 does not "know" the values to which they ought to be coded. ARCS57 uses lookup tables to convert from a named feature in the coverage (such as a LNDARE region for a land area) to a numeric code. These lookup tables were modified by the author to include the ice objects and attributes. The additional information to be included in the lookup tables was created using Microsoft Access 2000 and then exported to three files in dBASE IV file (DBF) format. The AML code developed by the author to import the information in these files and make the modifications is shown in Appendix V. This script need only be run once on each machine on which the tool is run.

3.1.6.2 Fix Node Attribute Table

The first step after importing the coverage is to create (or recreate if it exists) the input file's Node Attribute Table (NAT). The NAT has sometimes been found to be incomplete. Figure 3.2 shows an example of such a case. In this example, nodes are found only on the shorelines of Labrador and Greenland. Nodes should be at the start and end points of each arc in the coverage.

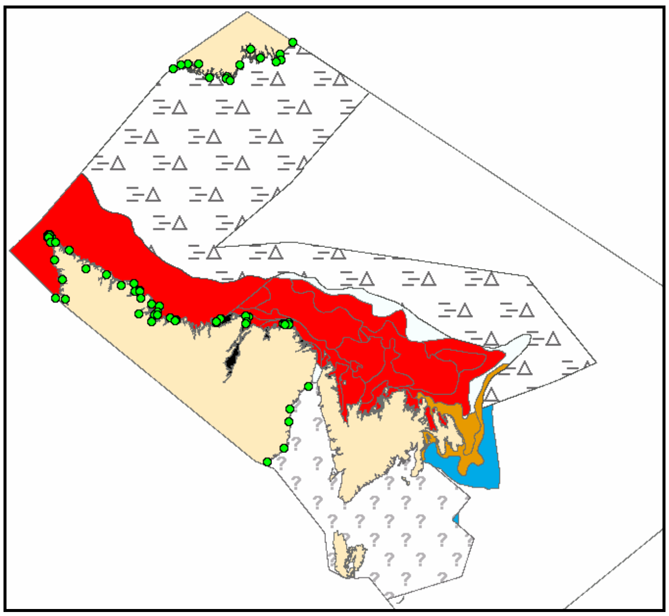


Figure 3.2. Ice chart of Newfoundland and Labrador with missing nodes (shown as green circles). Nodes are found only on some shorelines, not on any other arc.

3.1.6.3 Remove Special Cartographic Symbols

All special cartographic symbols must be removed. Such features include, but are not limited to, leader lines, arrows indicating flow direction, and symbols indicating strips and patches of ice [CIS, 2003]. All these features are non-geographic, i.e., they do not represent any real features. Using ArcEdit®, all arcs that have a non-zero value for the EGG_ID attribute are deleted (all geographic features have a value of zero). Each of the non-geographic features has an associated point. These points are distinguished from other points by their PNT_TYPE attribute values. They are also deleted. The annotations are also deleted, as they have no information that is required by the tool. Figure 3.3 shows a "before-and-after" example of the symbology removal.

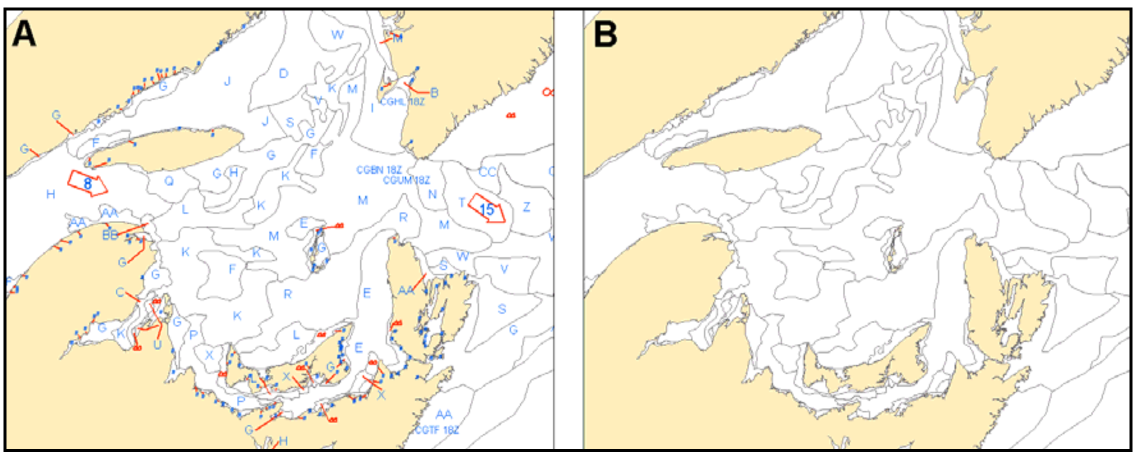


Figure 3.3. Ice chart with symbology removed. Land is shown in beige to assist viewing. (A) shows all arcs and annotations (text in blue) in the input coverage. Arcs to be deleted are in red. (B) shows the coverage after deletion.

What remains are all geographic arcs and one point inside each polygon (n.b. polygon topology has not yet been built), with a few exceptions where there are more than one point. Figure 3.4 shows an example of such a case. There are no polygons that do not contain a point. In all the datasets that were used for testing, never was it found that multiple points with different PNT_TYPE values were contained within the same polygon. Only like-valued points were found in the same polygon. For an unknown reason, each land polygon contains fourteen points, all positioned in exactly the same place with the same attribute values. These additional points are not removed; keeping them does not have an adverse effect on the results, and removing them only takes up processing. Adjacent arcs with identical LINE_TYPE values are dissolved into each other (LINE_TYPE is the only arc attribute that is used by the tool, so losing the values of all other attributes is of no consequence).

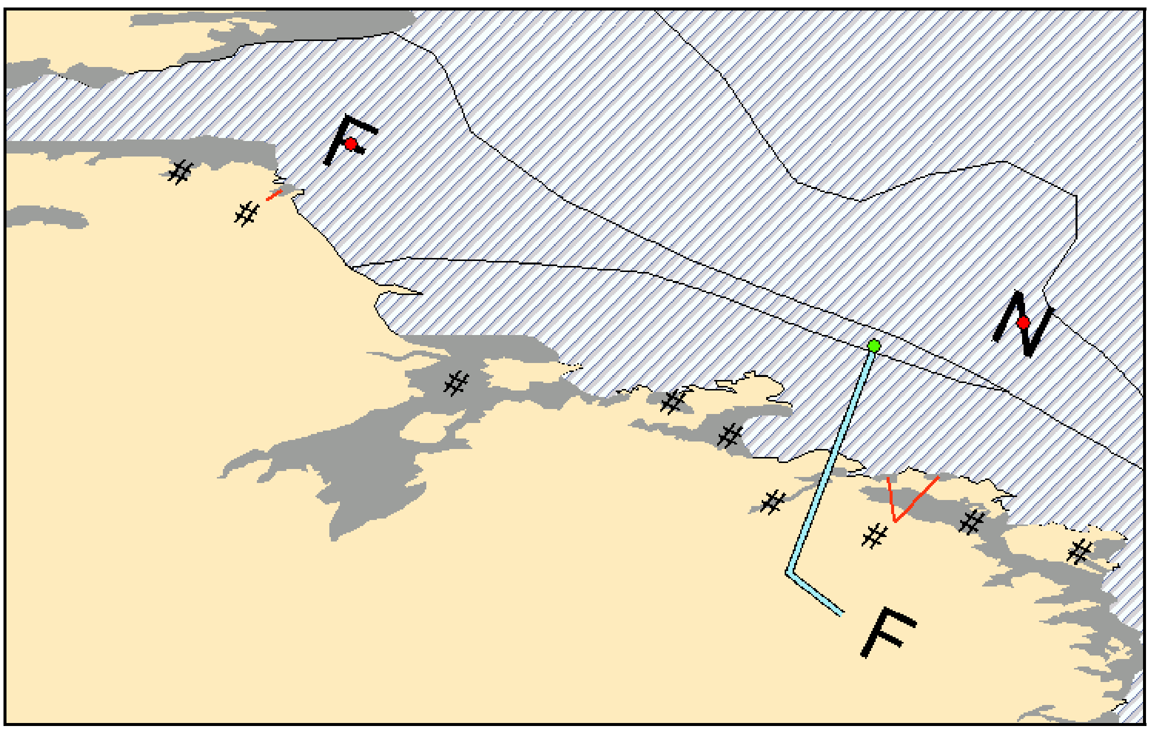


Figure 3.4. Example of two points, both labelled "F", in one polygon. The point whose label is inside the polygon has a PNT_TYPE value of 118, the other's value is 120.

3.1.6.4 WGS 84 Datum

All the charts at the CIS employ the Lambert Conformal Conic projection. They reference the North American Datum of 1927 (NAD 27) that is based on the Clarke 1866 spheroid [CIS, 2003]. All ENCs issued by CHS must be based on the WGS 84 datum, [IHO, 2000]. As such, any Ice Information MIO produced by CIS must be based on the same datum (WGS-84). Prior to converting to the WGS-84 datum, nodes are added to each arc at every 1000 metres. This helps to improve the accuracy of the projection transformation. Graphically speaking, altering the projection of a coverage is essentially just changing the coordinates of each vertex, node, and point in the coverage. An arc is really just a series of vertices. When changing the projection of a straight line made up of two end nodes and no intermediate vertices, the line will appear straight in the new projection (all that changes are the coordinates of the two nodes). If there are many vertices along the original straight line, each of the vertices will have new coordinates, and the line will most likely no longer be straight.

While the daily charts do all reference NAD 27, this information is not always included with each chart due to software limitations in ISIS [CIS, 2003]. The first step in projecting the data to WGS 84 is to add this datum information to the point and polygon coverages. The coverage's projection is then removed, the coordinate system changed from metres to decimal degrees, and the datum switched to North American Datum 1983 (NAD 83) using internal ESRI transformation routines. The coverage is then again changed to reference WGS 84 datum. Converting to first reference the NAD 83 datum and then the WGS 84 datum is the most effective way to convert from NAD 27 to WGS 84. This is more accurate than converting directly from NAD 27 to WGS 84 because it uses the most accurate way to convert between NAD 27 and NAD 83, the North American Datum Conversion (NADCON) standard [ESRI, 2002a]. (Note: ESRI does not provide details of the conversion in their supporting documentation; they merely state that this is the most accurate transformation method.) It is possible to convert directly from NAD 27 to WGS 84, but ArcInfo's internal projection routines do not use NADCON when converting between WGS and NAD datums. Figure 3.5 shows the chart before and after the projection alteration.

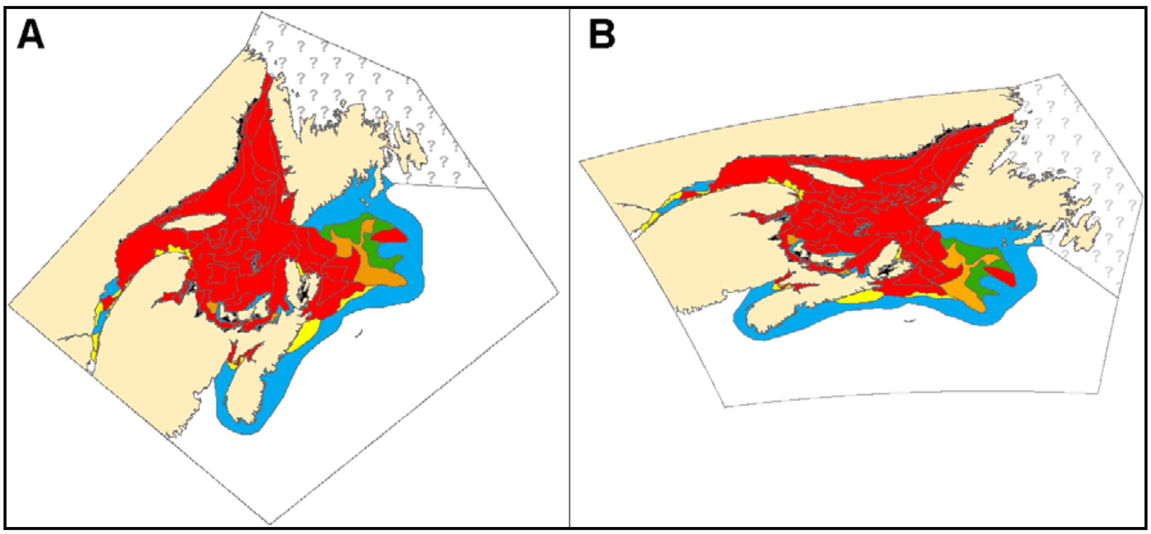


Figure 3.5. Ice chart's projection changed from Lambert Conformal Conic, NAD 27 (A) to decimal degrees, WGS 84 (Mercator projection used for display) (B).

3.1.6.5 Add Bounding Graticule

S-57 data are distributed in graticule-based cells defined by two meridians and two parallels [IHO, 2000]. When projected using a Mercator projection, the cells appear rectangular. A bounding rectangle must therefore be added to the coverage. This can only be done after the data have been properly projected (if done earlier, once the projection is altered, the bounding arcs would no longer be graticular). The graticule is added to the coverage in ArcEdit. It is spaced 0.01° from the maximum extents of the coverage. Before the graticule was added, it was necessary to "rebox" (ESRI terminology) the coverage. This is done to ensure that the coverage's boundary information file (BND) accurately describes the full extent of points and lines in the coverage [ESRI, 2002b]. The BND may not correctly describe the extent of the coverage because it is possible that tics (geographic control points for coverages) lie beyond the graticular extent of the points and lines. This happens when a coverage of a large area is divided. In most cases, the original tics of the large area remain. Some of the test coverages were found to have outlying tics. Figure 3.6 shows the addition of the bounding graticule.

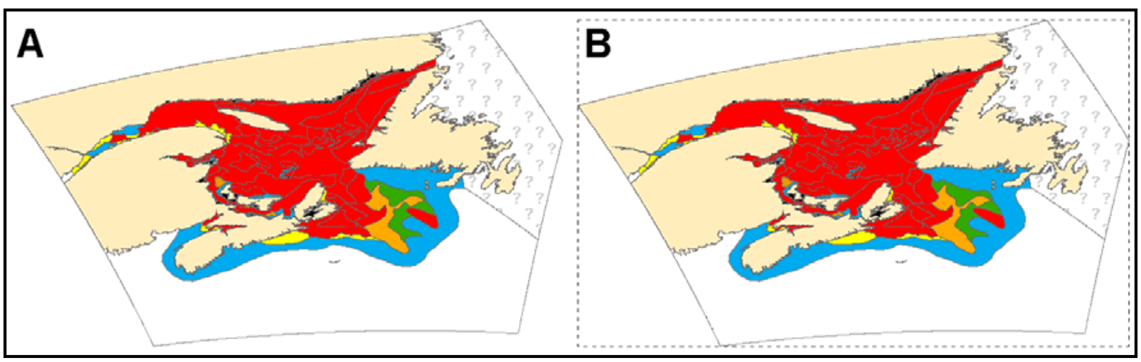


Figure 3.6. Ice chart with bounding graticule added. (A) shows the chart before the graticule is added, (B) shows the graticule as a dashed line.

3.1.6.6 Build Topology / Assign Feature Codes to Polygons

The final step before processing begins is to build polygon topology. The points in the coverage are first copied to another coverage; building polygon topology without first copying the points will destroy the points because points and polygons cannot exist in the same coverage.

Polygon topology is then built. The point attribute values are automatically transferred to the polygon that contains them. For those land polygons that contain more than one point, it is the attribute values of the point with the lowest valued internal identification number that are copied. For example, if there are two points contained in a polygon, Point A having an internal identification number of 100 and Point B having an internal number 200, the attributes of Point A will be copied to the polygon. As previously mentioned in Section 3.1.6.3, in none of the test data were there polygons that contained contradictory point values. Figure 3.4 shows an ice polygon on the east coast of Newfoundland and Labrador that contains two points with different PNT_TYPE values, 118 and 120. “118” indicates that the point’s Egg Code’s label (the letter on the chart) is inside the polygon and the Egg Code is in another part of the chart. “120” indicates that the point’s Egg Code’s label is outside the polygon – pointed to by a leader line – and the Egg Code is in another part of the chart. Since 118 and 120 both mean the same thing for this project (as do PNT_TYPE values 117 and 122), having these different values in the same polygon does not cause a problem. This is an example of the only type of case where different PNT_TYPE values are found in the same polygon (only PNT_TYPE values of 117, 118, 120, and 122 have been found in the same polygons). Figure 3.7 shows examples of how Egg Codes are places in, around, or away from their polygons. Polygons that contain Egg Codes have a PNT_TYPE value of 117, and those polygons that have their Egg Code next to them have a PNT_TYPE value of 122.

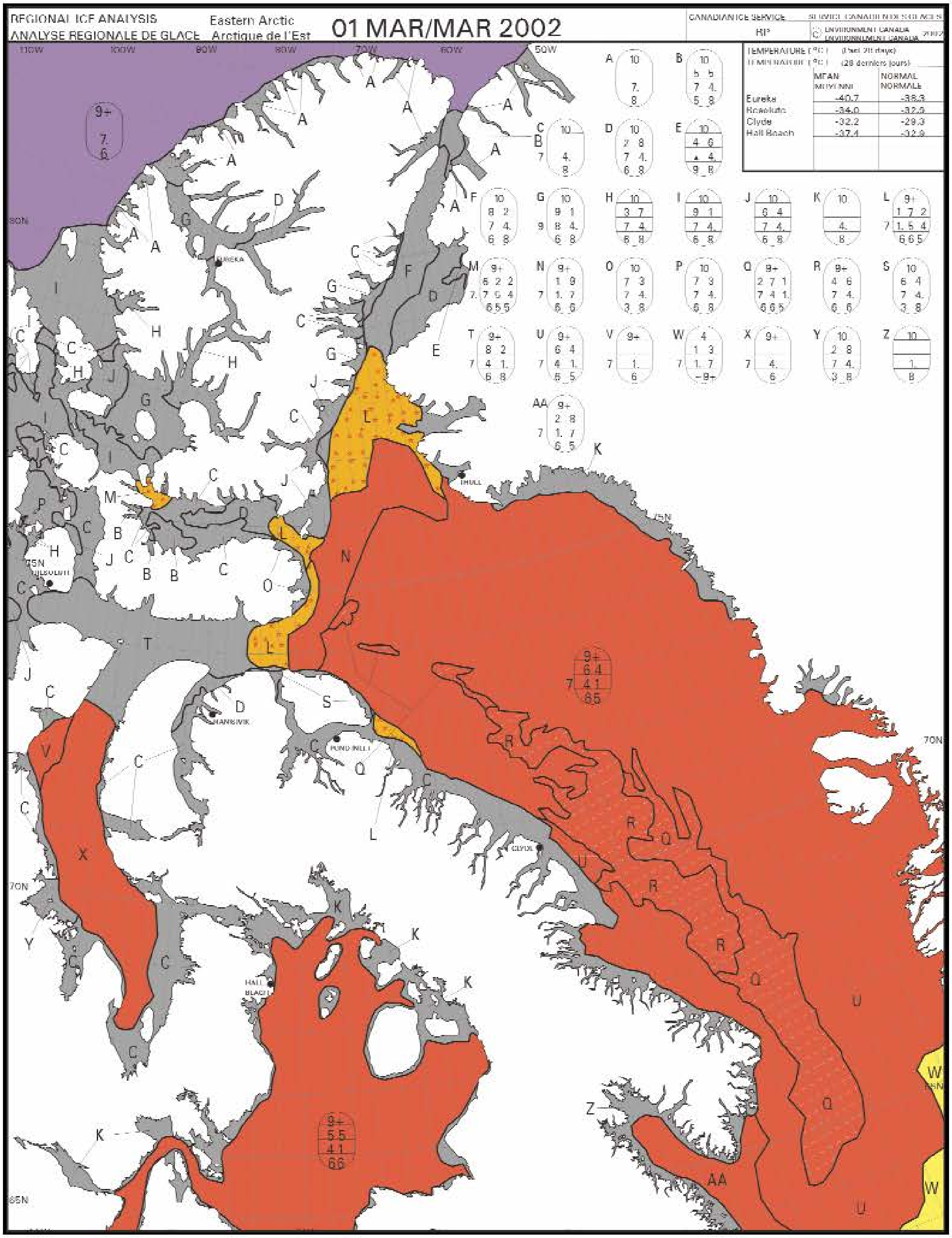


Figure 3.7. Egg Code placement on charts. Large polygons contain their Egg Codes. Some polygons only contain the letter of their Egg Code (which is in the upper-right of the chart). Small polygons only have lines pointing from their Egg Code letter to them.

There is one unique situation in the data that requires special attention. Arcs with a LINE_TYPE value of 151 are described as, "Iceberg Edge (Non-Topological)." When polygon topology is built, parts of the polygons that the arcs split have no attribute values. This is because polygon values are taken from the value of the first point in the polygon. In Figure 3.8, the non-topological line splits three polygons: on the left, the very narrow part of one of the orange polygons (the arrow in (A) points to the upper part of the polygon), the wide orange polygon that it splits twice, and the red polygon. The relationship between the Arc Attribute Table (AAT) and the Polygon Attribute Table (PAT) in the ESRI logical data structure is used to help solve this problem. Each arc's left and right polygon numbers are stored in the AAT, thus "connecting" each arc to its surrounding polygon(s). To assign attribute values to the polygons that are missing them, each polygon that borders one of the (LINE_TYPE = 151) arcs and is missing attribute values is selected. The arcs are then assigned the attribute values of their counterpart polygons. See Lines 460-520 in Appendix VI for further coding details.

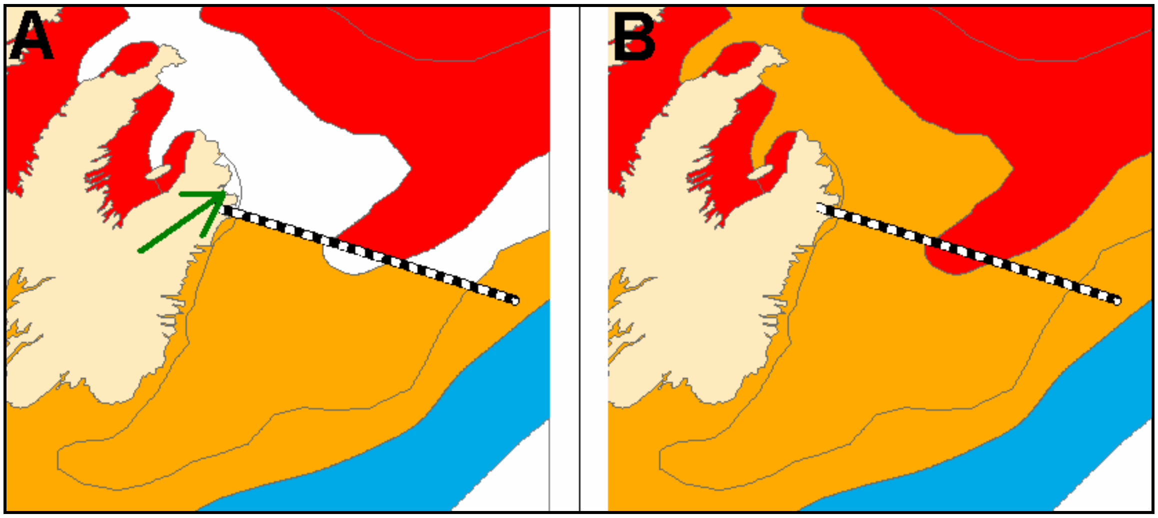


Figure 3.8. Non-topological LINE_TYPE 151. This is the thick line that alternates between black and white. (A) shows how polygon attributes are lost after building topology (in white). (B) shows the fixed polygons.

Following this, polygon label points are created (label points are required by ArcInfo to preserve attribute values for polygons) and topology is re-built [ESRI, 2002b].

3.1.7 Create Feature Objects, Meta Objects, and Vector Records

The coverage is now formatted so that vector records, feature objects, and meta objects can be exported correctly to S-57 format.

3.1.7.1 Feature Objects

The next step is to create feature objects. First, four feature lines are created. These objects are coastline (COALNE), ice line (ICELIN), ice fracture (ICEFRA), and ice lead (ICELEA). All but coastline are proposed ice objects. In the test data, neither ice fracture nor ice lead was created because their corresponding LINE_TYPE values did not exist in the input coverage. These routes are created with ARCROUTE and then edited in ArcEdit. They must be edited because ARCROUTE assigns all arcs in the coverage to a route. The unwanted routes must be deleted. For example, all routes in the coastline route that do not have a LINE_TYPE value of 140 are deleted.

Regions are then created to represent five feature areas: land area (LNDARE), depth area (DEPARE), sea area (SEAARE), iceberg area (BRGARE), and either sea ice (SEAICE) or lake ice (LACICE). Only the latter three are proposed ice objects; the first three are existing objects. These regions are created using the REGIONQUERY command in Arc. Unlike ARCROUTE, REGIONQUERY allows the polygons that are to make up the region to be selected. This means that ArcEdit does not need to be used to edit the regions.

Because tool development had reached a satisfactory level as a prototype [El-Rabbany, 2003], the creation of point features was not explored. Feature nodes are also not created, as there are no features represented by nodes in the CIS coverage.

3.1.7.2 Meta Objects

Meta objects are created next. Meta objects are feature area objects that are not real-world objects, but describe the data. S-57 requires two meta objects to be included in each exchange set. These are coverage (M_COVR) and quality of data (M_QUAL). M_QUAL must cover the entire cell. It contains two regions, one covering the area where there is data, the other covering area where there is not (this is the space between the bounding rectangle and the real data). M_QUAL is used to describe the quality of the data and can have many regions. For this prototype, the entire cell is given the same level of data quality, which is “unknown”.

3.1.7.3 Vector Records

Although it has been previously mentioned that an edge’s equivalent in ArcInfo is an arc, ARCS57 does not map an arc to an edge. Instead, each edge is mapped to one route [Cheung, 1997]. It is thus necessary to create a route (called VENAME) for each arc in the coverage (using the Arc command ARCROUTE). It is not documented by Cheung as to why routes are used and not arcs. In fact, Figure 8 in Cheung’s documentation seems to indicate that both arcs and routes are used to map to edges; the text however, only mentions arcs. Testing failed when a route was not created for each arc, and it is impossible to test if only routes can be used as routes are composed of arcs. No other ArcInfo features need to be created to map to any S-57 vector records.

3.1.7.4 Uniquely Identify Each Object and Record

S-57 specifications stipulate that each vector record requires a unique identifier. This identifier is its NAME attribute. NAME is composed of two letters followed by exactly 10 digits. The two letters are “VC” (for connected nodes), “VE” (for edges), or “VI” (for isolated nodes) [IHO, 2000]. After various required fields are added in Tables, a cursor moves through each record in the VENAME route, the AAT, and the NAT. For each record, the letters are concatenated with the internal identification number, with the appropriate number of zeros inserted between them. For example, a route with the internal number 269 would have a NAME value of “VE0000000269”.

3.1.7.5 Append Set A Attributes to Feature and Meta Objects

“Set A” attributes in S-57 are attributes that are unique to each object type (or at least they do not apply to all object types, as some attributes do apply to more than one object type). These attributes are added to the route and region tables in Tables. Like the vector records, each feature and vector object also requires a unique identifier. Each feature is assigned a name that begins with “FE” and is followed by ten digits [IHO, 2000]. A cursor moves through each feature and sequentially assigns a unique number to each. When the cursor moves through ice features, the Egg Code values are copied from the field EGG_ATTR to the proposed ice attribute fields.

3.1.7.6 Append Attribute Sets B and C

“Set B” and “C” attributes are attributes that apply to each object. They are stored in a separate INFO file. They are currently all empty values, except for the SORDAT field, which stores the production date of the source data [IHO, 2000]. The current date is assigned to this field.

3.1.8 Create Other Required Elements

There are two other elements of the exchange set that must still be created. These are the catalogue file, which is not part of the cell, and the Data Descriptive Record, which is.

3.1.8.1 Catalogue File

Each exchange set must contain one catalogue file. The catalogue file describes the contents of the exchange set, specifically the files contained in the set and the geographic bounds of the data. The catalogue file contains one record, the Catalogue Directory record, which is composed of one field (table in ArcInfo), the Catalogue Directory field (CATD).

The CATD is created and populated in Tables. All values are hard-coded except for the geographic bounds of the data and the Cyclic Redundancy Check (CRC) value. These boundary values are equal to the dimensions of the bounding rectangle plus 0.01°. It is necessary to add this because some errors can arise in the conversion process due to rounding. The values are only exported using two-decimal accuracy, so it often happens that without adding 0.01°, the stated bounds may be inside the bounding rectangle. This creates a minor error. S-57 viewing software will still display the data correctly, but errors are of course not desirable. The CRC value cannot be computed until after the S-57 file has been created. How the CRC is corrected is discussed in Section 3.1.9.

3.1.8.2 Data Descriptive Record

The data set file is composed of a Data Set General Information record, a Data Set Geographic Reference record, vector records, and feature records. The vector and feature records have already been created (Sections 3.1.7.3 and 3.1.7.1).

3.1.8.2.1 Data Set General Information Record

The Data Set General Information record is composed of two fields: Data Set Identification (DSID) and Data Set Structure Information (DSSI). Except for the issue date of the data and an optional comment, all the DSID values are hard-coded and it is unlikely that they would need to be modified by the user. The DSSI contains a count of each type of record in the data set. These values are all calculated – there is nothing the user can modify.

3.1.8.2.2 Data Set Geographical Reference Record

The Data Set Geographical Reference record contains only one field, Data Set Parameter (DSPM). The field is used to describe the datums and units of measurement used. The only subfield that the user controls is the Compilation Scale of Data (CSCL). This is set by the user in the GUI; however if the information exists in the input data look-up table, the user's input is over-ridden with that value.

3.1.8.3 Other Records and Fields

Edition 3.1 of the S-57 product specification defines other records and fields, specifically the Catalogue Cross Reference record (CATX), Data Set Projection (DSPR) field, Data Set Registration Control (DSRC) field, Data Set History (DSHT) field, and Data Set Accuracy (DSAC) field; however they are prohibited from use by Edition 3.1 of the S-57 product specifications.

3.1.9 Export to S-57

A report is automatically generated after running ARCS57, regardless of whether or not the operation succeeded. To make this report more useful, a list of each polygon that contains points with different PNT_TYPE values is appended. In all test data, no contradictory points have been found in the same polygon (PNT_TYPE values 118 and 120 have been found in the same polygon, but for this application they mean the same thing). The list is generated by intersecting the polygon coverage with the point coverage, then running statistics on the resulting point coverage.

The coverage is exported using the ARCS57 command. This creates a catalogue file and an S-57 cell file. The catalogue file does not have the correct CRC value for the cell. The catalogue is re-exported using the ENCREVISION command. This can be used to export a catalogue file with correct CRC values.

When complete, the log file created by ARCS57 is displayed (with the appended list). Total processing time ranges between one and five minutes. The main influencing factors on processing time are the complexity of the input coverage and the power of the computer's processor. The file size of the output MIO ranges from approximately 450 kilobytes to 800 kilobytes. Post-Processing

After the tool was created as an AML script, the author developed a graphical user interface (GUI), shown in Figure 3.9, to make the tool as simple to use as possible. Minimal input is required from the user, and once the required information is entered, the conversion process is entirely automated. As all the processing is done using an AML script, the tool requires ArcInfo to be installed. The GUI was written in the Microsoft Visual Basic 6 programming language. The code for the GUI is found in Appendix VII.

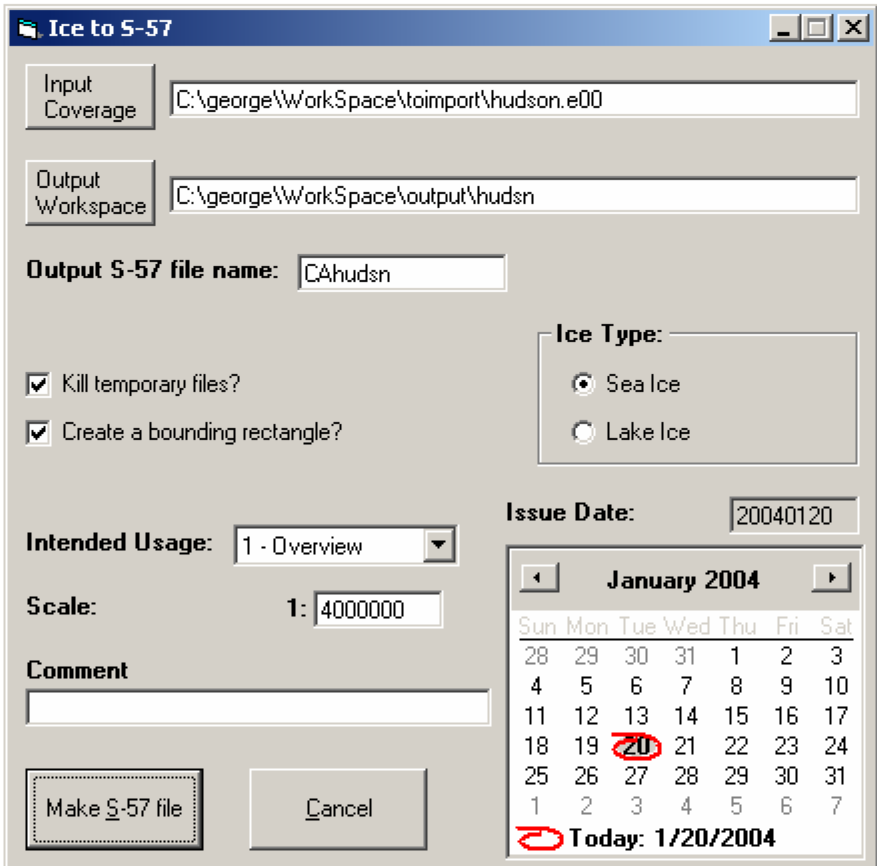


Figure 3.9. The tool's graphical user interface (GUI).

3.2 Defining S-52 Symbols and Colours

Apart from developing a method to efficiently incorporate CIS daily ice charts into S-57 formatted MIO for Ice Information, it was required that colours and symbols for the proposed ice objects be defined.

Colours were first based on the WMO colour standards for ice charts [Smolyanitsky, 2004]. These colours were adopted by the WMO in April 2004. For ice objects not covered by these specifications, the colours and symbols that are used by the CIS were incorporated into the proposed symbols and colours. Colours and symbols currently in use by the CIS are found in *MANICE* [CIS, 2002]. No colours or symbols were defined for ice objects that do not have a display style defined by the WMO or the CIS.

The proposed symbols and colours are defined in Appendix VIII. Each object is presented on its own page. The objects are ordered in the same way that they are presented in “ECDIS Ice Objects Version 3.0” [CIS, 2001]. Following the object name are the proposed S-57 code, the type of geometry or geometries of the objects (point, line, and/or area), the object’s attribute that will be used to determine how the object is displayed (if applicable), and the description of the attribute that is to be used. If the display is not dependant upon the value of an attribute, such as icebergs (proposed S-57 code ICEBRG), then the proposed symbol and colour for that object is shown. If the display is dependant upon an attribute value, what follows is a table of all possible attribute values, the description of each attribute value, and the proposed colour and symbol for each attribute value. In some instances, a note about the proposed symbology may follow.

CHAPTER 4
ANALYSIS AND DISCUSSION OF RESULTS

This chapter examines the quality and efficiency of the developed solution presented in Chapter 3. It then examines the CARIS-based solution that is also being developed by Dr. Agi. An alternative to these two post-production solutions is then discussed. All three solutions are compared in regard to speed, cost, and accuracy.

The desired situation is to produce an Ice Information MIO as efficiently as possible. For the purpose of this research, the efficiency of a solution is measured subjectively by combining the following:

1. The difference in time the solution takes relative to the original situation.

2. The cost of development.

3. The cost of implementation.

4. The cost of training.

Given these four requirements, an ideal solution requires neither additional time nor cost, and it is as accurate as the data that it is based on. In practice, the solution that requires the least time and cost while maintaining accuracy is the best. Therefore, for the purpose of creating a daily Ice Information MIO at the CIS, the ideal solution must involve a very small amount of additional processing time, low costs for implementation and training, and no loss of accuracy.

4.1 Analysis of the Developed Solution

The CIS requirements allow no more than one additional hour to convert their existing product to an Ice Information MIO [Fequet, 2003]. The less the additional time required to convert the ISIS output to an Ice Information MIO, the more time there is to ensure the quality and accuracy of the product, both before and after the conversion process. The researched solution transforms an ISIS output chart to an Ice Information MIO in as little as two minutes and as possibly as much as ten minutes. It is conceivable that, if the processing were handled by a stand-alone application instead of relying on ArcInfo, then the conversion time could possibly be reduced so it could run in less than one minute. This estimation is based on the author's knowledge of the researched solution, specifically what parts of the conversion take the most time.

4.1.1 Pre-Processing

The first 300 lines of the tool's AML code, which is shown in its entirely in Appendix VI, call routines, check for input errors, import the daily ice chart from E00 format, and ensure a clean workspace. The routine calls are virtually instantaneous. The input error checking is also very quick (less than one second on any computer). It parses the various arguments that are in the input command and ensures the required elements are present and that all arguments are valid.

Importing the E00 file requires between ten and fifteen seconds. It will not be necessary should the tool be directly integrated into ISIS. However, until that time it is best to assume the starting point is an E00 file.

4.1.1.1 Fix Node Attribute Table

In the test coverages provided by the CIS, the NAT was found to be either incomplete or entirely missing. A NAT is not a necessary element of a coverage if node-related information is not required. Since ARCS57 does require a complete NAT, creating or repairing the existing NAT is necessary. Line 320 in Appendix VI creates or rebuilds the NAT. The method employed by the author is the only way in ArcInfo to do this.

4.1.1.2 Remove Special Cartographic Symbols

Lines 311 to 343 in Appendix VI remove the special cartographic symbols from the coverage. This operation is the first of several that must be partially performed in ArcEdit. Using ArcEdit is a drawback because each launch of the sub-application takes several seconds (an average of six seconds on the system that the tool was developed on). Alone, these six seconds do not substantially contribute to the overall running time of the tool (as the overall processing time is approximately five minutes). However, the summed times of launches of sub-applications that the tool requires (ArcEdit, Tables, and INFO) does contribute substantially to it. These launches are discussed more in the following sections. The removal of the cartographic symbols is done as efficiently as possible in ArcEdit. A query selects the points and lines that have feature codes indicating they are cartographic symbols and these points and lines are then deleted automatically.

4.1.1.3 Project to WGS 84

The coverage's projection information is changed to reference the WGS 84 datum and use decimal degrees for its coordinate system. This is performed by Lines 345 to 403 in Appendix VI. As explained in Section 3.1.6.4, projection information is not always present in CIS daily charts due to software limitations in ISIS. Converting from NAD 27 to WGS 84 is done in the manner recommended by ESRI that will provide the most accurate transformation [ESRI, 2002a], but this is not the fastest conversion method available. The author chose accuracy over speed because the additional time required by the more accurate method was found to not exceed fifteen seconds during testing. As the projection transformation is only required to be performed once, the author deemed this extra time required to be acceptable.

Accuracy was again chosen over speed when the additional step of ensuring that each arc in the coverage has nodes no more than 1000 metres apart. The arcs were "densified" (ESRI's terminology) to improve the accuracy in the change of projection information. See Section 3.1.6.4 for details.

4.1.1.4 Add Bounding Graticule

The addition of the required bounding graticule, performed by Lines 405 to 425 of Appendix VI, is the second instance that the tool must launch a sub-application, this time again being ArcEdit. The only way to add new geographic features to a coverage is to do so using ArcEdit. The method used by the author, as described in Section 3.1.6.5, is the most efficient possible. The automation of the graticule creation also ensures that so long as each region's daily ice chart's boundaries remain the same, the extent of each daily Ice Information MIO will be exactly the same as the previous day's extent.

4.1.1.5 Build Topology / Assign Feature Codes to Polygons

As explained in Section 3.1.6.6, Lines 427 to 476 in Appendix VI transfer the feature codes from the points to the newly created polygons. While not necessary for the tool to be successful, some processing is done here in order to present a "cleaner" final product. Fields with information that will not be transferred to the Ice Information MIO are dropped from the point and polygon tables. This processing takes approximately one second to complete, thus with no significant effect on the overall processing time.

The bulk of the processing time for this section is expended when there are arcs with LINE_TYPE value of 115. This occurs because the assigning of PNT_TYPE values to polygons with missing values must be done in Tables. The time required to launch and exit Tables is approximately five seconds. The only other way to assign PNT_TYPE values to specific polygons would be to use INFO, and the loading time for that exceeds the loading time for Tables.

4.1.2 Create Vector Records, Feature Objects, and Meta Objects

The major part of the conversion process from ArcInfo coverage to S-57 objects is performed in this section, Lines 478 to 1680 of Appendix VI. This section not only takes up 60% of the AML code lines, but also testing showed that approximately 80% to 85% of the developed tool's total processing time was taken up by the creation of the records and objects.

4.1.2.1 Feature and Meta Objects

As explained in Sections 3.1.7.1 and 3.1.7.2, feature objects and meta objects were created in the same way. Their creation is performed by Lines 478 to 602 of Appendix VI. As Table 3.4 shows, S-57 area and line objects map to ArcInfo regions and routes, respectively. The Arc command REGIONQUERY was used to create regions. Creating regions is much faster than creating routes because there is no similar command in Arc for routes. Route creation, as explained in Section 3.1.7.1, requires editing in ArcEdit. Alternative methods to speed up route creation were investigated, but they all required more time to process.

4.1.2.2 Vector Records

S-57 specifications define four types of vector records: isolated nodes, connected nodes, edges, and faces. As stated in Section 3.1.7.3, ARCS57 maps ArcInfo geometry types to their corresponding S-57 vector record type. The only editing of the coverage required is the creation of routes for each arc in the coverage, as arcs alone are not mapped directly to edges. The creation of routes for vector records is done by Line 610 of Appendix VI.

4.1.2.3 Uniquely Identify Each Record and Object

Unique identification keys (the NAME field in each table) were not assigned to feature and meta objects immediately after they were created because it was more efficient to also create vector records at the same time. The original coding of the tool created and then populated the vector records with NAME values. The original coding then did the same for the feature and meta objects. While the flow initially seemed more logical, it was not efficient. Populating the records and objects with NAME values required loading Tables and then returning to Arc. Creating all the records and objects together and then populating them together eliminated the need for multiple, time-consuming launches and exits of Tables.

Assigning a NAME value to each record and object was done by using cursors, as mentioned in Sections 3.1.7.4 and 3.1.7.5. Time-wise, this is the most inefficient section of the tool’s code. The author believes that visiting each record is not what slows the tool; rather it is the time spent at each record. NAME must be twelve characters in length: two letters followed by ten digits. The two letters (the RCNM subfield) identify the type of record or object (edge, connected node, isolated node, etc.) and the number (the RCID subfield) is unique [IHO, 2000]. Because NAME must be characters, creating NAME values was found to be difficult. The code shown in Figure 4.1 was written to assign an RCID value to each record.

```
&SETVAR idval = 1
CURSOR uid DECLARE %outcov%.ratvename INFO RW
CURSOR uid OPEN
&DO &WHILE %:uid.aml$next% = .TRUE.
  &SETVAR :uid.rcid = %idval%
  &DO &WHILE [LENGTH %:uid.rcid%] < 10
    &SETVAR :uid.rcid = 0%:uid.rcid%
  &END
  &SETVAR idval = %idval% + 1
  CURSOR uid NEXT
&END
CURSOR uid CLOSE
CURSOR uid REMOVE
```

Figure 4.1. AML code for cursor to move through all records and assign a unique identification number (RCID).

In this example, IDVAL is variable set with the initial value of 1. A cursor named UID is declared and opened to parse through the table containing routes for the vector edge records. The cursor’s current record’s RCID value is set to IDVAL; in this case, for the first record, RCID is set to 1. Because RCID must be ten characters in length, the length of RCID is checked, and if it is less than ten, one leading zero is inserted. This insertion of leading zeros is repeated until the length of RCID is ten characters. The value of IDVAL is then incremented by 1, and the cursor moves on to the next record.

The problem with this code is that each record in each table is looked at up to ten times. While it is known that the creation and population of the vector and object tables is what takes up the major portion of processing time, it is believed that this time would be significantly reduced if each record were visited only once.

RCID must be unique. The author chose to assign RCID values starting from the value 1. Starting sequential numbering from 1 is both intuitive and common practice. Also, as far as the author can recall, all the sample S-57 cells that were examined had low RCID values, thus indicating that they likely start at 1 as well. Following the completion of the prototype tool, a possible solution to avoid looping through each record up to ten times was developed by the author.

S-57 specifications state that RCID can have a value between 1 and 4 294 967 294 (2^{32} - 2), and the only constraint is that when concatenated with RCNM to form NAME, NAME must be unique within the S-57 cell [IHO 2000]. This means that RCID can be duplicated, as long as those records with matching RCID values do not also have matching RCNM values. As just mentioned, the author began sequencing RCID from 1, as 1 is an intuitive starting value. This requires the insertion of up to nine leading zeros for each record. However, if the sequencing were to start at 1 000 000 000, no leading zeros would need to be concatenated. Furthermore, since each record would no longer need to be looped through several times, and since the NAME values do not need to be ordered in any way (just unique), 1 000 000 000 could be added to the ArcInfo coverage ID value, and the sum could be assigned to RCID. This operation can be carried out at the table level with one calculation, as opposed to the developed method which works at the record level and, for a simple coverage containing 1000 total elements (points, nodes, lines, routes, and regions), would require 8107 calculations (9 records having 10 iterations, 90 records having 9 iterations, 900 records having 8 iterations, and 1 record having 7 iterations).

Simply adding 1 000 000 000 would not work perfectly. This occurs because the ArcInfo coverage ID value would be duplicated in several different regions. For example, both the COALNE and ICELIN routes will have items with equal coverage ID values, and both will be assigned RCNM values of “FE”, thus creating duplicate NAME values. The simple solution to this problem is not to simply add 1 000 000 000 to all coverage ID values, but rather add 1 000 000 000 to all COALNE elements, 1 100 000 000 to all ICELIN elements, 1 200 000 000 to all ICEFRA elements, and so on. This amendment would eliminate any possible duplicate NAME values in the S-57 cell.

The only shortcoming of the author’s proposed alternate approach is that RCNM values will not be sequenced starting from 1. Again, this sequencing is not required by S-57 specifications; however it may be desirable to some.

A possible major benefit of this alternate approach is that because the RCID values are tied to a real value in the coverage (coverage ID), it may be possible to relate a daily ice chart back to a previous day’s ice chart based on NAME. As testing by the author found, this was not possible with the developed approach.

4.1.2.4 Append Set A Attributes to Feature and Meta Objects

Set “A” attributes are appended to feature and meta objects in the same cursors that assign RCID values to each record. As mentioned in Section 3.1.7.5, the Egg Code values in the coverage are mapped to their corresponding Set “A” attribute fields. While assigning NAME values may be possible without relying on cursors (see Section 4.1.2.3), the author does not believe that cursors can be abandoned entirely. Although further investigation is required, it is likely that visiting each record, extracting substrings from the Egg Code, and matching each substring with a proposed Ice Attribute value is the only way to copy the values in the ice chart coverage to Ice Objects. This must be done because Egg Code values need to be translated. For example, to get values for the Ice Attribute ICEACT, the value in the Egg Code “@” must be translated to “17”.

Cursors are used to transfer the Egg Code values because they are already in use to assign NAME values. It only made sense to “kill two birds with one stone.” With cursors possibly no longer necessary for assigning NAME values, batch copying of all Egg Code substrings to their corresponding Ice Attribute may be possible, followed by batch translations. This could be done in Tables.

4.1.2.5 Append Attribute Sets B and C

Lines 1596 to 1679 of Appendix VI append the Set “B” and Set “C” attributes. This is performed in both INFO and Tables. The current coding is for possible future use, as right now the CIS produces no data in the daily ice charts that is either a “B” or “C” attribute. The only fields that are used by this tool are INFORM, which stores up to 70 characters of general information, and SORDAT, which stores the date of the source data. The tool copies the entire Egg Code to INFORM and places the current date in SORDAT, although that is not entirely correct as the date of the data is not always the same as the date on which the ice chart is produced.

Should it be determined that no unique information needs to be placed in the “B” or “C” attributes, this section of the code can be skipped. Omitting this part will reduce the tool’s running time by approximately 30 seconds.

4.1.3 Create Other Required Elements

Creating the Catalogue File and Data Descriptive Record is a fast operation that is performed exclusively in Tables. The code is shown in Lines 1741 to 1906 of Appendix VI. The creation of these files is as efficient as possible because Tables provides the fastest means to create and populate tables in ArcInfo.

4.1.4 Export to S-57

As described in Section 3.1.9, Lines 1908 to 1993 of Appendix VI, convert the processed coverage to an S-57 cell. The inclusion of listing multiple points in polygons in the report that is generated does increase the overall processing time of the tool. However, the author considers this to be very useful information for the report, and the additional seconds are a fair cost. Should further testing show that multiple different-valued points never occur in the same polygon, this section can safely be removed.

4.1.5 Costs

Some costs related to the development and implementation of the developed solution, along with costs for training ice analysts how to use the developed solution, have been identified.

4.1.5.1 Development

The cost of development for the researched solution should be minimal. The time required to transform the prototype solution into a final product is very small when compared to the time required to develop the prototype. Only minor additions are required in order for the tool to be considered a final product. For example, the tool does not create any proposed S-57 point features. Also, not all of the ISIS PNT_TYPE and LINE_TYPE values were present in the test data; more sample data with these additional untested values ought to be tested.

Because the CIS already has the required hardware and software required to finalize the tool, the only costs involved in development would be for labour. Based on his previous development work on the tool, the author believes that four to six weeks would be required to finalize the tool. Six weeks of labour would cost the CIS approximately \$10 800 (assuming a 40-hour work week at a rate of \$45 per hour).

4.1.5.2 Implementation

The cost of implementation would be very small, if anything, because the researched solution does not alter ISIS and uses the current ISIS output. Implementation merely involves installing the developed application on one machine and updating the machine's ArcInfo installation's S-57 library files to recognize the proposed ice objects. The tool can then be run daily at the end of the chart creation process.

4.1.5.3 Training

Retraining would be required for all staff that would be involved in final daily chart production. Because of the simplicity of the developed GUI, the author believes that learning how to properly use the tool should not require more than ten minutes. The cost of such training is thus negligible.

4.1.6 Summary

The first time-consuming process is the front-end launching of ArcInfo. The removal of symbols from the ISIS coverage takes extra time because this process must be run in ArcEdit, and ArcEdit takes time to load. ArcEdit must be launched again to create the bounding graticule after the projection has been changed, and a third time to create routes (line features). Tables® is run five times during the conversion, and INFO® is run once. Each of these sub-application launches is time consuming.

Time-wise, the most inefficient part of the conversion process is its reliance on cursors. Cursors are used to loop through record sets. There are thirteen cursors used in the conversion code, most of which are used to assign unique identification codes to each vector record, feature object, and meta object.

The accuracy of any developed solution can only be as accurate as the most accurate projection transformation method between the NAD 27 and WGS 84 datums. The researched solution employs “the most accurate methods to PROJECT between the two datum types” [ESRI, 2002a] within ArcInfo; and the author’s insertion of nodes every 1000 metres into the coverage prior to the projection transformation helps ensure a high level of accuracy without sacrificing too much processing time.

4.2 Developed Solution vs. Previous Solutions

This section compares the developed solution to the previously proposed solutions that were discussed in Section 2.4.3. All previous solutions involve incorporating CARIS software products to produce ice chart MIOs.

The first attempt at integration was made by Lapointe. Because his conversion requires manual editing of S-57 objects, the time it takes to create an Ice Information MIO is greater than the maximum allowable time (one hour) [Lapointe, 2001]. While this solution does work, it unfortunately lacks the required efficiency and therefore must be deemed unacceptable in regards to the time requirements of this project. It would not be fair to compare the researched solution to Lapointe's solution because his work is really the first part of the CARIS-based solution, currently being researched by Dr. Agi.

The work of Diarbakerly and Huynh build upon Lapointe's output, as does the work done by Dr. Agi, which is the current cumulative CARIS-based solution. This solution is much more efficient in terms of processing time than Lapointe's earlier design. The processing, while semi-automated and requiring some attention of an operator, is easily completed in less than the maximum allowable one hour. While the actual processing time is much less than that of the researched solution [Agi and El-Rabbany, 2004], the main drawback to Dr. Agi's solution is that only the SEAICE Ice Object is created from the ISIS output; none of the other seventeen Ice Objects are created.

As stated in Section 4.1.5.2, the cost to implement the developed solution should be minimal. The cost of implementation for the CARIS-based solution within the CIS would be greater than the researched solution because a license to use the CARIS software would be required. A simple solution to this problem would be to have the ice charts turned into MIOs by CHS, not CIS. The cost to train staff at the CIS would not be too significant as Dr. Agi's tool is mostly automated [Agi and El-Rabbany, 2003].

Regarding the comparison of the developed solution and the CARIS-based solution, the conclusion reached by this author is that the developed solution is currently the better choice to be implemented for Ice Information MIO creation by the CIS. This is mainly because Dr. Agi's solution only creates the SEAICE Ice Object whereas the author's solution creates all eighteen Ice Objects.

4.3 Alternate Solutions

Two viable methods for producing an Ice Information MIO from a CIS daily ice chart have been developed. The author's developed solution is based on ESRI software, while the solution being completed by Dr. Agi is CARIS-based. Given the effectiveness of both solutions (they both create an S-57 dataset in well less than one hour) and the time spent developing them, researching another solution that incorporates new software offers little or no benefit.

In this section, all time requirement estimates are based on the author's knowledge of AML programming and customizing ArcInfo, as well as his understanding of ISIS. For wage cost estimates, an hourly rate of $45 is used for a workstation operator plus all overhead charges.

4.3.1 In-House Solution

The only viable alternate solution is to modify ISIS so that the output product is an Ice Information MIO, not a paper chart. While both the author's and Dr. Agi's tools are post-production solutions, a solution that is integrated directly into ISIS could offer several benefits.

4.3.1.1 Benefits

An in-house solution would enable operators to work directly with S-57 Objects, specifically the proposed Ice Objects. This would allow for a CIS MIO to be more complete, instead of simply a translation of a paper chart. For example, if the ice analyst wants to place an ice fracture on a chart, and wants it known that it is a very small fracture, there is no way to do this on a traditional paper chart. Thus in the current implementation of ISIS, this information would not be added. If ISIS was altered so that it was geared towards outputting an S-57 dataset (e.g., MIO) instead of a paper chart, the analyst could simply mark the fracture (just as with the current ISIS) and then add a value of 4 to the ICEFTY attribute (ice fracture type), which is the value for “very small fracture”.

Another advantage of integrating MIO creation into ISIS is that there would be no chance of a mistranslation. While operator error is always possible, an external application would not be required to convert file format. With every change in format, the chance for error increases.

An integrated solution might be a more accurate solution. Depending on how it is engineered, ISIS could be changed to be based on the WGS 84 datum. This would mean that no data would be altered due to a projection transformation.

4.3.1.2 Costs

In order to attempt to limit the natural bias of the author favouring his own developed solution over other possible solutions, in this section the author assumes best-case scenarios for all cost-incurring activities.

Two parts of ISIS would need to be modified in order to produce an Ice Information MIO. First, the user interface would need updating. Options would need to be added to it so that all the available S-57 ice objects and attributes were available. This is not difficult to do in a customized ArcInfo application. The second modification is to add the functionality that will convert the ice chart to an Ice Information MIO. The simplest method is to incorporate ARCS57 (ArcInfo's built-in S-57 converter). The alternative is to develop a new converter, however this would be unnecessary and thus over-costly.

The author estimates that modifying ISIS in this manner would require one programmer one month to develop functional alterations and two additional months to test for and correct any bugs in the new software. At the stated rate, finalizing development would cost the CIS approximately $23 400 (based on thirteen 40-hour work weeks).

Once developed, the cost of implementation would be close to nil. No additional software or hardware would be required, and the developed system would be tailor-made for the current setup of the CIS. The only cost would be in terms of the time required to update each workstation with the new software. The author estimates that the time required to accomplish this task is one work day (eight hours), which works out to $360 for one computer technician.

Training would involve no more than the cost of teaching analysts about the new ice codes available to them. The ice chart production methods should remain otherwise identical to the current system. The author estimates that no more than four hours of instruction and review of the new codes would be required for all ice analysts to become fully able to use the newly modified system. For twelve staff members (six or seven image analysts [Fequet, 2003] plus some supervisors and ice forecasters) and one instructor, the total cost for training would be approximately $585.

4.4 Summary Comparison

In a side-by-side comparison, the author's developed solution is recommended over the solution developed by Dr. Agi primarily because the author's tool creates all eighteen of the proposed Ice Objects while Dr. Agi's solution only creates the SEAICE Ice Object. The two solutions are otherwise very similar in terms of processing time cost of development and implementation.

Comparing the developed solution to the alternate solution of altering ISIS to output an Ice Information MIO, the author believes that the developed solution should be implemented as a short-term solution. The estimated cost of approximately $11 000 for the author's developed solution is far less than the estimated cost of approximately $24 500 for the alternative. However, because any external program is can only be a translator of what ISIS outputs, in order to take full advantage of the proposed Ice Objects and their attributes, at the very least, the ISIS vocabulary needs to be expanded to included all available object and attribute values.

It is the recommendation of this author that the researched solution be fully developed in order to begin producing Ice Information MIOs as soon as possible. In the meantime, though potentially costly, research and development into altering the primary output of ISIS from paper chart to Ice Information MIO should be pursued.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

Worldwide ice-charting agencies provide regular (often daily) ice charts to mariners. While many mariners use ECDIS to assist in their navigation, ice information is not sufficiently represented in ECDIS in order to provide safe navigation through ice-infested waters (in Edition 3.1 of the IHO standards for transmitting and displaying digital hydrographic data).

The CIS's daily ice chart production workflow is mainly geared towards (but not limited to) producing paper charts. In order to best serve mariners, the CIS should be prepared to create daily Ice Information MIOs daily. Efforts to create an Ice Information MIO from CIS daily ice charts using the proposed ice objects were undertaken beginning in 2001 by Lapointe, and were continued by Diarbakerly, Huynh, and Dr. Agi through 2003. These efforts were either partially or entirely based on CARIS software.

The primary objective of this research was to alter the daily ice chart production workflow at the CIS so that one of their output products is an electronic navigational chart in an efficient manner. The author met this objective by:

1. Reviewing relevant literature and past reports on production carried out for the CIS;

2. Visiting Canadian Ice Service offices in Ottawa to obtain a clearer picture of the strengths and weaknesses of existing software tools, data sources, and ice chart production methods employed by CIS staff;

3. Reviewing and comparing the production software and procedures developed and used by previous researchers involved in this project;

4. Developing a prototype tool that converts a CIS daily ice chart in E00 format to an Electronic Nautical Chart; and

5. Mapping the workflow process currently employed by CIS production staff and comparing it with a new method which employs the software prototype tool developed through this research.

At the time of the research, the CIS employed ArcInfo as a principal tool in its ice chart production. In order to develop the prototype tool described in (4) above, the author first had to "map" the ArcInfo data model to the S-57 data models, as well as relate existing CIS Chart Data to the "ECDIS ice objects" being proposed by the international standards community. Once these relationships were understood, the prototype was developed and tested to ensure it could complete the work in as "batch-oriented" a manner as possible to minimize unnecessary operator interaction.

As shown in Section 4.4, the author's developed solution is, when compared to both other previously researched solutions and to the author's own proposed alternate solutions, the most efficient solution. Desired results are achieved in approximately five minutes on a Pentium III PC, with minimal cost of implementation and no loss in accuracy. The author therefore recommended that the researched solution be fully developed in order to begin producing Ice Information MIOs as soon as possible.

The secondary objective of the project is to develop a colour and symbol scheme for displaying ice information in an ECDIS. This objective was also met by the author. Colours and symbols were selected first based on the WMO standards for displaying ice information, and then based on the CIS standards. If no international or Canadian display standard was in existence for a given ice feature, the author did not propose a new colour or symbol.

5.2 Contribution of the Research

Should CIS staff members implement the tool developed by the author, they will be able to efficiently produce daily Ice Information MIOs – something that they were not able to do at the time of this research.

This research will greatly assist mariners to safely navigate Canada's ice-infested waters. Besides the obvious benefit of safer navigation (a decrease in injuries and property damage), this increased safety will also provide economic benefits (through more cost-effective transport) and environmental benefits (through lower fuel requirements and lower risks of fuel spills).

At the time of this research, a CARIS-based solution was being investigated by Dr. Agi at Ryerson University. However, creating an Ice Information MIO from a CIS daily ice chart using only ArcInfo (which is a native application of ISIS) has not been done before.

This research may be beneficial to those who are interested in converting ArcInfo coverages to ENCs or MIOs and wish to use ArcInfo's built-in ARCS57 command. Based both on the author's experience in using the ARCS57 command and on the way in which ARCS57 was designed (Cheung, 1997), it is apparent that ARCS57 was created primarily to convert from a coverage that originated as an ENC back to an ENC. It is this author's hope that those who are interested in modifying coverages so that they can be converted to S-57 format by using ARCS57 will learn from the author's research presented here.

Regarding the author's proposed S-52 symbology for the proposed ice objects, the author believes that – at the time when this research was carried out – there were no other published proposed symbols and colours for the proposed ice objects and their attributes. For this reason, the symbology presented by the author should be of considerable value to those who do make the final recommendations regarding the symbols and colours to be used for displaying ice information in ECDIS.

The work of this thesis provides benefits on both the short and long term. The researched tool can have an immediate impact in assisting the production of Ice

Information MIOs at the CIS. The work in Appendix VIII provides an excellent base for a long term solution in regards to displaying ice information in ECDIS. The proposed symbols and colours should benefit the ice charting community world-wide, not just in Canada.

5.3 Recommendations for Future Research

Additional research is required regarding the S-52 symbology proposed by the author. As was discussed in Section 3.2, the author compiled the coding used by the WMO and the CIS in order to propose the symbology; no new symbology was designed by the author for the few ice attributes that do not have a CIS or WMO symbol and/or colour associated with them.

The tool developed by the author is a prototype. Should it be implemented by the CIS, several features must be completed in order for it to provide full functionality (as was discussed in Section 4.1.5.1).

Once the tool has been completed, new additional features could be researched in order to expand the scope and power of the tool. What immediately strikes the author as potentially useful to the end user would be the ability to edit the many attributes of individual ice objects. In its present state, with the exception of the information contained in the Egg Code, LINE_TYPE, and PNT_TYPE values, all attributes for each ice object type are assigned the same attribute values (for example, the object name of every ice object is left null). This is because there is no additional information included for individual ice objects in the original ArcInfo coverage that the current version of ISIS produces.

Such an addition to the tool would require at the minimum an update to the current GUI. It would also most likely require an alteration to ISIS, one that allowed ice analysts to enter information for each ice object while creating an ice chart. Without this alteration, all additional information would have to be entered after the ice chart was created in ISIS.

Another feature that would be very useful would be to add the ability to create “S-57 update files”. Currently, the tool generates only a complete Ice Information MIO. However, it would be possible for the tool to create an update file as well. An update file is one that is much smaller than a complete MIO as it contains only the changes in the MIO from the previous version of the chart (for Canadian ice charts, the previous version is generally the previous day’s ice chart). For example, an update file would never contain land boundaries as they are constant, and many fast ice boundaries would also not be included as they frequently do not change from day to day.

Finally, the proposed changes in S-57 Edition 4.0 need to be examined in order to determine the compatibility of what the author’s tool will produce and the new IHO specifications. It is possible that some alterations to the tool will need to be made in order to comply with the new standards. An additional benefit of these possible alterations and extensions is that this tool can easily be modified by any programmer that is fluent in the Arc Macro Language.

POSTSCRIPT

While the work described in this thesis was actually undertaken during the period ending in June, 2004, the author only finalized the preparation of this thesis in December, 2005. In the intervening months since the research was completed, further developments have taken place with respect to both the refinement of a proposed Ice Objects Catalogue for S-57 → S-100 and the planned IHO Registry that will include a separate Register for Ice Information.

Nevertheless, the author believes that the research effort described in this thesis was significant. Moreover, the results may still be valuable in identifying potential improvements to future production processes within the CIS and possibly other national ice monitoring organizations around the world.

REFERENCES

Agi, B., and A. El-Rabbany (2003). "Integration Of Digital Ice Chart With Electronic Chart Display And Information System (ECDIS) – Automated Preprocessing". Ryerson University, Toronto, Canada.

Agi, B., and A. El-Rabbany (2004). "Ice in ECDIS Project Report: The Integration Of Digital Ice Chart With Electronic Chart Display And Information System (ECDIS)". Ryerson University, Toronto, Canada.

Alexander, L. (2003a). "Marine Information Objects (MIOs) and ECDIS: Concept and Practice". *U.S. Hydrographic Conference*, Biloxi, Mississippi, 24-27 March, 2003.

Alexander, L. (2003b). "Electronic Charts – What, How, and Why: A Short Primer". Seminar presentation, University of New Brunswick, Fredericton, Canada. 22 October 2003.

Alexander, L. (2004). "Report of IHO-IEC Harmonization Group on Marine Information Objects (HGMIO)." 17th CHRIS Meeting, Rostock, Germany, 5-9 September 2004.

Alexander, L. (2006). Personal Communication. Center for Coastal and Ocean Mapping – Joint Hydrographic Center, University of New Hampshire. 10 February 2006.

Cheung, P. S. (1997). "Bi-Directional Data Converter of IHO S57". *1997 ESRI International User Conference Proceedings*, San Diego, California, 8-11 July, 1997.Environmental Systems Research Institute, Redlands, California.

Canadian Centre for Remote Sensing (2004). "RADARSAT-1 Technical Specifications – Summary". http://www.ccrs.nrcan.gc.ca/ccrs/data/satsens/radarsat/specs/radspec_e.html (updated 12 October 2004)

Climate Change Indicators Task Group (2003). "Climate, Nature, People: Indicators of Canada's Changing Climate". Canadian Council of Ministers of the Environment (CCME), Winnipeg, Manitoba.

Canadian Ice Service (n.d.). "Canadian Ice Service: Canada's Leading Source of Ice Information". Meteorological Service of Canada, Ottawa.

Canadian Ice Service (2001). "ECDIS Ice Objects Version 3.0". Meteorological Service of Canada, Ottawa.

Canadian Ice Service (2002). *MANICE: Manual of Standard Procedures for Observing and Reporting Ice Conditions*, 9th Ed., Meteorological Service of Canada, Ottawa.

Canadian Ice Service (2003). *CIS Daily Chart (Sea Ice) ISIS Format Data Description*, Meteorological Service of Canada, Ottawa.

Canadian Ice Service (2003b). "Egg Code Background". http://ice-glaces.ec.gc.ca/App/WsvPageDsp.cfm?ID=163 (updated 20 March 2003)

Canadian Ice Service (2003c). "What Are Ice Models?". http://ice-glaces.ec.gc.ca/App/WsvPageDsp.cfm?ID=128&LnId=5&Lang=eng (updated 20 March 2003)

Cardinal, A. (2004). Personal Communication. Developer/Programmer/Analyst, Canadian Ice Service, Environment Canada, Ottawa. 17-20 May 2004.

Chagnon, R. (2004). Personal Communication. Archive and Climate Manager, Canadian Ice Service, Environment Canada, Ottawa. 29 June 2004.

Centre for Research in Earth and Space Technology (n.d.). *Developing an Integrated Navigational Chart System for Ice Navigation.*

Conboy, B. (2005). "MODIS Web – Technical Specifications". http://modis.gsfc.nasa.gov/about/specs.html (current as of 25 May 2005)

Diarbakerly, S., A. El-Rabbany, and D. Coleman (2002). "On the Integration of Sea Ice Information into ECDIS"

El-Rabbany, A. (2001). "Developing an Integrated Navigation Chart System for Ice Navigation."

El-Rabbany, A. (2003). Personal communication. Associate Professor of Geomatics Engineering, Department of Civil Engineering, Ryerson University, Toronto, 28 November 2003.

El-Rabbany, A., B. Agi, M. El-Diasty, G. Dias, and D. J. Coleman (2004). "On the Development of an Integrated Navigational Chart System for Marine Navigation in Ice Covered Waters." Lighthouse Journal of the Canadian Hydrographic Association, Spring/Summer 2004, pp. 5-10.

Environmental Systems Research Institute (1995). *Understanding GIS. The ARC/INFO Method*. Environmental Systems Research Institute, California, USA.

Environmental Systems Research Institute (2002a). *Map Projections*, ESRI Press, Redlands, California.

Environmental Systems Research Institute (2002b). *ARC Commands*, ESRI Press, Redlands, California.

European Space Agency (2004). *ASAR Product Handbook.* European Space Agency, Falkingham, J. (2003). “ISIS: The Canadian Ice Mapping System.” Presented at IICWG – IV, St. Petersburg, 7-11 April 2003.

Fequet, D. (2003). Personal Communication. Senior Development Technician, Canadian Ice Service, Environment Canada, Ottawa. 26 November 2003.

Fequet, D. (2004). Personal Communication. Senior Development Technician, Canadian Ice Service, Environment Canada, Ottawa. 31 May 2004.

Fequet, D. (2005). Personal Communication. Senior Development Technician, Canadian Ice Service, Environment Canada, Ottawa. 2 June 2005.

Flett, D., R. De Abreu, and J. Falkingham (2004). Operational Experience with ENVISAT ASAR Wide Swath Data at the Canadian Ice Service. 2004 ENVISAT Symposium, Salzburg, Austria, 6-10 September 2004.

Hall, D. (2005). “The MODIS Snow/Ice Global Mapping Project: Data Product Validation”. http://modis-snow-ice.gsfc.nasa.gov/val.html (updated 24 February 2005)

Hetch, H., B. Berking, G. Büttgenback, M. Jonas, L. Alexander (2002). *The Electronic Chart: Functions, Potential and Limitations of a New Marine Navigation System*, GITC, The Netherlands.

Hong Kong Marine Department, Hydrographic Office (2005). “About ENC”. http://www.hydro.gov.hk/enc (updated 6 May 2005)

Huynh, B. (2002). “The Integration of Paper Ice Charts into ECDIS”.

HydroService AS (c2003), “S-57 edition 3.1 Objects & Attributes Catalogue”, HydroService AS, Egersund, Norway. http://www.s-57.com (current as of 28 May 2005)

International Hydrographic Bureau (2000). IHO Transfer Standard for Digital Hydrographic Data, Special Publication No. 57, Edition 3.1, Monaco.

International Hydrographic Bureau (2001). Specifications for Chart Content and Display Aspects of ECDIS, Special Publication No. 52, Edition 5, Monaco.

International Hydrographic Organization (1994). "International Hydrographic Dictionary" 5th ed. Monaco: IHB, 1994. Special publication S-32. Available from World Wide Web: http://www.iho.shom.fr/Dhydro/Html/site_edition/disclaimer.html (current as of 28 May 2005)

International Hydrographic Organization (2003). "Introduction to Electronic Chart Systems and ECDIS", http://www.iho.shom.fr/ECDIS/introduction.htm (current as of 28 May 2005)

International Hydrographic Organization (2004). "IHO – Background Information". http://www.iho.shom.fr/GEN_INFO/background.htm (updated 25 August 2004)

International Hydrographic Organization (2005). "The Next Edition of IHO S-57 (4.0) – Version 1.1, March 2005", http://ww.iho.shom.fr/ECDIS/S-57_Ed4_Information_Paper_ver1.1.pdf

International Hydrographic Organization Transfer Standard Maintenance and Application Development Working Group (TSMAD) (2004). "The Next Edition Of S-57 (4.0): A Primer", Draft Version 4, 11th TSMAD Meeting, 10-12 November 2004, International Hydrographic Bureau, Monaco.

International Ice Charting Working Group (2004a). "IICWG at NSIDC". http://nsidc.org/noaa/iicwg/ (current as of 28 May 2005)

International Ice Charting Working Group (2004b). "Ice Information Services: Socio-Economic Benefits and Earth Observation Requirements". IICWG, September 2004.

Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology Expert Team on Sea Ice, 2004. "JCOMM Meeting Report No. 28". JCOMM Expert Team on Sea Ice Second Session Steering Group for the Global Digital Sea Ice Data Bank Tenth Session, Hamburg, Germany, 15-17 April 2004. World Meteorological Organization.

Lapointe, C. (2001), "Integrating Sea Ice Information Into An Electronic Chart Display And Information System (ECDIS)". Bachelor of Science in Engineering Senior Report, Department of Geodesy and Geomatics Engineering, University of New Brunswick, Fredericton, Canada.

McCourt, S. (2003). Microsoft Excel file "CISdataType.xls". Canadian Ice Service, Ottawa, Canada.

Microsoft (2004a). "How To Select a Directory Without the Common Dialog Control". http://support.microsoft.com/kb/q179497 (updated 13 July 2004)

Microsoft (2004b). "How To Use a 32-Bit Application to Determine When a Shelled Process Ends". http://support.microsoft.com/kb/q129796 (updated 13 July 2004)

National Aeronautics and Space Administration (1996). "Special Sensor Microwave Imager (SSM/I)". http://podaac.jpl.nasa.gov:2031/sensor_docs/ssmi.html (updated 20 February 1996)

National Aeronautics and Space Administration (2004a). “Special Sensor Microwave Imager (SSM/I) Sensor Document”. http://ghrc.msfc.nasa.gov:5721/sensor_documents/ssmi_sensor.html (current as of 28 May 2005)

National Aeronautics and Space Administration (2004b). “WINDS: Missions: SeaWinds on QuikSCAT”. http://winds.jpl.nasa.gov/missions/quikscat/index.cfm (current as of 28 May 2005)

National Aeronautics and Space Administration (2005). “AMSR-E homepage”. http://www.ghcc.msfc.nasa.gov/AMSR (current as of 28 May 2005)

National Oceanic and Atmospheric Administration (2000). “QuikSCAT Ice Page”. http://manati.orbit.nesdis.noaa.gov/cgi-bin/qscat_ice.pl (updated 20 December 2000)

National Oceanic and Atmospheric Administration (2004). “Defence Meteorological Satellite Program – SSM/I Description”. http://dmsp.ngdc.noaa.gov/html/sensors/doc_ssmi.html (current as of 26 May 2005)

National Oceanic and Atmospheric Administration (2005). “NOAASIS – NOAA Satellite Information System for NOAA Meteorological / Weather Satellites”. http://noaasis.noaa.gov/NOAASIS/ml/avhrr.html (updated July 20 2005)

Ramsay, B., M. Manore, L. Weir, K. Wilson, and D. Bradley (1997). “Utilization of RADARSAT Data in the Canadian Ice Service”. Paper presented at International Symposium "Geomatics in the Era of RADARSAT", 25-30 May 1997, Ottawa, Canada.

Scheuermann, W. (1996). “What is ECDIS and what can it do?” http://www.sevencs.com/ecdis/whatisecdis.htm (updated 15 October 1996)

Scheuermann, W., and K. Pahmeyer (1999). “Ice Information in ECDIS”. http://www.sevencs.com/ecdis/iceinformation.htm (updated January 1999)

Smolyanitsky, V. (2004). “Colour Standard for Ice Charts”. Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology Expert Team on Sea Ice – Second Edition, Steering Group for the Project Global Digital Sea Ice Data Bank – Tenth Session, Hamburg, Germany, 15-17 April 2004. World Meteorological Organization.

Vatsa, G., and S. Chauhan (2002). “Advent of Electronic Navigational Chart for National Development and Navigational Safety”, Indian Cartographer, Volume 22 (“Convergence of Imagery, Information & Maps”), Number 25. Indian National Cartographic Association, Hyderabad, India, 2002.

Wells, D. (2006). Personal Communication. Professor Emeritus, Geodesy and Geomatics Engineering, University of New Brunswick. 13 February 2006.

World Meteorological Organization, 2004. “About WMO.” http://www.wmo.ch/index-en.html (current as of 28 May 2005)

BIBLIOGRAPHY

Grant, S.T., and J. Goodyear (2004). "ECDIS: Past, Present, and Future". UNESCO Ocean Teacher. http://ioc.unesco.org/oceanteacher/OceanTeacher2/02_InfTchSciCmm/01_CmpTch/10_enavsys/ecdis2.pdf

HydroService AS (2004). "IHO S-57 / ENC – Object and Attribute Catalogue". http://s-57.com (current as of 31 May 2005)

APPENDIX I
ICE MAPPING STANDARDS

Table I.1 shows the colour codes used by the CIS on ice charts for indicating total ice concentration. The WMO colour codes for total concentration are shown in Table I.2. In Table I.3, the WMO colour codes for the ice's stage of development are shown. Table I.4 shows the WMO hatching codes for total ice concentration.

Table I.1. CIS colour codes for total ice concentration [from CIS, 2002].

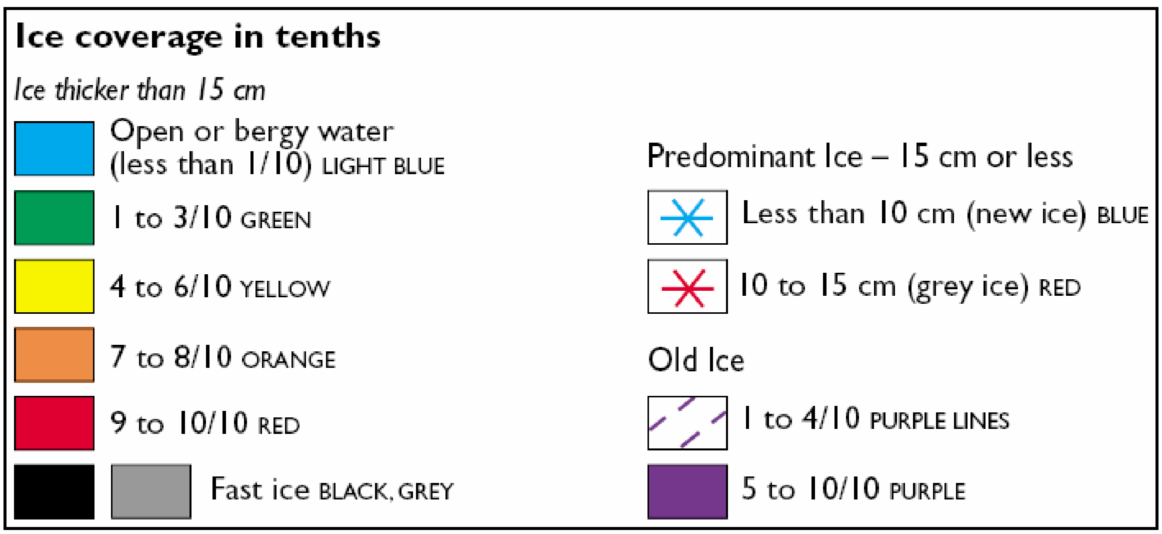


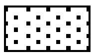
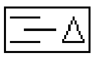
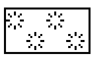
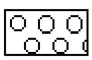
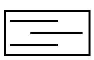
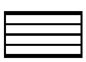
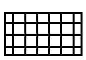
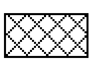
Table I.2. WMO colour codes for total ice concentration [from JCOMM, 2004].

Colour		RGB colour model	Total concentration (definition from WMO Nomenclature)	Number from WMO Nomenclature
alternative	prime			
white	blue	000-100-255	Ice free	4.2.8
	light blue	150-200-255	Less than one tenth (open water)	4.2.6
	light green	140-255-160	1/10 - 3/10 (very open ice)	4.2.5
	yellow	255-255-000	4/10 - 6/10 (open ice)	4.2.4
	orange	255-125-007	7/10 - 8/10 (close ice)	4.2.3
	red	255-000-000	9/10 - 10/10 (very close ice)	4.2.2
	grey	150-150-150	Fast ice	1.1.1
	light grey	210-210-210	Ice shelf	10.3
	? ? ?	255-255-255	Undefined ice	-
Optional	light pink	255-175-255	7/10-10/10 new ice	2.1
	magenta	255-100-255	9/10-10/10 nilas, grey ice (mainly on leads)	2.2, 2.4
Areas of No Information are annotated accordingly				

Table I.3. WMO colour codes for stage of ice development [from JCOMM, 2004].

Colour		RGB colour model	Stage of development (SoD)	Number from WMO Sea Ice Nomenclature
alternative	prime			
		000-100-255	Ice free	4.2.8
		150-200-255	<1/10 ice of unspecified SoD (open water)	4.2.6
		240-210-250	New ice	2.1
		255-175-255	Dark nilas	2.2.1
		255-100-255	Light nilas	2.2.2
		170-040-240	Young ice	2.4
		135-060-215	Grey ice	2.4.1
		220-080-235	Grey-white ice	2.4.2
		255-255-000	First-year ice (FY)	2.5
		155-210-000	FY thin ice (white ice)	2.5.1
		215-250-130	FY thin ice (white ice) first stage	2.5.1.1
		175-250-000	FY thin ice (white ice) second stage	2.5.1.2
		000-200-020	FY medium ice	2.5.2
		000-120-000	FY thick ice	2.5.3
		180-100-050	Old ice	2.6
		255-120-010	Second-year ice	2.6.1
		200-000-000	Multi-year ice	2.6.2
		150-150-150	Fast ice of unspecified SoD	2.6
		210-210-210	Ice shelf	10.3
	? ? ?	255-255-255	Ice of undefined SoD	-
	▲ ▲ ▲	255-255-255	Drifting ice of land origin (icebergs)	10.4.2
Areas of No Information are annotated accordingly				

Table I.4. WMO hatching codes for total ice concentration [Scheuermann and Pahmeyer, 1999].

Open or Bergy Water	
	Open water
	Bergy waters
New and Open Ice	
	New ice
	Open ice
	Very open ice
Level and More Compact Ice	
	Level ice
	Close ice
	Consolidated, compact or very close ice
Fast Ice	
	Fast ice

APPENDIX II
CIS PNT_TYPE FEATURE CODES

Table II.1 describes the ISIS PNT_TYPE values. PNT_TYPE values 143, 144, and 145 were discovered by the author and not documented in McCourt's Microsoft Excel® file.

Table II.1. CIS colour codes for total ice concentration [from CIS, 2002].

PNT_TYPE	PNT_NAME	Full Name	"Real" Feature	Description
100	ice_drift	Ice Drift		label point for Ice Drift
101	bergy_water	Bergy Water	X	Polygon label for bergy water
102	diverging	Diverging		label point for Diverging
103	converging	Converging		label point for Converging
104	ethickness	Estimated Thickness		label point for Estimated Thickness
105	mthickness	Measured Thickness		label point for Measured Thickness
106	fastice	Fastice	X	Polygon label for fast ice
107	open_water	Open Water	X	Polygon label for open water
108	melting_stage	Melting Stage		label point for Melting Stage
109	rafting	Rafting		label point for Rafting
110	ridges	Ridges		label point for Ridges
111	shearing	Shearing		label point for Shearing
112	strips_patches	Strips and Patches		label point for Strips and Patches
113	snow_cover	Snow Cover		label point for Snow Cover
114	zero_ice_drift	Zero Ice Drift		label point for Zero Ice Drift
115	ice_free	Ice Free	X	Polygon label for ice free
116	freetext	Free Text		label point for Free Text
117	inside_egg	Inside Egg	X	Polygon label for ice (egg inside a polygon)
118	remote_egg	Remote Egg Label	X	Polygon label for ice (label inside a polygon)
119	att_label	Attached Egg Label		label point for Attached Egg Label
120	att_label_anchor	Attached Egg Label Anchor	X	Polygon label for ice (label with a leader line)
121	att_egg	Attached Egg		label point for Attached Egg

PNT_TYPE	PNT_NAME	Full Name	“Real” Feature	Description
122	att_egg_anchor	Attached Egg Anchor	X	Polygon label for ice (egg with a leader line)
123	nodata_1	Large No Data	X	Polygon label for large no data
124	fastice_label	Fastice Label		label point for Fastice Label
125	ice_free_label	Ice Free Label		label point for Ice Free Label
126	open_water_label	Open Water Label		label point for Open Water Label
127	bergy_water_label	Bergy Water Label		label point for Bergy Water Label
128	nodata_2	Small No Data	X	Polygon label for small no data
129	freetext_label	Free Text Label		label point for Free Text Label
130	roughness	Relative Ice Roughness		label point for Relative Ice Roughness
131	roughness_label	Relative Ice Roughness Label		label point for Relative Ice Roughness Label
132	ship	Ship		label point for Ship
133	nodata_3	Micro No Data	X	
134	double_egg	Double Egg		label point for Double Egg
135	ethickness_label	Estimated Thickness Label		label point for Estimated Thickness Label
136	mthickness_label	Measured Thickness Label		label point for Measured Thickness Label
137	ice_island	Ice Island		label point for Ice Island
138	ice_island_label	Ice Island Label		label point for Ice Island Label
139	crack	Crack at Location		label point for Crack at Location
140	ice_glace	IceGlace Egg	X	Polygon label for a “ice/glace” area
143			X	Ice area (no attributes)
144			X	Ice area (no attributes)
145			X	Ice area (no attributes)
200	chartt_ll	Chart Template Lower Left Corner		label point for Chart Template Lower Left Corner

PNT_TYPE	PNT_NAME	Full Name	“Real” Feature	Description
201	chartt_ul	Chart Template Lower Left Corner		label point for Chart Template Lower Left Corner
202	chartt_ur	Chart Template Lower Left Corner		label point for Chart Template Lower Left Corner
203	chartt_lr	Chart Template Lower Left Corner		label point for Chart Template Lower Left Corner
204	chartt_rem_eggs	Chart Template		label point for Chart Template
205	chartt_placename	Chart Template		label point for Chart Template
211	chartt_shadebox_1	Shaded legend box		label point for Shaded legend box
212	chartt_shadebox_2	Shaded legend box		label point for Shaded legend box
213	chartt_shadebox_3	Shaded legend box		label point for Shaded legend box
214	chartt_shadebox_4	Shaded legend box		label point for Shaded legend box
215	chartt_shadebox_5	Shaded legend box		label point for Shaded legend box
216	chartt_shadebox_6	Shaded legend box		label point for Shaded legend box
217	chartt_shadebox_7	Shaded legend box		label point for Shaded legend box
218	chartt_shadebox_8	Shaded legend box		label point for Shaded legend box
219	chartt_shadebox_9	Shaded legend box		label point for Shaded legend box
220	chartt_shadebox_10	Shaded legend box		label point for Shaded legend box
400	land	Land	X	Polygon label for land
401	predef_loc	Predefined Location		label point for Predefined Location
900	egg_centroid	TEMPORARY		temporary label for egg centroid

PNT_TYPE	PNT_NAME	Full Name	“Real” Feature	Description
934	inside_eggedge	TEMPORARY		temporary label for inside egg edge
935	outside_eggedge	TEMPORARY		temporary label for outside egg edge
950	sym_centroid	TEMPORARY Symbol Centre Point		temporary label for symbology centroid
951	sym_pivot	TEMPORARY Symbol Pivot Point		temporary label for symbology pivot point

APPENDIX III
CIS LINE_TYPE FEATURE CODES

ISIS LINE_TYPE values are described in Table III.1.

Table III.1. ISIS PNT_TYPE Values and Descriptions [after McCourt, 2003].

LINE_TYPE	**LINE_NAME**	**Full Name**	**"Real" Feature**	**Description**
8	neat	Analysis Neatline Boundary	X	line for edge of analysis
8	chartt_neat	Chart Template Neatline Boundary		line for Chart Template Neatline Boundary
9	chartt_construct	Chart Template Construction Line		line for Chart Template Construction Line
10	chartt_rem_eggs	Chart Template Remote Eggs		line for Chart Template Remote Eggs
11	chartt_legend	Chart Template Legend Line		line for Chart Template Legend Line
12	chartt_tbnd	Chart Template Temperature Boundary		line for Chart Template Temperature Boundary
13	chartt_tline	Chart Template Temperature Line		line for Chart Template Temperature Line
14	chartt_legend_int	Chart Template Legend Interior Line		line for Chart Template Legend Interior Line
15	chartt_erase	Chart Template Erase Polyline		line for Chart Template Erase Polyline
16	chartt_shadebox	Chart Template Legend Polyline		line for Chart Template Legend Polyline
17	chartt_dashed	Chart Template Dashed Line		line for Chart Template Dashed Line

LINE_TYPE	LINE_NAME	Full Name	"Real" Feature	Description
18	chartt_aoi_bnd	Chart Template AOI boundary		line for Chart Template AOI boundary
101	inside_egg	Inside Egg Shell		line for Inside Egg Shell
101	legend	Legend		line for Legend
102	eggleader	Leader Line		line for Leader Line
103	eggleader_assoc	Assoicated Leader Line		line for Assoicated Leader Line
104	att_egg	Attached Egg Shell		line for Attached Egg Shell
105	anno_egg	Not used		line for Not used
106	symlead_fi	Leader Line for Fast Ice		line for Leader Line for Fast Ice
107	symlead_fi_assoc	Associated Leader Line for Fast Ice		line for Associated Leader Line for Fast Ice
108	symlead_if	Leader Line for Ice Free		line for Leader Line for Ice Free
109	symlead_if_assoc	Associated Leader Line for Ice Free		line for Associated Leader Line for Ice Free
110	symlead_bw	Leader Line for Bergy Water		line for Leader Line for Bergy Water
111	symlead_bw_assoc	Associated Leader Line for Bergy Water		line for Associated Leader Line for Bergy Water
112	symlead_ow	Leader Line for Open Water		line for Leader Line for Open Water
113	symlead_ow_assoc	Associated Leader Line for Open Water		line for Associated Leader Line for Open Water
114	symlead_rr	Leader Line for Relative Ice Roughness		line for Leader Line for Relative Ice Roughness
115	symlead_rr_assoc	Associated Leader Line for Relative Ice Roughness		line for Associated Leader Line for Relative Ice Roughness
116	symlead_il	Leader Line for Ice Island		line for Leader Line for Ice Island
117	fast	Fast Ice	X	line for fast ice edge

LINE_TYPE	LINE_NAME	Full Name	"Real" Feature	Description
118	symlead_et	Leader Line for Estimated Ice Thickness		line for Leader Line for Estimated Ice Thickness
119	symlead_mt	Leader Line for Measured Ice Thickness		line for Leader Line for Measured Ice Thickness
120	symlead_ft	Leader Line for Free Text		line for Leader Line for Free Text
121	latlong_1deg	1 Degree Latitude and Longitude		line for 1 Degree Latitude and Longitude
122	ice_edge	Ice Edge	X	line for ice edge
123	latlong_5deg	5 Degree Latitude and Longitude		line for 5 Degree Latitude and Longitude
133	open_water_edge	Open Water Edge	X	line for open water edge
140	coast	Coast Line	X	line for coastline
141	inland_lake	Inland Lake Line	X	line for inland lakes
150	iceberg_edge	Topological Iceberg Edge	X	line for iceberg edge
151	iceberg_edge_nt	NonTopological Iceberg Edge	X	line for iceberge edge through ice (non-topological)
162	estimated_ice	Estimated Ice Edge	X	line for Estimated Ice Edge
171	crack	Crack	X	line for Crack
183	open_water_lead	Open Water Lead	X	line for Open Water Lead
190	frozen_lead	Frozen Water Lead	X	line for Frozen Water Lead
201	radar_limit	Radar Limit	X	line for Radar Limit
218	undercast_limit	Undercast Limit	X	line for Undercast Limit
222	visual_limit	Visual Limit	X	line for Visual Limit
223	construction	Construction		line for Construction
224	ice_strength	Ice Strength isoline		line for Ice Strength isoline
300	sym_rot_angle	Temporary line used to set rotation		line for Temporary line used to set rotation
301	sym_converging	Symbol Line		line for Symbol Line

LINE_TYPE	LINE_NAME	Full Name	“Real” Feature	Description
302	sym_drift	Symbol Line		line for Symbol Line
303	sym_zero_drift	Symbol Line		line for Symbol Line
304	sym_ridges	Symbol Line		line for Symbol Line
305	sym_diverging	Symbol Line		line for Symbol Line
306	sym_shearing	Symbol Line		line for Symbol Line
307	sym_openwater	Symbol Line		line for Symbol Line
308	sym_fastice	Symbol Line		line for Symbol Line
309	sym_melting	Symbol Line		line for Symbol Line
310	sym_bergywat	Symbol Line		line for Symbol Line
311	sym_rafting	Symbol Line		line for Symbol Line
312	sym_strips	Symbol Line		line for Symbol Line
313	sym_ethickness	Symbol Line		line for Symbol Line
314	sym_mthickness	Symbol Line		line for Symbol Line
315	sym_snowcover	Symbol Line		line for Symbol Line
316	sym_icefree	Symbol Line		line for Symbol Line
317	sym_roughness	Symbol Line		line for Symbol Line
318	sym_iceisland	Symbol Line		line for Symbol Line
319	sym_crack	Symbol Line		line for Symbol Line
399	sym_hidden	Symbol Line		line for Symbol Line
400	boundary_clip	Temporary line for clipping analysis extent		line for Temporary line for clipping analysis extent

APPENDIX IV
ICE OBJECTS DEFINITIONS

Descriptions of proposed Ice Objects that relate directly to an ISIS code are provided in Table IV.1. Descriptions of their attributes are provided in Table IV.2.

Table IV.1. Description of Proposed ECDIS Ice Objects that relate directly to an ISIS PNT_TYPE or LINE_TYPE value [after CIS, 2001].

Object Code	Object Class	Description
BRGARE	Iceberg Area	An area at sea in which icebergs, floebergs, bergy bits, or growlers are present
COALNE	Coastline	The line where shore and water meet.
ICEFRA	Ice Fracture	Any break or rupture through very close pack ice, compact ice, consolidated ice, fast ice, or a single floe, resulting from deformation processes. Fractures may contain brash ice and/or be covered with nilas and/or young ice. Their lengths may vary from a few metres to many kilometres.
ICELEA	Ice Lead	Any fracture or passage-way through ice which is navigable by surface vessels.
ICELIN	Ice Line	A measured, observed, or estimated limit of the ice-infested waters.
LACICE	Lake Ice	An area on a lake that contains ice.
LNDARE	Land Area	The solid portion of the Earth’s surface, as opposed to sea, water.
SEAICE	Sea Ice	An area at sea that contains ice.

Table IV.2. Description of Proposed ECDIS Ice Object Attributes that relate directly to an ISIS PNT_TYPE or LINE_TYPE value [after CIS, 2001].

Attribute Code	Ice Attribute	Description
ICEACT	Ice Attribute Concentration Total	The total concentration of ice in an area.
ICEAPC	Ice Attribute Partial Cncentration	The partial concentrations of ice in an area.
ICECVT	Ice Coverage Type	The type of ice coverage in an area.
ICEFLZ	Floe Sizes	The predominate forms of ice floe sizes corresponding to the ice Stages of Development.

Attribute Code	Ice Attribute	Description
ICELSO	Lake Ice Stage of Development	The ages and thicknesses of lake ice.
ICESOD	Ice Stage of Development	The ages and thicknesses of the ice.
ICELNC	Ice Line Category	The limits of ice-infested waters or boundaries between the areas of different types of concentrations.
ICEFTY	Ice Fracture Type	The type of ice fracture.
ICELTY	Ice Lead Type	The type of lead.
ICELST	Ice Lead Status	The surface nature of the lead.

APPENDIX V
ARC MACRO LANGUAGE CODE FOR “UPDATE_S57_FOR_ICE.AML” SCRIPT

```
&SETVAR myspace = [SHOW &WORKSPACE]

/* (re)import ice INFO files
&IF [EXISTS %ARCHOME%\template\s57\s57.objl_ice -INFO] = .TRUE. &THEN
KILLINFO %ARCHOME%\template\s57\s57.objl_ice
&IF [EXISTS %ARCHOME%\template\s57\s57.attl_ice -INFO] = .TRUE. &THEN
KILLINFO %ARCHOME%\template\s57\s57.attl_ice
&IF [EXISTS %ARCHOME%\template\s57\s57.o2a_ice -INFO] = .TRUE. &THEN
KILLINFO %ARCHOME%\template\s57\s57.o2a_ice

DBASEINFO objl_ice.dbf %ARCHOME%\template\s57\s57.objl_ice DEFINE
nocode nocode 4 6 B
colabel colabel 6 6 C
codesc codesc 100 100 C
END

DBASEINFO attl_ice.dbf %ARCHOME%\template\s57\s57.attl_ice DEFINE
nacode nacode 4 6 B
calabel calabel 6 6 C
ctype ctype 1 1 C
cadesc cadesc 100 100 C
info_type info_type 1 1 C
info_lengt info_length 2 4 B
END

DBASEINFO o2a_ice.dbf %ARCHOME%\template\s57\s57.o2a_ice DEFINE
nocode nocode 4 6 B
nacode nacode 4 6 B
cset cset 1 1 C
END

&WORKSPACE %ARCHOME%\template\s57

/* merge ice records into rest of S-57 records
&DATA ARC INFO
ARC
/* add or replace objects
SELECT S57.OBJL
RESELECT NOCODE GE 201 AND NOCODE LE 218
PURGE
YES
SELECT S57.OBJL_ICE
MERGE INTO S57.OBJL ON NOCODE
/* add or replace attributes
SELECT S57.ATTL
RESELECT NACODE GE 201 AND NACODE LE 234
PURGE
YES
SELECT S57.ATTL_ICE
MERGE INTO S57.ATTL ON NACODE
/* add or replace object to attribute link
SELECT S57.O2A
RESELECT NOCODE GE 201 AND NOCODE LE 218
PURGE
```

49. YES
50. SELECT S57.O2A_ICE
51. MERGE INTO S57.O2A ON NOCODE, NACODE
52. Q STOP
53. &END

54. &WORKSPACE %myspace%

APPENDIX VI
ARC MACRO LANGUAGE CODE FOR "ICE2S57.AML" SCRIPT

```
/**********************************************************************************************
/*    Program: ICE2S57.AML
/*    Purpose: Convert a CIS ice chart to S-57 format.
/*---------------------------------------------------------------------------------------------
/*
/*      Usage: ICE2S57 <in_cover> <out_workspace> <out_cover> <SEAICE | LACICE> {TEMPS | NOTEMPS}
/*                       {BOX | NOBOX} {intended_usage} {issue_date} {scale} {comment}
/*
/*  Arguments: INE00 - input e00 file from CIS
/*              OUTSPACE - output workspace - safer if it doesn't exist
/*              OUTCOV - output coverage name - also will be name of output S-57 file
/*              ICETYPE - sea ice or lake ice
/*              KILLTEMPS - kill temporary coverages or not
/*              BOUNDBOX - create a bounding rectangle or not - necessary unless one exists
/*              INTU - intended usage code (1 to 6)
/*              ISDT - issue date in format YYYYMMDD
/*              CSCL - compilation scale - (1:4000000 is entered simply as 4000000)
/*              COMT - comment, up to 70 characters
/*
/*   Routines: INPUTS - verify inputs are legal
/*              IMPORTER - import e00
/*              SYMBOLOGY - remove non-geography features
/*              FIXPROJECTION - reproject to lat-long WGS84
/*              BOUNDBOX - add bounding rectangle
/*              TOPOLOGY - build topology
/*              ROUTE_REGION - create S-57 meta and feature objects (routes and regions in ARC)
/*              VRID - adds atrributes to VENAME, AAT, and NAT which become VRID in S-57 file
/*              POP_RCID - adds unique RCID value to each object
/*              POP_REGION - populates meta and feature object attribute values
/*              ATTR - populates table containing S-57 B-level and C-level attributes
/*              CATD - create CATD field
/*              DSID - create DSID field
/*              DSSI - create DSSI field
/*              DSPM - create DSPM field
/*              MULTIPOINTS - create a list of polygons with different-valued points
/*              KILLTEMPS - kills temporary coverages, if requested
/*              MAKES57 - converts processed coverage to S-57
/*
/*    Globals: none
/*
```

```
/*-----------------------------------------------------------------------------------------------
/*      Calls: none
/*-----------------------------------------------------------------------------------------------
/*      Notes: Sometimes this AML fails for no apparent reason when it enters tables.  It just
/*             needs to be run again - things almost always work out.
/*
/*             If a bounding rectangle already exists, it must contain a value of 'xx' for the
/*             'region' field.
/*
/*             DSHT and DSAC cannot be exported for some unknown reason.  It seems to be a
/*             problem with the ARCS57 command.
/*
/*-----------------------------------------------------------------------------------------------
/* Created by: George Dias
/* Created on: November 1, 2003
/*************************************************************************************************
&ARGS ine00 outspace outcov icetype killtemps boundbox intu isdt cscl comt
&SEVERITY &ERROR &ROUTINE bailout
&TERMINAL 9999
&PT

/*DEFINE PRECISION OF OUTPUT DATASETS
PRECISION DOUBLE DOUBLE
&MESSAGES &OFF &ALL

&CALL inputs
&CALL importer
&CALL symbology
&CALL fixprojection
&IF %boundbox% = 'box' &THEN
&CALL boundbox
&CALL topology
&CALL route_region
&CALL vrid
&CALL pop_rcid
&CALL pop_region
&CALL attr
TABLES
&CALL catd
&CALL dsid
&CALL dssi
&CALL dspm
QUIT
&CALL multipoints
&IF %killtemps% = 'notemps' &THEN
&CALL killtemps
```

```
&CALL makes57
&MESSAGES &POPUP
&TYPE 'Mission: accomplished in: '[TRUNCATE [CALC %timed% / 60]]' minutes and '[MOD %timed% 60]' second(s).'
&WORKSPACE %startspace%
&PT &OFF
&MESSAGES &ON
&RETURN

&ROUTINE inputs
/*****************************************************************
/* CHECK IF INPUTS ARE CORRECT
/*****************************************************************
&MESSAGES &POPUP
/*INE00
&SETVAR %ine00% = [QUOTE [UNQUOTE %ine00%]]
&IF [NULL %ine00%] = .TRUE. &THEN
&RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace> <out_cover> <SEAICE | LACICE> ~
/&               {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage} ~
/&               {issue_date} {scale} {comment}
&IF [EXISTS %ine00% -FILE] = .FALSE. &THEN
&RETURN &WARNING Error: Exchange file %ine00% does not exist.

/*OUTSPACE
&SETVAR %outspace% = [QUOTE [UNQUOTE %outspace%]]
&IF [NULL %outspace%] = .TRUE. &THEN
&SETVAR %outspace% = &WORKSPACE
&IF [EXISTS %outspace% -WORKSPACE] = .FALSE. &THEN
CREATEWORKSPACE %outspace%

/*OUTCOV
&SETVAR %outcov% = [QUOTE [UNQUOTE %outcov%]]
&IF [NULL %outcov%] = .TRUE. &THEN
&RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace> <out_cover> <SEAICE | LACICE> ~
/&               {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage} ~
/&               {issue_date} {scale} {comment}
&IF [EXISTS %outspace%\%outcov% -COVER] = .TRUE. &THEN
&DO
&SETVAR killit = [QUERY 'Output coverage '%outspace%'\'%outcov%' exists.  Do you want to replace it' .FALSE.]
&IF %killit% = .TRUE. &THEN
&DO
&MESSAGES &OFF &ALL
KILL %outspace%\%outcov% ALL
&MESSAGES &POPUP
&END
&ELSE
&RETURN
&END
&SETVAR outcov = [UPCASE %outcov%]
```

```
/*ICETYPE
&SETVAR icetype = [LOCASE %icetype%]
&IF [NULL %icetype%] = .TRUE. OR ( %icetype% <> 'seaice' AND %icetype% <> 'lacice' ) &THEN
&RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace> <out_cover> <SEAICE | LACICE> ~
/&                {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage} ~
/&                {issue_date} {scale} {comment}

/*KILLTEMPS
&SETVAR killtemps = [LOCASE %killtemps%]
&IF [NULL %killtemps%] = .TRUE. OR %killtemps% = '#' &THEN
&SETVAR killtemps = 'temps'
&ELSE &IF %killtemps% <> 'temps' AND %killtemps% <> 'notemps' &THEN
&RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace> <out_cover> <SEAICE | LACICE> ~
/&                {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage} ~
/&                {issue_date} {scale} {comment}

/*BOUNDBOX
&SETVAR boundbox = [LOCASE %boundbox%]
&IF [NULL %boundbox%] = .TRUE. OR %boundbox% = '#' &THEN
&SETVAR boundbox = 'box'
&ELSE &IF %boundbox% <> 'box' AND %boundbox% <> 'nobox' &THEN
&RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace> <out_cover> <SEAICE | LACICE> ~
/&                {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage} ~
/&                {issue_date} {scale} {comment}

/*INTU
&IF [NULL %intu%] = .TRUE. OR [QUOTE %intu%] = '#' &THEN
&SETVAR intu = 1
&IF [TYPE %intu%] <> -1 &THEN
&RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace> <out_cover> <SEAICE | LACICE> ~
/&                {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage} ~
/&                {issue_date} {scale} {comment}
&IF %intu% < 1 OR %intu% > 6 &THEN
&RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace> <out_cover> <SEAICE | LACICE> ~
/&                {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage} ~
/&                {issue_date} {scale} {comment} ~
/&-> {intended_usage} must be an integer between 1 and 6.

/*ISDT
&IF [NULL %isdt%] = .TRUE. OR [QUOTE %isdt%] = '#' &THEN
&SETVAR isdt = [SUBSTR [DATE -YEAR] 1 2][DATE -TAG]
&IF [SUBSTR %isdt% 1 4] < 1900 OR [SUBSTR %isdt% 1 4] > 2100 &THEN
```

```
&RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace> <out_cover> <SEAICE | LACICE> ~
/&               {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage} ~
/&               {issue_date} {scale} {comment} ~
/&-> {issue_date} must be an 8-character number in the form of YYYYMMDD. ~
/&-> the YYYY value entered is outlandish.
&IF [TYPE %isdt%] <> -1 OR [LENGTH %isdt%] <> 8 &THEN
&RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace> <out_cover> <SEAICE | LACICE> ~
/&               {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage} ~
/&               {issue_date} {scale} {comment} ~
/&-> {issue_date} must be an 8-character number in the form of YYYYMMDD.
&IF [SUBSTR %isdt% 5 2] > 12 &THEN
&RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace> <out_cover> <SEAICE | LACICE> ~
/&               {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage} ~
/&               {issue_date} {scale} {comment} ~
/&-> {issue_date} must be an 8-character number in the form of YYYYMMDD. ~
/&-> the MM value entered is illegal.
&DO i &LIST 01 03 05 07 08 10 12
&IF [SUBSTR %isdt% 5 2] = %i% &THEN
&IF [SUBSTR %isdt% 7 2] > 31 &THEN
&RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace> <out_cover> <SEAICE | LACICE> ~
/&               {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage} ~
/&               {issue_date} {scale} {comment} ~
/&-> {issue_date} must be an 8-character number in the form of YYYYMMDD. ~
/&-> the DD value entered is illegal for the month given.
&END
&DO i &LIST 04 06 09 11
&IF [SUBSTR %isdt% 5 2] = %i% &THEN
&IF [SUBSTR %isdt% 7 2] > 30 &THEN
&RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace> <out_cover> <SEAICE | LACICE> ~
/&               {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage} ~
/&               {issue_date} {scale} {comment} ~
/&-> {issue_date} must be an 8-character number in the form of YYYYMMDD. ~
/&-> the DD value entered is illegal for the month given.
&END
&IF [SUBSTR %isdt% 5 2] = 02 &THEN
&IF [SUBSTR %isdt% 7 2] > 29 &THEN
&RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace> <out_cover> <SEAICE | LACICE> ~
/&               {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage} ~
```

```
/&                {issue_date} {scale} {comment} ~
/&-> {issue_date} must be an 8-character number in the form of YYYYMMDD. ~
/&-> the DD value entered is illegal for the month given.

/*CSCL
&SETVAR cscl = [LOCASE %cscl%]
&IF [NULL %cscl%] = .TRUE. OR [QUOTE %cscl%] = '#' &THEN
&SETVAR cscl = -9998
&IF [TYPE %cscl%] <> -1 &THEN
&RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace> <out_cover> <SEAICE | LACICE> ~
/&                {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage} ~
/&                {issue_date} {scale} {comment} ~
/&-> {scale} must be an integer either greater than 0 or -9998 (null).
&IF %cscl% < 1 AND %cscl% <> -9998 &THEN
&RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace> <out_cover> <SEAICE | LACICE> ~
/&                {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage} ~
/&                {issue_date} {scale} {comment} ~
/&-> {scale} must be an integer either greater than 0 or -9998 (null).

/*COMT
&SETVAR comt = [QUOTE [UNQUOTE %comt%]]

&MESSAGES &OFF &ALL
&RETURN

&ROUTINE importer
/******************************************************************
/* IMPORT EXCHANGE FILE
/******************************************************************
&TYPE 'Importing file...'
&SETVAR startspace = [SHOW &WORKSPACE]
&WORKSPACE %outspace%

/*GET FILE NAME WITHOUT PATH
&SETVAR incov = [AFTER %ine00% \]
&DO &UNTIL [SEARCH %incov% \] = 0
&SETVAR incov = [AFTER %incov% \]
&END
/*REMOVE EXTENSION
&SETVAR incov = [BEFORE %incov% .]
/*LIMIT TO MAX 10 CHARACTERS
&SETVAR incov = [SUBSTR %incov% 1 10]

&MESSAGES &POPUP
&IF [EXISTS %incov% -COVER] = .TRUE. &THEN
&DO
&SETVAR killit = [QUERY 'Input Coverage '%incov%' exists.  Do you want to replace it' .FALSE]
```

```
&IF %killit% = .TRUE. &THEN
&DO
&MESSAGES &OFF &ALL
KILL %incov% ALL
&MESSAGES &POPUP
&END
&ELSE
&RETURN &WARNING 'Coverage %incov% was not imported.'
&END

&MESSAGES &OFF &ALL
IMPORT COVER %ine00% %incov%

&IF [EXISTS %incov% -COVER] = .FALSE. &THEN
&RETURN &WARNING 'Error: Coverage %incov% was not imported.'
&MESSAGES &OFF &ALL

/*TEMPORARY COVERAGE NAMES
&SETVAR cov_poly = temp_pol
&SETVAR cov_dis = temp_dis
&SETVAR cov_int = temp_int
&SETVAR cov_densify = temp_dens
&SETVAR cov_tempproj = temp_prj
&SETVAR cov_reproj = temp_reprj
&SETVAR lt151 = temp_151
&SETVAR outcov_p = %outcov%_

/*KILL COVERAGES IF THEY ALREADY EXIST
&IF [EXISTS %cov_poly% -COVER] = .TRUE. &THEN
KILL %cov_poly% ALL
&IF [EXISTS %cov_dis% -COVER] = .TRUE. &THEN
KILL %cov_dis% ALL
&IF [EXISTS %cov_int% -COVER] = .TRUE. &THEN
KILL %cov_int% ALL
&IF [EXISTS %cov_densify% -COVER] = .TRUE. &THEN
KILL %cov_densify% ALL
&IF [EXISTS %cov_tempproj% -COVER] = .TRUE. &THEN
KILL %cov_tempproj% ALL
&IF [EXISTS %cov_reproj% -COVER] = .TRUE. &THEN
KILL %cov_reproj% ALL
&IF [EXISTS %lt151% -COVER] = .TRUE. &THEN
KILL %lt151% ALL
&IF [EXISTS %outcov_p% -COVER] = .TRUE. &THEN
KILL %outcov_p% ALL
&IF [EXISTS %outcov%.stat -INFO] = .TRUE. &THEN
KILLINFO %outcov%.stat
&RETURN

&ROUTINE symbology
/***********************************************************
/* remove symbology, duplicate points, clean up
/***********************************************************
/* remove annotation
DROPFEATURES %incov% ANNO.egg GEOMETRY
DROPFEATURES %incov% ANNO.sym GEOMETRY
```

```
/* NODES MAY BE MISSING
BUILD %incov% NODE

&TYPE 'Removing symbology...'
ARCEDIT
EDITCOVER %incov%

/* remove symbol arcs (egg_id <> 0)
EDITFEATURE ARC
SELECT egg_id <> 0
&IF [SHOW NUMBER SELECTED] > 0 &THEN
DELETE
/* remove points asociated with symbol arcs
EDITFEATURE POINT
SELECT pnt_type <> 101 AND pnt_type <> 106 AND pnt_type <> 107
AND pnt_type <> 115 AND pnt_type <> 117 AND pnt_type <> 118 AND
pnt_type <> 120 AND pnt_type <> 122 AND pnt_type <> 123 AND
pnt_type <> 128 AND pnt_type <> 133 AND pnt_type <> 137 AND
pnt_type <> 140 AND pnt_type <> 143 AND pnt_type <> 144 AND
pnt_type <> 400
&IF [SHOW NUMBER SELECTED] > 0 &THEN
DELETE
SAVE ALL YES
QUIT

/* dissolve lines based on line_type
DISSOLVE %incov% %cov_dis% line_type LINE
/* copy points over - they get dropped during dissolve
COPYFEATURES %incov% POINT %cov_dis% POINT
&RETURN

&ROUTINE fixprojection
/*****************************************************************
/* REPROJECT TO WGS84
/*****************************************************************
&TYPE 'Reprojecting data to WGS84, lat-long...'
/*Add NAD27 to projection definition because it may be missing
PROJECTDEFINE COVER %cov_dis%
DATUM NAD27
PARAMETERS
~
~
~
~
~
~

&DESCRIBE %cov_dis%
&IF %PRJ$DATUM% <> 'WGS84' OR %PRJ$NAME% <> 'GEOGRAPHIC' OR
%PRJ$UNITS% <> 'DD' &THEN
&DO
/*ADD VERTEX EVERY 100m TO IMPROVE REJPROJECTION ACCURACY
DENSIFYARC %cov_dis% %cov_densify% 1000 VERTEX
```

```
&IF %PRJ$DATUM% = 'NAD27' &THEN
&DO
/*IF NAD27, FIRST PROJECT TO NAD83 DECIMAL DEGREES
PROJECT COVER %cov_densify% %cov_tempproj%
OUTPUT
PROJECTION GEOGRAPHIC
UNITS DD
DATUM NAD83
SPHEROID GRS80
PARAMETERS
END

/*REDFINE DATUM TO NAR_C SO CONVERSION TO WGS84 IS POSSIBLE
PROJECTDEFINE COVER %cov_tempproj%
PROJECTION GEOGRAPHIC
UNITS DD
DATUM NAR_C
SPHEROID GRS80
PARAMETERS
&END
&ELSE
/*if not NAD27, set new varname to orig input
&SETVAR cov_tempproj = %cov_densify%

/*REPROJECT TO WGS84 DECIMAL DEGREES
PROJECT COVER %cov_tempproj% %outcov%
OUTPUT
PROJECTION GEOGRAPHIC
UNITS DD
DATUM WGS84
SPHEROID WGS84
PARAMETERS
END
&END
&ELSE
&SETVAR outcov = %cov_dis%
&RETURN

&ROUTINE boundbox
/*****************************************************************
/* DRAW BOUNDING POLYGON
/*****************************************************************
&TYPE 'Adding a rectangular boundary...'
/*FIRST REMOVE TICS OUTSIDE OF TRUE COVERAGE EXTENT
REBOX %outcov%
ARCEDIT
&DESCRIBE %outcov%
EDITCOVER %outcov%
EDITFEATURE ARC
COORDINATE KEYBOARD
ADD
2, [CALC %DSC$XMIN% - 0.01], [CALC %DSC$YMAX% + 0.01]
1, [CALC %DSC$XMIN% - 0.01], [CALC %DSC$YMIN% - 0.01]
1, [CALC %DSC$XMAX% + 0.01], [CALC %DSC$YMIN% - 0.01]
1, [CALC %DSC$XMAX% + 0.01], [CALC %DSC$YMAX% + 0.01]
```

```
2, [CALC %DSC$XMIN% - 0.01], [CALC %DSC$YMAX% + 0.01]
9
SAVE ALL YES
&RETURN

&ROUTINE topology
/************************************************************
/* Build polygon topology / get feature codes from points
/************************************************************
&TYPE 'Building topology...'
/* check for LINE_TYPE 151 before exiting AE
ASELECT ALL
SELECT LINE_TYPE = 151
&SETVAR lt151 = [SHOW NUMBER SELECTED]
QUIT

/* Create point-only coverage
COPY %outcov% %outcov_p%
DROPFEATURES %outcov_p% NODE GEOMETRY
DROPFEATURES %outcov_p% LINE GEOMETRY
BUILD %outcov_p% POINT
/* Lose extra fields from coverage
DROPITEM %outcov_p%.pat %outcov_p%.pat egg_id aegg_id egg_name egg_scale user_attr rotation /* egg_attr
/* Build polygon topology
BUILD %outcov% POLY
/* Lose extra fields from coverage
DROPITEM %outcov%.pat %outcov%.pat aegg_id egg_id egg_name egg_scale user_attr rotation

/* IF THERE ARE LINE_TYPE 151 ARCS, FIX TOPOLOGY
&IF %lt151% > 0 &THEN
&DO
/* CREATE RELATES BETWEEN PAT & AAT
RELATE DROP $ALL
RELATE ADD lpol %outcov%.pat INFO lpoly# %outcov%# ORDERED RW
RELATE ADD rpol %outcov%.pat INFO rpoly# %outcov%# ORDERED RW

/* COPY PNT_TYPE TO NEW POLYGONS WITH NO ID VALUES
TABLES
SELECT %outcov%.aat
RESELECT line_type = 151 AND lpol//%outcov%-id = 0
CALCULATE lpol//pnt_type = rpol//pnt_type
CALCULATE lpol//egg_attr = rpol//egg_attr
ASELECT
RESELECT line_type = 151 AND rpol//%outcov%-id = 0
CALCULATE rpol//pnt_type = lpol//pnt_type
CALCULATE rpol//egg_attr = lpol//egg_attr
QUIT
RELATE DROP $ALL
&END

/* add polygon label to bounding rectangle, renumber labels, disassociate them from points
CREATELABELS %outcov%
```

```
/* rebuild to store labels for next build
BUILD %outcov% POLY
&RETURN

&ROUTINE route_region
/***************************************************************
/* CREATE ROUTES AND REGIONS (S-57 FEATURE OBJECTS)
/***************************************************************
&TYPE 'Creating feature and meta objects...'
/*first drop routes and regions if they exist
&IF [EXISTS %outcov% -SECTION.vename] = .TRUE. &THEN
DROPFEATURES %outcov% SECTION.vename
&IF [EXISTS %outcov% -SECTION.icelin] = .TRUE. &THEN
DROPFEATURES %outcov% SECTION.icelin
&IF [EXISTS %outcov% -SECTION.icefra] = .TRUE. &THEN
DROPFEATURES %outcov% SECTION.icefra
&IF [EXISTS %outcov% -SECTION.icelea] = .TRUE. &THEN
DROPFEATURES %outcov% SECTION.icelea
&IF [EXISTS %outcov% -REGION.m_covr] = .TRUE. &THEN
DROPFEATURES %outcov% REGION.m_covr
&IF [EXISTS %outcov% -REGION.m_qual] = .TRUE. &THEN
DROPFEATURES %outcov% REGION.m_qual
&IF [EXISTS %outcov% -REGION.lndare] = .TRUE. &THEN
DROPFEATURES %outcov% REGION.lndare
&IF [EXISTS %outcov% -REGION.depare] = .TRUE. &THEN
DROPFEATURES %outcov% REGION.depare
&IF [EXISTS %outcov% -REGION.seaice] = .TRUE. &THEN
DROPFEATURES %outcov% REGION.seaice
&IF [EXISTS %outcov% -REGION.lacice] = .TRUE. &THEN
DROPFEATURES %outcov% REGION.lacice
&IF [EXISTS %outcov% -REGION.brgare] = .TRUE. &THEN
DROPFEATURES %outcov% REGION.brgare
&IF [EXISTS %outcov% -REGION.seaare] = .TRUE. &THEN
DROPFEATURES %outcov% REGION.seaare

/*"vename" is the required for each arc
ARCROUTE %outcov% vename %outcov%#

/*icelin is the ice limit line
ARCROUTE %outcov% icelin line_type line_type
/*icefra is an ice fracture line
ARCROUTE %outcov% icefra line_type line_type
/*icelea is an ice lead
ARCROUTE %outcov% icelea line_type line_type
/*metadata for coverage and extent of spatial objects within the cell
POLYREGION %outcov% %outcov% m_covr

ARCEDIT
EDITCOVER %outcov%
EDITFEATURE ROUTE.icelin
SELECT line_type <> 133 AND line_type <> 150 AND line_type <> 151 AND line_type <> 162
DELETE
EDITFEATURE ROUTE.icefra
```

```
SELECT line_type <> 171
DELETE
EDITFEATURE ROUTE.icelea
SELECT line_type <> 183 AND line_type <> 190
DELETE
EDITFEATURE REGION.m_covr
SELECT pnt_type <> 0
MERGE SELECT
CALCULATE pnt_type = 999
CALCULATE m_covr-id = 2
QUIT YES

&MESSAGES &OFF
/*required metadata for showing that a uniform quality of data exists
REGIONQUERY %outcov% # m_qual # CONTIGUOUS
RESELECT pnt_type <> 0 /*region <> 'xx'
~
N
N

/*land area
REGIONQUERY %outcov% # lndare # CONTIGUOUS
RESELECT pnt_type = 400
~
N
N

/*depth area
REGIONQUERY %outcov% # depare # CONTIGUOUS
RESELECT pnt_type <> 400 AND pnt_type <> 0 /*region <> 'xx'
~
N
N

/*SEAICE or LACICE area
REGIONQUERY %outcov% # %icetype% # CONTIGUOUS pnt_type egg_attr
RESELECT pnt_type <> 115 AND pnt_type <> 400 AND pnt_type <> 0 /*region <> 'xx' AND pnt_type <> 101
~
N
N

/*brgare area
REGIONQUERY %outcov% # brgare # CONTIGUOUS pnt_type egg_attr
RESELECT pnt_type = 101
~
N
N

/*sea area
REGIONQUERY %outcov% # seaare # CONTIGUOUS
RESELECT pnt_type = 115
~
N
```

```
N
&MESSAGES &OFF &ALL
&RETURN

&ROUTINE vrid
&TYPE 'Setting up RCID field...'
TABLES
/*WILL FORM PART OF VRID
ADDITEM %outcov%.ratvename name 12 12 C
ADDITEM %outcov%.ratvename rver 2 6 B
ADDITEM %outcov%.ratvename ruin 1 1 C
ADDITEM %outcov%.ratvename hordat 2 6 B
ADDITEM %outcov%.ratvename posacc 4 8 F 2
ADDITEM %outcov%.ratvename quapos 2 6 B
ADDITEM %outcov%.ratvename usag 1 1 C

&SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -ROUTE.vename name -FULLDEF]]
SELECT %outcov%.ratvename
REDEFINE
%starcol% rcnm 2 2 C /*13
[CALC %starcol% + 2] rcid 10 10 C /*15
~

SELECT %outcov%.ratvename
CALCULATE rcnm = "VE"
CALCULATE rcid = ""
CALCULATE rver = 1
CALCULATE ruin = "I"
CALCULATE hordat = 2 /* this is WGS84
CALCULATE posacc = -9998
CALCULATE quapos = -9998
CALCULATE usag = "E"

/*WORK THE NAT
ADDITEM %outcov%.nat name 12 12 C
ADDITEM %outcov%.nat rver 2 6 B
ADDITEM %outcov%.nat ruin 1 1 C
ADDITEM %outcov%.nat hordat 2 6 B
ADDITEM %outcov%.nat posacc 4 8 F 2
ADDITEM %outcov%.nat quapos 2 6 B
ADDITEM %outcov%.nat temp 10 10 I

&SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -NODE name -FULLDEF]]
SELECT %outcov%.nat
REDEFINE
%starcol% rcnm 2 2 C /*14
[CALC %starcol% + 2] rcid 10 10 C /*16
~

SELECT %outcov%.nat
CALCULATE rcnm = "VC"
CALCULATE rcid = ""
CALCULATE rver = 1
```

```
CALCULATE ruin = "I"
CALCULATE hordat = 2 /* this is WGS84
CALCULATE posacc = -9998
CALCULATE quapos = -9998
CALCULATE temp = %outcov%#
QUIT
&RETURN

&ROUTINE pop_rcid
&TYPE 'Populating RCID field...'
&SETVAR idval = 1
/*ROUTE
CURSOR uid DECLARE %outcov%.ratvename INFO RW
CURSOR uid OPEN
&DO &WHILE %:uid.aml$next% = .TRUE.
&SETVAR :uid.rcid = %idval%
&DO &WHILE [LENGTH %:uid.rcid%] < 10
&SETVAR :uid.rcid = 0%:uid.rcid%
&END
&SETVAR idval = %idval% + 1
CURSOR uid NEXT
&END
CURSOR uid CLOSE
CURSOR uid REMOVE

/*NAT
CURSOR uid DECLARE %outcov%.nat INFO RW
CURSOR uid OPEN
&DO &WHILE %:uid.aml$next% = .TRUE.
&SETVAR :uid.rcid = %:uid.temp%
&DO &WHILE [LENGTH %:uid.rcid%] < 10
&SETVAR :uid.rcid = 0%:uid.rcid%
&END
CURSOR uid NEXT
&END
CURSOR uid CLOSE
CURSOR uid REMOVE

DROPITEM %outcov%.nat %outcov%.nat temp
&RETURN

&ROUTINE pop_region
&TYPE 'Adding attributes to feature and meta objects...'
TABLES
/*M_COVR
ADDITEM %outcov%.patm_covr lnam 17 17 C
ADDITEM %outcov%.patm_covr name 12 12 C
ADDITEM %outcov%.patm_covr rver 2 6 B
ADDITEM %outcov%.patm_covr ruin 1 1 C
ADDITEM %outcov%.patm_covr grup 2 6 B
ADDITEM %outcov%.patm_covr catcov 2 6 B

&SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -REGION.m_covr
lnam -FULLDEF]]
SELECT %outcov%.patm_covr
```

```
REDEFINE
%starcol% agen 2 2 C /*25
[CALC %starcol% + 2] fidn 10 10 C /*27
[CALC %starcol% + 12] fids 5 5 C /*37
[CALC %starcol% + 17] rcnm 2 2 C /*42
[CALC %starcol% + 19] rcid 10 10 C /*44
~

CALCULATE agen = "CA"
CALCULATE fidn = ""
CALCULATE fids = "00000"
CALCULATE rcnm = "FE"
CALCULATE rcid = ""
CALCULATE rver = 1
CALCULATE ruin = "I"
CALCULATE grup = 2

RESELECT pnt_type <> 0 /*region <> 'xx'
CALCULATE catcov = 1

NSELECT
CALCULATE catcov = 2

/*M_QUAL
ADDITEM %outcov%.patm_qual lnam 17 17 C
ADDITEM %outcov%.patm_qual name 12 12 C
ADDITEM %outcov%.patm_qual rver 2 6 B
ADDITEM %outcov%.patm_qual ruin 1 1 C
ADDITEM %outcov%.patm_qual grup 2 6 B
/*  ADDITEM %outcov%.patm_qual catqua 2 6 B
ADDITEM %outcov%.patm_qual catzoc 2 6 B
ADDITEM %outcov%.patm_qual drval1 4 8 F 2
ADDITEM %outcov%.patm_qual drval2 4 8 F 2
ADDITEM %outcov%.patm_qual posacc 4 8 F 2
ADDITEM %outcov%.patm_qual souacc 4 8 F 2
ADDITEM %outcov%.patm_qual surend 8 8 C
ADDITEM %outcov%.patm_qual sursta 8 8 C
ADDITEM %outcov%.patm_qual tecsou 70 70 C
ADDITEM %outcov%.patm_qual verdat 2 6 B

&SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -REGION.m_qual
lnam -FULLDEF]]
SELECT %outcov%.patm_qual
REDEFINE
%starcol% agen 2 2 C /*25
[CALC %starcol% + 2] fidn 10 10 C /*27
[CALC %starcol% + 12] fids 5 5 C /*37
[CALC %starcol% + 17] rcnm 2 2 C /*42
[CALC %starcol% + 19] rcid 10 10 C /*44
~

CALCULATE agen = "CA"
CALCULATE fidn = ""
CALCULATE fids = "00000"
CALCULATE rcnm = "FE"
```

```
CALCULATE rcid = ""
CALCULATE rver = 1
CALCULATE ruin = "I"
CALCULATE grup = 2
/*  CALCULATE catqua = 5
CALCULATE catzoc = 6
CALCULATE drval1 = -9998
CALCULATE drval2 = -9998
CALCULATE posacc = -9998
CALCULATE souacc = -9998
CALCULATE surend = "[SUBSTR [DATE -YEAR] 1 2][DATE -TAG]"
CALCULATE sursta = "[SUBSTR [DATE -YEAR] 1 2][DATE -TAG]"
CALCULATE tecsou = "IGNORED"
CALCULATE verdat = -9998

/*LAND
ADDITEM %outcov%.patlndare lnam 17 17 C
ADDITEM %outcov%.patlndare name 12 12 C
ADDITEM %outcov%.patlndare rver 2 6 B
ADDITEM %outcov%.patlndare ruin 1 1 C
ADDITEM %outcov%.patlndare grup 2 6 B
ADDITEM %outcov%.patlndare condtn 2 6 B
ADDITEM %outcov%.patlndare objnam 70 70 C
ADDITEM %outcov%.patlndare nobjnm 70 70 C
ADDITEM %outcov%.patlndare status 70 70 C

&SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -REGION.lndare
lnam -FULLDEF]]
SELECT %outcov%.patlndare
REDEFINE
%starcol% agen 2 2 C /*25
[CALC %starcol% + 2] fidn 10 10 C /*27
[CALC %starcol% + 12] fids 5 5 C /*37
[CALC %starcol% + 17] rcnm 2 2 C /*42
[CALC %starcol% + 19] rcid 10 10 C /*44
~

CALCULATE agen = "CA"
CALCULATE fidn = ""
CALCULATE fids = "00000"
CALCULATE rcnm = "FE"
CALCULATE rcid = ""
CALCULATE rver = 1
CALCULATE ruin = "I"
CALCULATE grup = 1
CALCULATE condtn = -9998
CALCULATE objnam = "IGNORED"
CALCULATE nobjnm = "IGNORED"
CALCULATE status = "1"

/*DEEP
ADDITEM %outcov%.patdepare lnam 17 17 C
ADDITEM %outcov%.patdepare name 12 12 C
ADDITEM %outcov%.patdepare rver 2 6 B
ADDITEM %outcov%.patdepare ruin 1 1 C
```

```
ADDITEM %outcov%.patdepare grup 2 6 B
ADDITEM %outcov%.patdepare drval1 4 8 F 2
ADDITEM %outcov%.patdepare drval2 4 8 F 2
ADDITEM %outcov%.patdepare quasou 70 70 C
ADDITEM %outcov%.patdepare souacc 4 8 F 2
ADDITEM %outcov%.patdepare verdat 2 6 B

&SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -REGION.depare
lnam -FULLDEF]]
SELECT %outcov%.patdepare
REDEFINE
%starcol% agen 2 2 C /*25
[CALC %starcol% + 2] fidn 10 10 C /*27
[CALC %starcol% + 12] fids 5 5 C /*37
[CALC %starcol% + 17] rcnm 2 2 C /*42
[CALC %starcol% + 19] rcid 10 10 C /*44
~

CALCULATE agen = "CA"
CALCULATE fidn = ""
CALCULATE fids = "00000"
CALCULATE rcnm = "FE"
CALCULATE rcid = ""
CALCULATE rver = 1
CALCULATE ruin = "I"
CALCULATE grup = 1
CALCULATE drval1 = 0
CALCULATE drval2 = 10000
CALCULATE quasou = "IGNORED"
CALCULATE souacc = -9998
CALCULATE verdat = -9998

/*SEAICE or LACICE
ADDITEM %outcov%.pat%icetype% lnam 17 17 C
ADDITEM %outcov%.pat%icetype% name 12 12 C
ADDITEM %outcov%.pat%icetype% rver 2 6 B
ADDITEM %outcov%.pat%icetype% ruin 1 1 C
ADDITEM %outcov%.pat%icetype% grup 2 6 B
ADDITEM %outcov%.pat%icetype% nobjnm 70 70 C
ADDITEM %outcov%.pat%icetype% objnam 70 70 C
ADDITEM %outcov%.pat%icetype% iceact 2 6 B
ADDITEM %outcov%.pat%icetype% iceapc 70 70 C
&IF [LOCASE %icetype%] = 'seaice' &THEN
ADDITEM %outcov%.pat%icetype% icesod 70 70 C
&ELSE
ADDITEM %outcov%.pat%icetype% icelso 70 70 C
ADDITEM %outcov%.pat%icetype% iceflz 70 70 C
ADDITEM %outcov%.pat%icetype% icecvt 2 6 B
ADDITEM %outcov%.pat%icetype% icemax 4 8 F 2
ADDITEM %outcov%.pat%icetype% icemin 4 8 F 2
ADDITEM %outcov%.pat%icetype% icemlt 2 6 B
ADDITEM %outcov%.pat%icetype% icescv 2 6 B
ADDITEM %outcov%.pat%icetype% icerdv 2 6 B
ADDITEM %outcov%.pat%icetype% icercn 2 6 B
ADDITEM %outcov%.pat%icetype% icedos 2 6 B
```

```
&SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -REGION.%icetype%
lnam -FULLDEF]]
SELECT %outcov%.pat%icetype%
REDEFINE
%starcol% agen 2 2 C /*25
[CALC %starcol% + 2] fidn 10 10 C /*27
[CALC %starcol% + 12] fids 5 5 C /*37
[CALC %starcol% + 17] rcnm 2 2 C /*42
[CALC %starcol% + 19] rcid 10 10 C /*44
~

CALCULATE agen = "CA"
CALCULATE fidn = ""
CALCULATE fids = "00000"
CALCULATE rcnm = "FE"
CALCULATE rcid = ""
CALCULATE rver = 1
CALCULATE ruin = "I"
CALCULATE grup = 2
CALCULATE objnam = "IGNORED"
CALCULATE nobjnm = "IGNORED"
/* iceact, iceapc, icesod, icelso, iceflz are extracted from the
egg code
CALCULATE icecvt = -9998
CALCULATE icemax = -9998
CALCULATE icemin = -9998
CALCULATE icemlt = -9998
CALCULATE icescv = -9998
CALCULATE icerdv = -9998
CALCULATE icercn = -9998
CALCULATE icedos = -9998

/*SEA
ADDITEM %outcov%.patseaare lnam 17 17 C
ADDITEM %outcov%.patseaare name 12 12 C
ADDITEM %outcov%.patseaare rver 2 6 B
ADDITEM %outcov%.patseaare ruin 1 1 C
ADDITEM %outcov%.patseaare grup 2 6 B
ADDITEM %outcov%.patseaare objnam 70 70 C
ADDITEM %outcov%.patseaare nobjnm 70 70 C
ADDITEM %outcov%.patseaare catsea 2 6 B

&SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -REGION.seaare
lnam -FULLDEF]]
SELECT %outcov%.patseaare
REDEFINE
%starcol% agen 2 2 C /*25
[CALC %starcol% + 2] fidn 10 10 C /*27
[CALC %starcol% + 12] fids 5 5 C /*37
[CALC %starcol% + 17] rcnm 2 2 C /*42
[CALC %starcol% + 19] rcid 10 10 C /*44
~

CALCULATE agen = "CA"
```

```
CALCULATE fidn = ""
CALCULATE fids = "00000"
CALCULATE rcnm = "FE"
CALCULATE rcid = ""
CALCULATE rver = 1
CALCULATE ruin = "I"
CALCULATE grup = 2
CALCULATE objnam = "IGNORED"
CALCULATE nobjnm = "IGNORED"
CALCULATE catsea = 2

/*BRGARE
ADDITEM %outcov%.patbrgare lnam 17 17 C
ADDITEM %outcov%.patbrgare name 12 12 C
ADDITEM %outcov%.patbrgare rver 2 6 B
ADDITEM %outcov%.patbrgare ruin 1 1 C
ADDITEM %outcov%.patbrgare grup 2 6 B
ADDITEM %outcov%.patbrgare objnam 70 70 C
ADDITEM %outcov%.patbrgare nobjnm 70 70 C
ADDITEM %outcov%.patbrgare icebnm 4 8 F 2

&SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -REGION.brgare
lnam -FULLDEF]]
SELECT %outcov%.patbrgare
REDEFINE
%starcol% agen 2 2 C /*25
[CALC %starcol% + 2] fidn 10 10 C /*27
[CALC %starcol% + 12] fids 5 5 C /*37
[CALC %starcol% + 17] rcnm 2 2 C /*42
[CALC %starcol% + 19] rcid 10 10 C /*44
~

CALCULATE agen = "CA"
CALCULATE fidn = ""
CALCULATE fids = "00000"
CALCULATE rcnm = "FE"
CALCULATE rcid = ""
CALCULATE rver = 1
CALCULATE ruin = "I"
CALCULATE grup = 2
CALCULATE objnam = "IGNORED"
CALCULATE nobjnm = "IGNORED"
CALCULATE icebnm = -9998

/*ICELIN
ADDITEM %outcov%.raticelin lnam 17 17 C
ADDITEM %outcov%.raticelin name 12 12 C
ADDITEM %outcov%.raticelin rver 2 6 B
ADDITEM %outcov%.raticelin ruin 1 1 C
ADDITEM %outcov%.raticelin grup 2 6 B
ADDITEM %outcov%.raticelin objnam 70 70 C
ADDITEM %outcov%.raticelin nobjnm 70 70 C
ADDITEM %outcov%.raticelin icelnc 2 6 B
```

```
&SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -ROUTE.icelin lnam -FULLDEF]]
SELECT %outcov%.raticelin
REDEFINE
%starcol% agen 2 2 C /*25
[CALC %starcol% + 2] fidn 10 10 C /*27
[CALC %starcol% + 12] fids 5 5 C /*37
[CALC %starcol% + 17] rcnm 2 2 C /*42
[CALC %starcol% + 19] rcid 10 10 C /*44
~

CALCULATE agen = "CA"
CALCULATE fidn = ""
CALCULATE fids = "00000"
CALCULATE rcnm = "FE"
CALCULATE rcid = ""
CALCULATE rver = 1
CALCULATE ruin = "I"
CALCULATE grup = 2
CALCULATE objnam = "IGNORED"
CALCULATE nobjnm = "IGNORED"

RESELECT line_type = 133
CALCULATE icelnc = 5

SELECT %outcov%.raticelin
RESELECT line_type = 150 OR line_type = 151
CALCULATE icelnc = 7

SELECT %outcov%.raticelin
RESELECT line_type = 162
CALCULATE icelnc = 6

/*ICEFRA
ADDITEM %outcov%.raticefra lnam 17 17 C
ADDITEM %outcov%.raticefra name 12 12 C
ADDITEM %outcov%.raticefra rver 2 6 B
ADDITEM %outcov%.raticefra ruin 1 1 C
ADDITEM %outcov%.raticefra grup 2 6 B
ADDITEM %outcov%.raticefra objnam 70 70 C
ADDITEM %outcov%.raticefra nobjnm 70 70 C
ADDITEM %outcov%.raticefra icefty 2 6 B

&SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -ROUTE.icefra lnam -FULLDEF]]
SELECT %outcov%.raticefra
REDEFINE
%starcol% agen 2 2 C /*25
[CALC %starcol% + 2] fidn 10 10 C /*27
[CALC %starcol% + 12] fids 5 5 C /*37
[CALC %starcol% + 17] rcnm 2 2 C /*42
[CALC %starcol% + 19] rcid 10 10 C /*44
~

CALCULATE agen = "CA"
```

```
CALCULATE fidn = ""
CALCULATE fids = "00000"
CALCULATE rcnm = "FE"
CALCULATE rcid = ""
CALCULATE rver = 1
CALCULATE ruin = "I"
CALCULATE grup = 2
CALCULATE objnam = "IGNORED"
CALCULATE nobjnm = "IGNORED"
CALCULATE icefty = 8

/*ICELEA
ADDITEM %outcov%.raticelea lnam 17 17 C
ADDITEM %outcov%.raticelea name 12 12 C
ADDITEM %outcov%.raticelea rver 2 6 B
ADDITEM %outcov%.raticelea ruin 1 1 C
ADDITEM %outcov%.raticelea grup 2 6 B
ADDITEM %outcov%.raticelea objnam 70 70 C
ADDITEM %outcov%.raticelea nobjnm 70 70 C
ADDITEM %outcov%.raticelea icelty 2 6 B
ADDITEM %outcov%.raticelea icelst 2 6 B

&SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -ROUTE.icelea lnam -FULLDEF]]
SELECT %outcov%.raticelea
REDEFINE
%starcol% agen 2 2 C /*25
[CALC %starcol% + 2] fidn 10 10 C /*27
[CALC %starcol% + 12] fids 5 5 C /*37
[CALC %starcol% + 17] rcnm 2 2 C /*42
[CALC %starcol% + 19] rcid 10 10 C /*44
~

CALCULATE agen = "CA"
CALCULATE fidn = ""
CALCULATE fids = "00000"
CALCULATE rcnm = "FE"
CALCULATE rcid = ""
CALCULATE rver = 1
CALCULATE ruin = "I"
CALCULATE grup = 2
CALCULATE objnam = "IGNORED"
CALCULATE nobjnm = "IGNORED"
CALCULATE icelty = 1
CALCULATE icelst = 1
QUIT

&TYPE 'Assigning unique RCID values to each object...'

&SETVAR idval = 1
/*UNIQUE IDs FOR M_COVR
CURSOR uid DECLARE %outcov%.patm_covr INFO RW
CURSOR uid OPEN
&DO &WHILE %:uid.aml$next% = .TRUE.
&SETVAR :uid.rcid = %idval%
```

```
&SETVAR :uid.fidn = %idval%
&DO &WHILE [LENGTH %:uid.rcid%] < 10
&SETVAR :uid.rcid = 0%:uid.rcid%
&SETVAR :uid.fidn = 0%:uid.fidn%
&END
&SETVAR idval = %idval% + 1
CURSOR uid NEXT
&END
CURSOR uid CLOSE
CURSOR uid REMOVE

/*UNIQUE IDs FOR M_QUAL
CURSOR uid DECLARE %outcov%.patm_qual INFO RW
CURSOR uid OPEN
&DO &WHILE %:uid.aml$next% = .TRUE.
&SETVAR :uid.rcid = %idval%
&SETVAR :uid.fidn = %idval%
&DO &WHILE [LENGTH %:uid.rcid%] < 10
&SETVAR :uid.rcid = 0%:uid.rcid%
&SETVAR :uid.fidn = 0%:uid.fidn%
&END
&SETVAR idval = %idval% + 1
CURSOR uid NEXT
&END
CURSOR uid CLOSE
CURSOR uid REMOVE

/*UNIQUE IDs FOR LNDARE
CURSOR uid DECLARE %outcov%.patlndare INFO RW
CURSOR uid OPEN
&DO &WHILE %:uid.aml$next% = .TRUE.
&SETVAR :uid.rcid = %idval%
&SETVAR :uid.fidn = %idval%
&DO &WHILE [LENGTH %:uid.rcid%] < 10
&SETVAR :uid.rcid = 0%:uid.rcid%
&SETVAR :uid.fidn = 0%:uid.fidn%
&END
&SETVAR idval = %idval% + 1
CURSOR uid NEXT
&END
CURSOR uid CLOSE
CURSOR uid REMOVE

/*UNIQUE IDs FOR DEPARE
CURSOR uid DECLARE %outcov%.patdepare INFO RW
CURSOR uid OPEN
&DO &WHILE %:uid.aml$next% = .TRUE.
&SETVAR :uid.rcid = %idval%
&SETVAR :uid.fidn = %idval%
&DO &WHILE [LENGTH %:uid.rcid%] < 10
&SETVAR :uid.rcid = 0%:uid.rcid%
&SETVAR :uid.fidn = 0%:uid.fidn%
&END
&SETVAR idval = %idval% + 1
CURSOR uid NEXT
```

```
&END
CURSOR uid CLOSE
CURSOR uid REMOVE

/*UNIQUE IDs FOR SEAICE
/*ALSO EXTRACT EGG CODES HERE
CURSOR uid DECLARE %outcov%.pat%icetype% INFO RW
CURSOR uid OPEN
&DO &WHILE %:uid.aml$next% = .TRUE.
&SETVAR :uid.rcid = %idval%
&SETVAR :uid.fidn = %idval%
&DO &WHILE [LENGTH %:uid.rcid%] < 10
&SETVAR :uid.rcid = 0%:uid.rcid%
&SETVAR :uid.fidn = 0%:uid.fidn%
&END

&IF [NULL %:uid.egg_attr%] = .FALSE. &THEN
&DO
&SETVAR egg_string = [SUBST %:uid.egg_attr% '_' ',']
/* ICEACT (Ct)
&SELECT [EXTRACT 1 %egg_string%]
&WHEN 1
&SETVAR :uid.iceact = 1
&WHEN 2
&SETVAR :uid.iceact = 2
&WHEN 3
&SETVAR :uid.iceact = 3
&WHEN 4
&SETVAR :uid.iceact = 4
&WHEN 5
&SETVAR :uid.iceact = 5
&WHEN 6
&SETVAR :uid.iceact = 6
&WHEN 7
&SETVAR :uid.iceact = 7
&WHEN 8
&SETVAR :uid.iceact = 8
&WHEN 9
&SETVAR :uid.iceact = 9
&WHEN 9+
&SETVAR :uid.iceact = 15
&WHEN 10
&SETVAR :uid.iceact = 16
&WHEN @
&SETVAR :uid.iceact = 17
&END

/* ICEAPC (Ca)
&SELECT [EXTRACT 2 %egg_string%]
&WHEN 1
&SETVAR :uid.iceapc = 1
&WHEN 2
&SETVAR :uid.iceapc = 2
&WHEN 3
&SETVAR :uid.iceapc = 3
```

```
&WHEN 4
&SETVAR :uid.iceapc = 4
&WHEN 5
&SETVAR :uid.iceapc = 5
&WHEN 6
&SETVAR :uid.iceapc = 6
&WHEN 7
&SETVAR :uid.iceapc = 7
&WHEN 8
&SETVAR :uid.iceapc = 8
&WHEN 9
&SETVAR :uid.iceapc = 9
&WHEN 9+
&SETVAR :uid.iceapc = 10
&WHEN 10
&SETVAR :uid.iceapc = 11
&WHEN @
&SETVAR :uid.iceapc = 13
&END

/* ICEAPC (Cb,Cc,Cd)
&DO i = 3 &TO 5
&SELECT [EXTRACT %i% %egg_string%]
&WHEN 1
&SETVAR :uid.iceapc = %:uid.iceapc%,1
&WHEN 2
&SETVAR :uid.iceapc = %:uid.iceapc%,2
&WHEN 3
&SETVAR :uid.iceapc = %:uid.iceapc%,3
&WHEN 4
&SETVAR :uid.iceapc = %:uid.iceapc%,4
&WHEN 5
&SETVAR :uid.iceapc = %:uid.iceapc%,5
&WHEN 6
&SETVAR :uid.iceapc = %:uid.iceapc%,6
&WHEN 7
&SETVAR :uid.iceapc = %:uid.iceapc%,7
&WHEN 8
&SETVAR :uid.iceapc = %:uid.iceapc%,8
&WHEN 9
&SETVAR :uid.iceapc = %:uid.iceapc%,9
&WHEN 9+
&SETVAR :uid.iceapc = %:uid.iceapc%,10
&WHEN 10
&SETVAR :uid.iceapc = %:uid.iceapc%,11
&WHEN @
&SETVAR :uid.iceapc = %:uid.iceapc%,13
&END
&END

&IF [LOCASE %icetype%] = 'seaice' &THEN
&DO
/* ICESOD (So)
&SELECT [EXTRACT 6 %egg_string%]
&WHEN @
```

```
&SETVAR :uid.icesod = 0
&WHEN 1
&SETVAR :uid.icesod = 1
&WHEN 2
&SETVAR :uid.icesod = 2
&WHEN 3
&SETVAR :uid.icesod = 3
&WHEN 4
&SETVAR :uid.icesod = 4
&WHEN 5
&SETVAR :uid.icesod = 5
&WHEN 6
&SETVAR :uid.icesod = 6
&WHEN 7
&SETVAR :uid.icesod = 7
&WHEN 8
&SETVAR :uid.icesod = 7
&WHEN 9
&SETVAR :uid.icesod = 7
&WHEN 1.
&SETVAR :uid.icesod = 8
&WHEN 4.
&SETVAR :uid.icesod = 9
&WHEN 7.
&SETVAR :uid.icesod = 10
&WHEN 8.
&SETVAR :uid.icesod = 11
&WHEN 9.
&SETVAR :uid.icesod = 12
&WHEN ^.
&SETVAR :uid.icesod = 13
&WHEN X
&SETVAR :uid.icesod = 14
&END

/* ICESOD (Sa,Sb,Sc,Sd,Se)
&DO i = 7 &TO 11
&SELECT [EXTRACT %i% %egg_string%]
&WHEN @
&SETVAR :uid.icesod = %:uid.icesod%,0
&WHEN 1
&SETVAR :uid.icesod = %:uid.icesod%,1
&WHEN 2
&SETVAR :uid.icesod = %:uid.icesod%,2
&WHEN 3
&SETVAR :uid.icesod = %:uid.icesod%,3
&WHEN 4
&SETVAR :uid.icesod = %:uid.icesod%,4
&WHEN 5
&SETVAR :uid.icesod = %:uid.icesod%,5
&WHEN 6
&SETVAR :uid.icesod = %:uid.icesod%,6
&WHEN 7
&SETVAR :uid.icesod = %:uid.icesod%,7
&WHEN 8
```

```
&SETVAR :uid.icesod = %:uid.icesod%,7
&WHEN 9
&SETVAR :uid.icesod = %:uid.icesod%,7
&WHEN 1.
&SETVAR :uid.icesod = %:uid.icesod%,8
&WHEN 4.
&SETVAR :uid.icesod = %:uid.icesod%,9
&WHEN 7.
&SETVAR :uid.icesod = %:uid.icesod%,10
&WHEN 8.
&SETVAR :uid.icesod = %:uid.icesod%,11
&WHEN 9.
&SETVAR :uid.icesod = %:uid.icesod%,12
&WHEN ^.
&SETVAR :uid.icesod = %:uid.icesod%,13
&WHEN X
&SETVAR :uid.icesod = %:uid.icesod%,14
&END
&END
&END
&ELSE
&DO
/* ICESLO (So)
&SELECT [EXTRACT 6 %egg_string%]
&WHEN @
&SETVAR :uid.icelso = 0
&WHEN 1
&SETVAR :uid.icelso = 1
&WHEN 4
&SETVAR :uid.icelso = 2
&WHEN 5
&SETVAR :uid.icelso = 3
&WHEN 7
&SETVAR :uid.icelso = 4
&WHEN 1.
&SETVAR :uid.icelso = 5
&WHEN X
&SETVAR :uid.icelso = 6
&END

/* ICESLO (Sa,Sb,Sc,Sd,Se)
&DO i = 7 &TO 11
&SELECT [EXTRACT %i% %egg_string%]
&WHEN @
&SETVAR :uid.icelso = %:uid.icelso%,0
&WHEN 1
&SETVAR :uid.icelso = %:uid.icelso%,1
&WHEN 4
&SETVAR :uid.icelso = %:uid.icelso%,2
&WHEN 5
&SETVAR :uid.icelso = %:uid.icelso%,3
&WHEN 7
&SETVAR :uid.icelso = %:uid.icelso%,4
&WHEN 1.
&SETVAR :uid.icelso = %:uid.icelso%,5
```

```
&WHEN X
&SETVAR :uid.icelso = %:uid.icelso%,6
&END
&END
&END

/* ICEFLZ (Fa)
&SELECT [EXTRACT 12 %egg_string%]
&WHEN 0
&SETVAR :uid.iceflz = 1
&WHEN 1
&SETVAR :uid.iceflz = 2
&WHEN 2
&SETVAR :uid.iceflz = 3
&WHEN 3
&SETVAR :uid.iceflz = 4
&WHEN 4
&SETVAR :uid.iceflz = 5
&WHEN 5
&SETVAR :uid.iceflz = 6
&WHEN 6
&SETVAR :uid.iceflz = 7
&WHEN 7
&SETVAR :uid.iceflz = 8
&WHEN 8
&SETVAR :uid.iceflz = 9
&WHEN 9
&SETVAR :uid.iceflz = 10
&WHEN @
&SETVAR :uid.iceflz = 11
&WHEN X
&SETVAR :uid.iceflz = 12
&END

/* ICEFLZ (Fb,Fc,Fd,Fe)
&DO i = 13 &TO 16
&SELECT [EXTRACT %i% %egg_string%]
&WHEN 0
&SETVAR :uid.iceflz = %:uid.iceflz%,1
&WHEN 1
&SETVAR :uid.iceflz = %:uid.iceflz%,2
&WHEN 2
&SETVAR :uid.iceflz = %:uid.iceflz%,3
&WHEN 3
&SETVAR :uid.iceflz = %:uid.iceflz%,4
&WHEN 4
&SETVAR :uid.iceflz = %:uid.iceflz%,5
&WHEN 5
&SETVAR :uid.iceflz = %:uid.iceflz%,6
&WHEN 6
&SETVAR :uid.iceflz = %:uid.iceflz%,7
&WHEN 7
&SETVAR :uid.iceflz = %:uid.iceflz%,8
&WHEN 8
&SETVAR :uid.iceflz = %:uid.iceflz%,9
```

```
&WHEN 9
&SETVAR :uid.iceflz = %:uid.iceflz%,10
&WHEN @
&SETVAR :uid.iceflz = %:uid.iceflz%,12
&WHEN X
&SETVAR :uid.iceflz = %:uid.iceflz%,12
&END
&END

&END

&ELSE
/* bergy water not in egg code
&IF %:uid.pnt_type% = 101 &THEN
&SETVAR :uid.iceact = 17

/* fast ice not in egg code
&IF %:uid.pnt_type% = 106 &THEN
&SETVAR :uid.iceact = 16

/* open water not in egg code
&IF %:uid.pnt_type% = 107 &THEN
&SETVAR :uid.iceact = 17

&SETVAR idval = %idval% + 1
CURSOR uid NEXT
&END
CURSOR uid CLOSE
CURSOR uid REMOVE

/*UNIQUE IDs FOR BRGARE
CURSOR uid DECLARE %outcov%.patbrgare INFO RW
CURSOR uid OPEN
&DO &WHILE %:uid.aml$next% = .TRUE.
&SETVAR :uid.rcid = %idval%
&SETVAR :uid.fidn = %idval%
&DO &WHILE [LENGTH %:uid.rcid%] < 10
&SETVAR :uid.rcid = 0%:uid.rcid%
&SETVAR :uid.fidn = 0%:uid.fidn%
&END
&SETVAR idval = %idval% + 1
CURSOR uid NEXT
&END
CURSOR uid CLOSE
CURSOR uid REMOVE

/*UNIQUE IDs FOR SEAARE
CURSOR uid DECLARE %outcov%.patseaare INFO RW
CURSOR uid OPEN
&DO &WHILE %:uid.aml$next% = .TRUE.
&SETVAR :uid.rcid = %idval%
&SETVAR :uid.fidn = %idval%
&DO &WHILE [LENGTH %:uid.rcid%] < 10
&SETVAR :uid.rcid = 0%:uid.rcid%
&SETVAR :uid.fidn = 0%:uid.fidn%
```

```
&END
&SETVAR idval = %idval% + 1
CURSOR uid NEXT
&END
CURSOR uid CLOSE
CURSOR uid REMOVE

/*UNIQUE IDs FOR ICELIN
CURSOR uid DECLARE %outcov%.raticelin INFO RW
CURSOR uid OPEN
&DO &WHILE %:uid.aml$next% = .TRUE.
&SETVAR :uid.rcid = %idval%
&SETVAR :uid.fidn = %idval%
&DO &WHILE [LENGTH %:uid.rcid%] < 10
&SETVAR :uid.rcid = 0%:uid.rcid%
&SETVAR :uid.fidn = 0%:uid.fidn%
&END
&SETVAR idval = %idval% + 1
CURSOR uid NEXT
&END
CURSOR uid CLOSE
CURSOR uid REMOVE

/*UNIQUE IDs FOR ICEFRA
CURSOR uid DECLARE %outcov%.raticefra INFO RW
CURSOR uid OPEN
&DO &WHILE %:uid.aml$next% = .TRUE.
&SETVAR :uid.rcid = %idval%
&SETVAR :uid.fidn = %idval%
&DO &WHILE [LENGTH %:uid.rcid%] < 10
&SETVAR :uid.rcid = 0%:uid.rcid%
&SETVAR :uid.fidn = 0%:uid.fidn%
&END
&SETVAR idval = %idval% + 1
CURSOR uid NEXT
&END
CURSOR uid CLOSE
CURSOR uid REMOVE

/*UNIQUE IDs FOR ICELEA
CURSOR uid DECLARE %outcov%.raticelea INFO RW
CURSOR uid OPEN
&DO &WHILE %:uid.aml$next% = .TRUE.
&SETVAR :uid.rcid = %idval%
&SETVAR :uid.fidn = %idval%
&DO &WHILE [LENGTH %:uid.rcid%] < 10
&SETVAR :uid.rcid = 0%:uid.rcid%
&SETVAR :uid.fidn = 0%:uid.fidn%
&END
&SETVAR idval = %idval% + 1
CURSOR uid NEXT
&END
CURSOR uid CLOSE
CURSOR uid REMOVE
&RETURN
```

```
&ROUTINE attr
&TYPE 'Adding B-level and C-level attributes to feature objects...'
&IF [EXISTS %outcov%.attr -INFO] = .TRUE. &THEN
KILLINFO %outcov%.attr
&DO i &LIST A B C D E F G H
&IF [EXISTS %outcov%.attr_%i% -INFO] = .TRUE. &THEN
KILLINFO %outcov%.attr_%i%
&END

/*ATTR
PULLITEMS %outcov%.pat%icetype% %outcov%.attr lnam
PULLITEMS %outcov%.pat%icetype% %outcov%.attr_a lnam egg_attr
PULLITEMS %outcov%.patlndare %outcov%.attr_b lnam
PULLITEMS %outcov%.patdepare %outcov%.attr_c lnam
PULLITEMS %outcov%.patseaare %outcov%.attr_d lnam
PULLITEMS %outcov%.patbrgare %outcov%.attr_e lnam
PULLITEMS %outcov%.raticelin %outcov%.attr_f lnam
PULLITEMS %outcov%.raticefra %outcov%.attr_g lnam
PULLITEMS %outcov%.raticelea %outcov%.attr_h lnam

&DATA ARC INFO
&MESSAGES &OFF &ALL
ARC
SELECT [UPCASE %outcov%].ATTR_B
MERGE INTO [UPCASE %outcov%].ATTR ON LNAM
SELECT [UPCASE %outcov%].ATTR_C
MERGE INTO [UPCASE %outcov%].ATTR ON LNAM
SELECT [UPCASE %outcov%].ATTR_D
MERGE INTO [UPCASE %outcov%].ATTR ON LNAM
SELECT [UPCASE %outcov%].ATTR_E
MERGE INTO [UPCASE %outcov%].ATTR ON LNAM
SELECT [UPCASE %outcov%].ATTR_F
MERGE INTO [UPCASE %outcov%].ATTR ON LNAM
SELECT [UPCASE %outcov%].ATTR_G
MERGE INTO [UPCASE %outcov%].ATTR ON LNAM
SELECT [UPCASE %outcov%].ATTR_H
MERGE INTO [UPCASE %outcov%].ATTR ON LNAM
Q STOP
&END

JOINITEM %outcov%.attr %outcov%.attr_a %outcov%.attr lnam

TABLES
ADDITEM %outcov%.attr inform 70 70 C
ADDITEM %outcov%.attr ninfom 70 70 C
ADDITEM %outcov%.attr ntxtds 70 70 C
ADDITEM %outcov%.attr picrep 70 70 C
ADDITEM %outcov%.attr scamax 4 12 B
ADDITEM %outcov%.attr scamin 4 12 B
ADDITEM %outcov%.attr txtdsc 70 70 C
ADDITEM %outcov%.attr pubref 70 70 C
ADDITEM %outcov%.attr recdat 8 8 C
ADDITEM %outcov%.attr recind 70 70 C
```

```
ADDITEM %outcov%.attr sordat 8 8 C
ADDITEM %outcov%.attr sorind 70 70 C

SELECT %outcov%.attr
CALCULATE inform = egg_attr
CALCULATE ninfom = "IGNORED"
CALCULATE ntxtds = "IGNORED"
CALCULATE picrep = "IGNORED"
CALCULATE scamax = -9998
CALCULATE scamin = -9998
CALCULATE txtdsc = "IGNORED"
CALCULATE pubref = "IGNORED"
CALCULATE recdat = "IGNORED"
CALCULATE recind = "IGNORED"
/*  CALCULATE recdat = "[SUBSTR [DATE -YEAR] 1 2][DATE -TAG]"
/*  CALCULATE recind = "CA,C1,digi"
CALCULATE sordat = "[SUBSTR [DATE -YEAR] 1 2][DATE -TAG]"
CALCULATE sorind = "IGNORED"

DROPITEM %outcov%.attr egg_attr

QUIT

&DO i &LIST A B C D E F G H
&IF [EXISTS %outcov%.attr_%i% -INFO] = .TRUE. &THEN
KILLINFO %outcov%.attr_%i%
&END
&RETURN

/****************************************************************
/* CATALOGUE DIRECTORY RECORD
/*  - CATD
/****************************************************************
&ROUTINE catd
/*********************************************
/*CATALOG DIRECTORY FIELD
/*********************************************
&TYPE 'Creating catalog file...'
&DESCRIBE %outcov%
&IF [EXISTS catd -INFO] &THEN
KILL catd

DEFINE catd
rcnm 2 2 C
rcid 10 10 C
file 70 70 C
lfil 70 70 C
volm 70 70 C
impl 3 3 C
slat 4 8 F 2
wlon 4 8 F 2
nlat 4 8 F 2
elon 4 8 F 2
crcs 70 70 C
comt 70 70 C
```

```
~

SELECT catd
ADD
/*Catalog File
"CD"
0000000001
"CATALOG.031"
~
"V01X01"
"ASC"
-9998
-9998
-9998
-9998
~
"Exchange Set Catalog file..."

/*Coverage
"CD"
0000000002
[UPCASE %outcov%].000
~
"V01X01"
"BIN"
[CALC %DSC$YMIN% - 0.01]
[CALC %DSC$XMIN% - 0.01]
[CALC %DSC$YMAX% + 0.01]
[CALC %DSC$XMAX% + 0.01]
"00000000"  /*JUST TEMPORARY
"Ice objects"
~
&RETURN

/****************************************************************
/* DATA SET GENERAL INFORMATION RECORD
/*  - DSID
/*  - DSSI
/****************************************************************
&ROUTINE dsid
&TYPE 'Adding data set information fields...'
/****************************************************************
/* DATA SET IDENTIFICATION FIELD
/****************************************************************
&IF [EXISTS %outcov%.dsid -INFO] = .TRUE. &THEN
KILL %outcov%.dsid

DEFINE %outcov%.dsid
rcnm 2 2 C
rcid 10 10 C
expp 1 1 C
intu 2 6 B
dsnm 70 70 C
edtn 70 70 C
updn 70 70 C
```

```
uadt 8 8 C
isdt 8 8 C
sted 4 4 C
prsp 3 3 C
psdn 70 70 C
pred 70 70 C
prof 2 2 C
agen 2 2 C
comt 70 70 C
~

SELECT %outcov%.dsid
ADD
"DS"
"0000000001"
"N"
1
[UPCASE %outcov%].000
"1"
"0"
%isdt%   /*from user input, UADT is same as ISDT for new data sets
%isdt%   /*from user input
"03.1"
"ENC"
~
"2.0"
"EN"
"CA"
%comt%   /*from user input
~
&RETURN

&ROUTINE dssi
/*****************************************************************
/* DATA SET STRUCTURE INFORATION FIELD
/*****************************************************************
&IF [EXISTS %outcov%.dssi -INFO] = .TRUE. &THEN
KILL %outcov%.dssi

DEFINE %outcov%.dssi
dstr 2 2 C
aall 1 1 C
nall 1 1 C
nomr 4 12 B
nocr 4 12 B
nogr 4 12 B
nolr 4 12 B
noin 4 12 B
nocn 4 12 B
noed 4 12 B
nofa 4 12 B
~

/*count meta records
```

```
SELECT %outcov%.patm_covr
&SETVAR metas = [SHOW NUMBER SELECT]
SELECT %outcov%.patm_qual
&SETVAR metas = %metas% + [SHOW NUMBER SELECT]

/*count geo records
SELECT %outcov%.patlndare
&SETVAR geos = [SHOW NUMBER SELECT]
SELECT %outcov%.patdepare
&SETVAR geos = %geos% + [SHOW NUMBER SELECT]
&IF [LOCASE %icetype%] = 'seaice' &THEN
SELECT %outcov%.patseaice
&ELSE
SELECT %outcov%.patlacice
&SETVAR geos = %geos% + [SHOW NUMBER SELECT]
SELECT %outcov%.patbrgare
&SETVAR geos = %geos% + [SHOW NUMBER SELECT]
SELECT %outcov%.patseaare
&SETVAR geos = %geos% + [SHOW NUMBER SELECT]
SELECT %outcov%.raticelin
&SETVAR geos = %geos% + [SHOW NUMBER SELECT]

SELECT %outcov%.dssi
ADD
"CN"
"1"             /* ATTF lexical level
"1"             /* NATF lexical level
%metas%         /* meta records
/* cartographic records not allowed
%geos%          /* geo records
/* collection records
/* isolated node records (points)
%DSC$MAX_NODE% /* connected node records
%DSC$ARCS%      /* edge records
/* face records not allowed
~
&RETURN

/****************************************************************
/* DATA SET GEOGRAPHICAL REFERENCE RECORD
/*  - DSPM
/****************************************************************
&ROUTINE dspm
/****************************************************************
/* DATA SET PARAMETER FIELD
/****************************************************************
&IF [EXISTS %outcov%.dspm -INFO] = .TRUE. &THEN
KILL %outcov%.dspm

&IF [EXISTS %incov%.lut -INFO] = .TRUE. &THEN
&DO
SELECT %incov%.lut
&SETVAR cscl = [SHOW RECORD 1 SCALE]
&END
```

```
SELECT %outcov%.patlndare
&SETVAR geos = [SHOW NUMBER SELECT]

DEFINE %outcov%.dspm
rcnm 2 2 C
rcid 10 10 C
hdat 2 6 B
vdat 2 6 B
sdat 2 6 B
cscl 4 12 B
duni 2 6 B
huni 2 6 B
puni 2 6 B
coun 2 2 C
comf 4 12 B
somf 4 12 B
comt 70 70 C
~

SELECT %outcov%.dspm
ADD
"DP"
"0000000001"
/* must be '2' - WGS84
/* mean sea level
/* mean sea level
%cscl%       /* scale from user input OR LUT, if it exists
/* must be '1' - metres
/* must be '1' - metres
/* must be '1' - metres
"LL"         /* must be 'll' - lat/long
10000000     /* 10000000 ensures cell is at best accurate to 0.000001 degrees
/* must be '10'
%comt%       /* comment from user input
~
&RETURN

&ROUTINE multipoints
/*****************************************************************
/* FIND POLYS WITH MUTIPLE DIFFERENT-VALUED POINTS
/*****************************************************************
INTERSECT %outcov_p% %outcov% %cov_int% POINT
STATISTICS %cov_int%.pat %outcov%.stat %outcov%#
MINIMUM pnt_type
MAXIMUM pnt_type
END

TABLES
SELECT %outcov%.stat
RESELECT min-pnt_type = max-pnt_type
PURGE
YES
SORT frequency %outcov%#
QUIT
```

```
&RETURN

&ROUTINE killtemps
/****************************************************************
/* CLEAN-UP TEMP FILES
/****************************************************************
&TYPE 'Killing temporary files...'
&IF [EXISTS %incov% -COVER] = .TRUE. &THEN
KILL %incov% ALL
&IF [EXISTS %cov_poly% -COVER] = .TRUE. &THEN
KILL %cov_poly% ALL
&IF [EXISTS %cov_dis% -COVER] = .TRUE. &THEN
KILL %cov_dis% ALL
&IF [EXISTS %cov_int% -COVER] = .TRUE. &THEN
KILL %cov_int% ALL
&IF [EXISTS %cov_densify% -COVER] = .TRUE. &THEN
KILL %cov_densify% ALL
&IF [EXISTS %cov_reproj% -COVER] = .TRUE. &THEN
KILL %cov_reproj% ALL
&IF [EXISTS %cov_tempproj% -COVER] = .TRUE. &THEN
KILL %cov_tempproj% ALL
&IF [EXISTS %lt151% -COVER] = .TRUE. &THEN
KILL %lt151% ALL
&RETURN

&ROUTINE makes57
/****************************************************************
/* CONVERT TO S-57
/****************************************************************
&TYPE 'Making S-57 file...'
&IF [EXISTS %outcov%_log.txt -FILE] = .TRUE. &THEN
&SYSTEM DEL %outcov%_log.txt
&IF [EXISTS 'c:\temp' -DIRECTORY] = .FALSE. &THEN
&SYSTEM  MKDIR c:\temp

/* Make the S-57
ARCS57 [SHOW &WORKSPACE] %outcov%_log.txt

/* export catalog to create proper CRC
&IF [EXISTS %outcov%_log2.txt -FILE] = .TRUE. &THEN
&SYSTEM DEL %outcov%_log2.txt
ENCREVISION EXPORTCATALOG [SHOW &WORKSPACE] %outcov%_log2.txt
&IF [EXISTS %outcov%_log2.txt -FILE] = .TRUE. &THEN
&SYSTEM DEL %outcov%_log2.txt
&IF [EXISTS catd -INFO] = .TRUE. &THEN
KILLINFO catd
/* import catalog with proper CRC
ENCREVISION IMPORTCATALOG catalog.030 [SHOW &WORKSPACE]

/* rename catalog to 031, this is version 3.1
&IF [EXISTS CATALOG.031 -FILE] = .TRUE. &THEN
&SYSTEM DEL CATALOG.031
&SYSTEM RENAME CATALOG.030 CATALOG.031

&SETVAR timed = [TRUNCATE [SHOW &PT TIME]]
```

```
/* APPEND PROCESSING TIME TO REPORT
&SETVAR logopen = [OPEN [SHOW &WORKSPACE]\%outcov%_log.txt logstatus -APPEND]
&SETVAR record = 'Total Processing time: '[TRUNCATE [CALC %timed% / 60]]' minutes and '[MOD %timed% 60]' second(s).'
/*  &SETVAR record = ''
&IF [WRITE %logopen% %record%] = 0 &THEN
&SETVAR closelog = [CLOSE -ALL]

/* APPEND DUPLICATE POINT LIST TO REPORT
LISTOUTPUT [SHOW &WORKSPACE]\%outcov%_log.txt APPEND
LIST %outcov%.stat

&SYSTEM NOTEPAD.EXE %outcov%_log.txt
&RETURN

/*****************************************************************
&ROUTINE BAILOUT
/*****************************************************************
&SEVERITY &ERROR &IGNORE
&DELVAR .*
&PT &OFF
&MESSAGES &POPUP
&RETURN &WARNING An error has occurred in ICE2S57.AML.
```

APPENDIX VII
VISUAL BASIC CODE FOR "ICE2S57.EXE" USER INTERFACE

The GUI of the developed application is composed of three modules. The first, “frms57.frm”, is the main part of the GUI and was developed entirely by the author. The second, “modWaitForShell.bas”, is based mainly on sample code from Microsoft [Microsoft, 2004b]. It disallows the user to interact with the GUI until the processing in ArcInfo has been completed. The third module is “modFolderBrowser.bas”. It is also based on sample code from Microsoft [Microsoft, 2004a]. It allows the user to select an output directory.

Module: frms55.frm

```
1.    VERSION 5.00
2.    Object = "{F9043C88-F6F2-101A-A3C9-08002B2F49FB}#1.2#0";
      "COMDLG32.OCX"
3.    Object = "{86CF1D34-0C5F-11D2-A9FC-0000F8754DA1}#2.0#0";
      "Mscomct2.ocx"
4.    Begin VB.Form frmS57
5.    BorderStyle     =   1  'Fixed Single
6.    Caption         =   "Ice to S-57"
7.    ClientHeight    =   6165
8.    ClientLeft      =   45
9.    ClientTop       =   435
10.   ClientWidth     =   6480
11.   LinkTopic       =   "Form1"
12.   MaxButton       =   0   'False
13.   ScaleHeight     =   6165
14.   ScaleWidth      =   6480
15.   StartUpPosition =   3  'Windows Default
16.   Begin VB.CommandButton cmdCancel
         Caption         =   "&Cancel"
         Height          =   615
         Left            =   1800
         TabIndex        =   15
         Top             =   5400
         Width           =   1335
17.   End
18.   Begin VB.TextBox txtIsdt
         BackColor       =   &H8000000F&
         Height          =   285
         Left            =   5400
         Locked          =   -1  'True
         MaxLength       =   8
         TabIndex        =   16
         Top             =   3360
         Width           =   975
19.   End
20.   Begin VB.CommandButton cmdRunAML
         Caption         =   "Make &S-57 file"
         Height          =   615
         Left            =   120
         TabIndex        =   14
         Top             =   5400
         Width           =   1335
21.   End
22.   Begin VB.TextBox txtComt
         Height          =   285
         Left            =   120
         MaxLength       =   70
         TabIndex        =   13
         Top             =   4800
         Width           =   3495
23.   End
24.   Begin VB.TextBox txtCscl
         Height          =   285
```

```
      Left            =   2280
      TabIndex        =   11
      Text            =   "4000000"
      Top             =   4065
      Width           =   975
25.  End
26.  Begin MSComCtl2.MonthView MonthView1
      BeginProperty DataFormat
      Type            =   1
      Format          =   "yyyy.MM.dd"
      HaveTrueFalseNull=   0
      FirstDayOfWeek  =   0
      FirstWeekOfYear =   0
      LCID            =   4105
      SubFormatType   =   3
      EndProperty
      Height          =   2370
      Left            =   3720
      TabIndex        =   12
      Top             =   3720
      Width           =   2700
      _ExtentX        =   4763
      _ExtentY        =   4180
      _Version        =   393216
      ForeColor       =   -2147483630
      BackColor       =   -2147483633
      Appearance      =   1
      StartOfWeek     =   20578305
      CurrentDate     =   37936
27.  End
28.  Begin VB.ComboBox cboIntu
      Height          =   315
      Left            =   1680
      Style           =   2  'Dropdown List
      TabIndex        =   10
      Top             =   3570
      Width           =   1695
29.  End
30.  Begin VB.Frame frmIceType
      Caption         =   "Ice Type:"
      BeginProperty Font
      Name            =   "MS Sans Serif"
      Size            =   8.25
      Charset         =   0
      Weight          =   700
      Underline       =   0   'False
      Italic          =   0   'False
      Strikethrough   =   0   'False
      EndProperty
      Height          =   1095
      Left            =   3960
      TabIndex        =   7
      Top             =   2040
      Width           =   2415
      Begin VB.OptionButton optSeaLake
```

```
        Caption         =   "Lake Ice"
        Height          =   255
        Index           =   1
        Left            =   240
        TabIndex        =   9
        Top             =   720
        Width           =   1815
        End
        Begin VB.OptionButton optSeaLake
        Caption         =   "Sea Ice"
        Height          =   255
        Index           =   0
        Left            =   240
        TabIndex        =   8
        Top             =   360
        Value           =   -1  'True
        Width           =   1815
        End
31.  End
32.  Begin VB.CheckBox chkBoundingRectangle
        Caption         =   "Create a bounding rectangle?"
        Height          =   255
        Left            =   120
        TabIndex        =   6
        Top             =   2760
        Value           =   1  'Checked
        Width           =   2415
33.  End
34.  Begin VB.CheckBox chkKillTemps
        Caption         =   "Kill temporary files?"
        Height          =   255
        Left            =   120
        TabIndex        =   5
        Top             =   2400
        Width           =   1815
35.  End
36.  Begin VB.TextBox txtOutcov
        Height          =   285
        Left            =   2160
        MaxLength       =   8
        TabIndex        =   4
        Text            =   "CAxxxxxx"
        Top             =   1545
        Width           =   1575
37.  End
38.  Begin VB.CommandButton cmdOutspace
        Caption         =   "Output Workspace"
        Height          =   495
        Left            =   120
        TabIndex        =   2
        Top             =   840
        Width           =   975
39.  End
40.  Begin VB.TextBox txtOutspace
        Height          =   285
```

```
         Left             =   1200
         TabIndex         =   3
         Top              =   960
         Width            =   5175
41.   End
42.   Begin VB.CommandButton cmdIncov
         Caption          =   "Input Coverage"
         Height           =   495
         Left             =   120
         TabIndex         =   0
         Top              =   120
         Width            =   975
43.   End
44.   Begin VB.TextBox txtIncov
         Height           =   285
         Left             =   1200
         TabIndex         =   1
         Top              =   240
         Width            =   5175
45.   End
46.   Begin MSComDlg.CommonDialog CommonDialog1
         Left             =   5640
         Top              =   1440
         _ExtentX         =   847
         _ExtentY         =   847
         _Version         =   393216
47.   End
48.   Begin VB.Label Label1
         Alignment        =   1  'Right Justify
         Caption          =   "1:"
         BeginProperty Font
         Name             =   "MS Sans Serif"
         Size             =   8.25
         Charset          =   0
         Weight           =   700
         Underline        =   0   'False
         Italic           =   0   'False
         Strikethrough    =   0   'False
         EndProperty
         Height           =   255
         Left             =   1880
         TabIndex         =   21
         Top              =   4100
         Width            =   375
49.   End
50.   Begin VB.Label lblComt
         Caption          =   "Comment"
         BeginProperty Font
         Name             =   "MS Sans Serif"
         Size             =   8.25
         Charset          =   0
         Weight           =   700
         Underline        =   0   'False
         Italic           =   0   'False
         Strikethrough    =   0   'False
```

```
         EndProperty
         Height          =   255
         Left            =   120
         TabIndex        =   20
         Top             =   4560
         Width           =   1575
51.   End
52.   Begin VB.Label lblCscl
         Caption         =   "Scale:"
         BeginProperty Font
         Name            =   "MS Sans Serif"
         Size            =   8.25
         Charset         =   0
         Weight          =   700
         Underline       =   0   'False
         Italic          =   0   'False
         Strikethrough   =   0   'False
         EndProperty
         Height          =   255
         Left            =   120
         TabIndex        =   19
         Top             =   4080
         Width           =   1575
53.   End
54.   Begin VB.Label lblIsdt
         Caption         =   "Issue Date:"
         BeginProperty Font
         Name            =   "MS Sans Serif"
         Size            =   8.25
         Charset         =   0
         Weight          =   700
         Underline       =   0   'False
         Italic          =   0   'False
         Strikethrough   =   0   'False
         EndProperty
         Height          =   255
         Left            =   3720
         TabIndex        =   22
         Top             =   3375
         Width           =   1335
55.   End
56.   Begin VB.Label lblIntu
         Caption         =   "Intended Usage:"
         BeginProperty Font
         Name            =   "MS Sans Serif"
         Size            =   8.25
         Charset         =   0
         Weight          =   700
         Underline       =   0   'False
         Italic          =   0   'False
         Strikethrough   =   0   'False
         EndProperty
         Height          =   255
         Left            =   120
         TabIndex        =   18
```

```
      Top             =   3600
      Width           =   1575
   End
   Begin VB.Label lblOutcov
      Caption         =   "Output S-57 file name:"
      BeginProperty Font
      Name            =   "MS Sans Serif"
      Size            =   8.25
      Charset         =   0
      Weight          =   700
      Underline       =   0   'False
      Italic          =   0   'False
      Strikethrough   =   0   'False
      EndProperty
      Height          =   255
      Left            =   120
      TabIndex        =   17
      Top             =   1560
      Width           =   1935
   End
   End
   Attribute VB_Name = "frmS57"
   Attribute VB_GlobalNameSpace = False
   Attribute VB_Creatable = False
   Attribute VB_PredeclaredId = True
   Attribute VB_Exposed = False
   Option Explicit
   Dim thisPath As String

   Private Sub Form_Load()
   '********************************************
   ' set initial values
   '********************************************
   cboIntu.AddItem "1 - Overview"
   cboIntu.AddItem "2 - General"
   cboIntu.AddItem "3 - Coastal"
   cboIntu.AddItem "4 - Approach"
   cboIntu.AddItem "5 - Harbour"
   cboIntu.AddItem "6 - Berthing"
   cboIntu.Text = "1 - Overview"
   MonthView1.Value = Date
   thisPath = App.Path
   Call MonthView1_DateClick(Date)
   End Sub

   Private Sub MonthView1_DateClick(ByVal DateClicked As Date)
   Dim month As String
   Dim day As String
   Dim isdt As String

   '********************************************
   ' add leading zero if month/day is 1 digit
   '********************************************
   If MonthView1.month < mvwOctober Then
   month = 0 & MonthView1.month
```

```
Else
month = MonthView1.month
End If

If MonthView1.day < 10 Then
day = 0 & MonthView1.day
Else
day = MonthView1.day
End If

isdt = MonthView1.Year & month & day

MonthView1.DayBold(MonthView1.Value) = True

txtIsdt.Text = isdt
End Sub

Private Sub cmdIncov_Click()
'*******************************************
' launch file browser
'*******************************************
CommonDialog1.Filter = "ArcInfo Interchange files (*.e00) | *.e00"
CommonDialog1.ShowOpen
txtIncov.Text = CommonDialog1.Filename
End Sub

Private Sub cmdOutspace_Click()
'*******************************************
' Opens a Browse Folders Dialog Box
'*******************************************
Dim lpIDList As Long
Dim sBuffer As String
Dim szTitle As String
Dim tBrowseInfo As BrowseInfo

'*******************************************
' Text in the gray area under the title bar
'*******************************************
szTitle = "Select the folder to save the S-57 file:"

With tBrowseInfo
.hWndOwner = Me.hWnd 'Owner Form
.lpszTitle = lstrcat(szTitle, "")
.ulFlags = BIF_USENEWUI + BIF_RETURNONLYFSDIRS + BIF_DONTGOBELOWDOMAIN
End With

lpIDList = SHBrowseForFolder(tBrowseInfo)

If (lpIDList) Then
sBuffer = Space(MAX_PATH)
SHGetPathFromIDList lpIDList, sBuffer
sBuffer = Left(sBuffer, InStr(sBuffer, vbNullChar) - 1)
txtOutspace.Text = sBuffer
```

```
End If
End Sub

Private Sub MonthView1_SelChange(ByVal StartDate As Date, ByVal
EndDate As Date, Cancel As Boolean)
Dim i As Integer
'*******************************************
' bold the selected day
'*******************************************
For i = 1 To 42
MonthView1.DayBold(MonthView1.VisibleDays(i)) = False
Next
End Sub

Private Sub cmdRunAML_Click()
On Error GoTo ErrorHandler
Dim sealake As String
Dim killtemps As String
Dim boundbox As String
Dim crcs As String

'*******************************************
' get arguments to pass
'*******************************************
If optSeaLake(0) = True Then
sealake = "seaice"
Else
sealake = "lacice"
End If

If chkKillTemps.Value = 1 Then
killtemps = "notemps"
Else
killtemps = "temps"
End If

If chkBoundingRectangle.Value = 1 Then
boundbox = "box"
Else
boundbox = "nobox"
End If

If Right(Trim(txtOutspace.Text), 1) = "\" Then
txtOutspace.Text = Left(Trim(txtOutspace.Text),
Len(Trim(txtOutspace.Text)) - 1)
End If

'*******************************************
' launch arc & run AML
'*******************************************
ExecCmd "arc &run " & Chr(34) & thisPath & "\ice2s57.aml" & _
          " " & txtIncov.Text & " " & _
          txtOutspace.Text & " " & txtOutcov.Text & " " & sealake
          & _
```

```
            " " & killtemps & " " & boundbox & " " &
            cboIntu.ListIndex + 1 & " " & _
            txtIsdt.Text & " " & txtCscl.Text & " " & Chr(39) &
            txtComt.Text & _
            Chr(39) & Chr(34)
Exit Sub

ErrorHandler:
Call MsgBox("Hrmm.. something went terribly wrong." & vbCrLf &
vbCrLf & Err.Description, vbExclamation)
End Sub
Private Sub cmdCancel_Click()
Unload Me
End Sub
```

Module: modWaitForShell.mod

```
Private Type STARTUPINFO
cb As Long
lpReserved As String
lpDesktop As String
lpTitle As String
dwX As Long
dwY As Long
dwXSize As Long
dwYSize As Long
dwXCountChars As Long
dwYCountChars As Long
dwFillAttribute As Long
dwFlags As Long
wShowWindow As Integer
cbReserved2 As Integer
lpReserved2 As Long
hStdInput As Long
hStdOutput As Long
hStdError As Long
End Type

Private Type PROCESS_INFORMATION
hProcess As Long
hThread As Long
dwProcessID As Long
dwThreadID As Long
End Type

Private Declare Function WaitForSingleObject Lib _
"kernel32" (ByVal hHandle As Long, ByVal dwMilliseconds _
As Long) As Long

Declare Function CreateProcessA Lib "kernel32" _
(ByVal lpApplicationName As Long, ByVal lpCommandLine As _
String, ByVal lpProcessAttributes As Long, ByVal _
lpThreadAttributes As Long, ByVal bInheritHandles As Long, _
ByVal dwCreationFlags As Long, ByVal lpEnvironment As Long, _
ByVal lpCurrentDirectory As Long, lpStartupInfo As _
STARTUPINFO, lpProcessInformation As PROCESS_INFORMATION) _
As Long

Declare Function CloseHandle Lib "kernel32" (ByVal hObject _
As Long) As Long

Private Const NORMAL_PRIORITY_CLASS = &H20&
Private Const INFINITE = -1&

Public Sub ExecCmd(cmdline$)
Dim proc As PROCESS_INFORMATION
Dim start As STARTUPINFO

' Initialize the STARTUPINFO structure:
start.cb = Len(start)
```

```
' Start the shelled application:
ret& = CreateProcessA(0&, cmdline$, 0&, 0&, 1&, _
NORMAL_PRIORITY_CLASS, 0&, 0&, start, proc)

' Wait for the shelled application to finish:
ret& = WaitForSingleObject(proc.hProcess, INFINITE)
ret& = CloseHandle(proc.hProcess)
End Sub
```

Module: modFolderBrowser.mod

```
Option Explicit

Public Const BIF_RETURNONLYFSDIRS = 1
Public Const BIF_DONTGOBELOWDOMAIN = 2
Public Const MAX_PATH = 260
Public Const BIF_USENEWUI = &H40

Declare Function SHBrowseForFolder Lib "shell32" (lpbi As
BrowseInfo) As Long

Declare Function SHGetPathFromIDList Lib _
                     "shell32" (ByVal pidList As Long, _
                     ByVal lpBuffer As String) As Long

Declare Function lstrcat Lib "kernel32" Alias "lstrcatA" _
                     (ByVal lpString1 As String, _
                     ByVal lpString2 As String) As Long

Type BrowseInfo
hWndOwner As Long
pIDLRoot As Long
pszDisplayName As Long
lpszTitle As Long
ulFlags As Long
lpfnCallback As Long
lParam As Long
iImage As Long
End Type
```

APPENDIX VIII
PROPOSED S-52 COLOURS AND SYMBOLS

Object: **Sea Ice**

Code: SEAICE
Geometry: Area
Display Using: Unique value based on either a combination of ICEACT and ICESOD attributes or just ICESOD – user may select
Attribute Description: Ice total concentration (CT), ice stage of development

Symbols for combined ICEACT and ICESOD:

ICEACT Value	ICESOD Value	Description	Symbol
1	-	1/10 TC	
2	-	2/10 TC	
3	-	3/10 TC	
4	-	4/10 TC	
5	-	5/10 TC	
6	-	6/10 TC	
7	-	7/10 TC	
7	1	7/10 TC, new ice	
8	-	8/10 TC	
8	1	8/10 TC, new ice	
9	-	9/10 TC	
9	1	9/10 TC, new ice	
9	2 or 4	9/10 TC, nilas/ice rind or grey ice	
10	-	< 1/10 – 2/10 TC	
11	-	1 – 3/10 TC	
12	-	4 – 6/10 TC	
13	-	7 – 8/10 TC	
13	1	7 – 8/10 TC, new ice	
14	-	9 – < 10/10 TC	
14	1	9 – < 10/10 TC, new ice	
14	2 or 4	9 – < 10/10 TC, nilas/ice rind or grey ice	
15	-	10/10 TC with openings	
15	1	10/10 TC with openings, new ice	
15	2 or 4	10/10 TC with openings, nilas/ice rind or grey ice	
16	-	10/10 TC without openings	
17	-	< 1/10 TC	

18	-	Undetermined or unknown	? ? ?

Symbols used for ICESOD only:

ICESOD Value	Description	Symbol
0	No ice present	
1	New ice	
2	Nilas, ice rind	
3	Young ice	
4	Grey ice	
5	Grey-white ice	
6	First-year ice	
7	Thin first-year ice	
8	Medium first-year ice	
9	Thick first-year ice	
10	Old ice	
11	Second-year ice	
12	Multi-year ice	
13	Ice of land origin	▲ ▲ ▲
14	Undetermined or unknown	? ? ?

Object: **Lake Ice**

Code: LACICE

Geometry: Area

Display Using: Unique value based on either a combination of ICEACT and ICELSO attributes or just ICELSO – user may select

Attribute Description: Ice total concentration (CT), ice stage of development

Symbols for combined ICEACT and ICELSO:

ICEACT Value	ICELSO Value	Description	Symbol
1	-	1/10 TC	
2	-	2/10 TC	
3	-	3/10 TC	
4	-	4/10 TC	
5	-	5/10 TC	
6	-	6/10 TC	
7	-	7/10 TC	
7	1	7/10 TC, new lake ice	
8	-	8/10 TC	
8	1	8/10 TC, new lake ice	
9	-	9/10 TC	
9	1	9/10 TC, new lake ice	
9	2	9/10 TC, thin lake ice	
10	-	< 1/10 – 2/10 TC	
11	-	1 – 3/10 TC	
12	-	4 – 6/10 TC	
13	-	7 – 8/10 TC	
13	1	7 – 8/10 TC, new lake ice	
14	-	9 – < 10/10 TC	
14	1	9 – < 10/10 TC, new lake ice	
14	2	9 – < 10/10 TC, thin lake ice	
15	-	10/10 TC with openings	
15	1	10/10 TC with openings, new lake ice	
15	2	10/10 TC with openings, thin lake ice	
16	-	10/10 TC without openings	
17	-	< 1/10 TC	

18	-	Undetermined or unknown	? ? ?

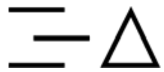
Symbols used for ICELSO only:

ICELSO Value	Description	Symbol
1	New lake ice	
2	Thin lake ice	
3	Medium lake ice	
4	Thick lake ice	
5	Very thick lake ice	
6	Undetermined or unknown	? ? ?

Object:	**Ice Advisory Area**
Code:	ICEADV
Geometry:	Area
Display Using:	Single symbol
Symbol:	Undetermined

Object: **Iceberg Area**

Code: BRGARE
Geometry: Area
Display Using: Single symbol
Attributes not represented: Number of icebergs in area (ICEBNM)

Symbol: 

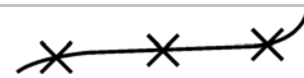
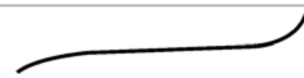
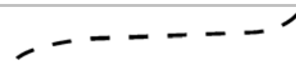
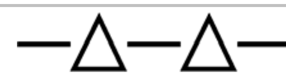
Object: Land Ice

Code:	LNDICE
Geometry:	Area
Display Using:	Undetermined
Symbol:	Undetermined

Object: Ice Line

Code: ICELIN
Geometry: Line
Display Using: Unique value
Attribute: Ice Line Category
Attribute Description: ICELNC

Symbols:

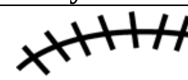
Value	Description	Symbol
1	Limit of undercast / data limit	
2	Ice edge from radar	
3	Limit of radar observation	
4	Limit of visual observation	
5	Observed edge or boundary	
6	Estimated edge or boundary	
7	Iceberg limit	
8	Undetermined / unknown	

Object:	**Ice Route**
Code:	ICERTE
Geometry:	Line
Display Using:	Single symbol
Symbol:	Undetermined

Object: Ice Fracture

Code: ICEFRA
Geometry: Line
Display Using: Single symbol
Attribute: ICEFTY
Attribute Description: Ice fracture type

Symbols:

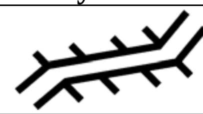
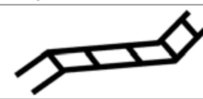
Value	Description	Symbol
1	Crack	
2	Tide crack	
3	Flaw	
4	Very small fracture	
5	Small fracture	
6	Medium fracture	
7	Large fracture	
8	Undetermined or unknown	

Object:	**Ice Polynya**
Code:	ICEPOL
Geometry:	Area
Display Using:	Undetermined
Symbol:	Undetermined

Object: Ice Lead

Code:	ICELEA
Geometry:	Line or area
Display Using:	Unique value
Attribute:	ICELST
Attribute Description:	Ice lead status
Attribute not represented:	Ice lead type (ICELTY)

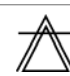
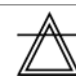
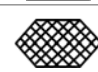
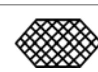
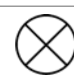
Symbols:

Value	Description	Symbol
1	Open lead	
2	Frozen lead	
3	Undetermined or unknown	

Object: Iceberg

Code: ICEBRG
Geometry: Point and area
Display Using: Unique value
Attributes: ICEBSZ and ICEBSH
Attribute Description: Iceberg size, Iceberg shape
Attributes not represented: Iceberg local conditions (ICEBLC)
Iceberg direction (ICEBDR)

Symbols:

ICEBSZ Value	Description	Symbol	If ICEBSH = 1
Null			
1	Growler		
2	Bergy bit		
3	Small iceberg		
4	Medium iceberg		
5	Large iceberg		
6	Very large iceberg		
7	Ice island fragment		
8	Ice island		
9	Radar target		

Object: Floeberg

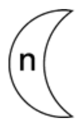
Code:	FLOBRG
Geometry:	Point or area
Display Using:	Single symbol
Symbol:	
Note:	If geometry is an area, symbol is repeated throughout area.

Object: Ice/Snow Thickness

Code:	ICETHK
Geometry:	Point
Display Using:	Single symbol
Attributes:	ICETCK and/or ICESCT
Attribute Description:	Ice thickness, snow thickness

Symbols:

ICETCK: 

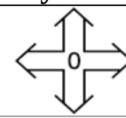
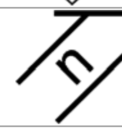
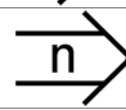
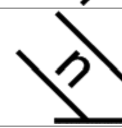
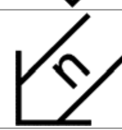
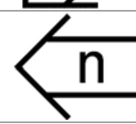
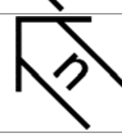
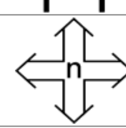
ICESCT: 

Note: “n” is the thickness of ice or snow.
If both ICETCK and ICESCT are not null, the symbols can be placed side by side.

Object: Ice Movement

Code: ICEMOV
Geometry: Point or area
Display Using: Single symbol
Attributes: ICEBSP and ICEBDR
Attribute Description: Ice drift speed, ice drift direction

Symbols:

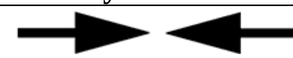
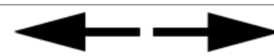
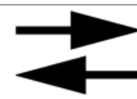
ICEBDR Value	Description	Symbol
1	No ice motion	
2	Ice drift to NE	
3	Ice drift to E	
4	Ice drift to SE	
5	Ice drift to S	
6	Ice drift to SW	
7	Ice drift to W	
8	Ice drift to NW	
9	Ice drift to N	
10	Variable drift direction	
11	Undetermined or unknown	

Note: “n” is the speed of drift in knots.

Object: Ice Dynamics

Code: ICEDYN
Geometry: Point and area
Display Using: Unique symbol
Attribute: ICEMPC
Attribute Description: Ice motion process category

Symbols:

Value	Description	Symbol
1	Slight compacting	1 
2	Considerable compacting	2 
3	Strong compacting	3 
4	Diverging	
5	Shearing	
6	Undetermined or unknown	

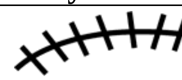
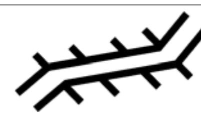
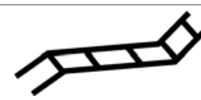
Object: Ice Ridge

Code:	ICERDG
Geometry:	Point, line, or area
Display Using:	Single symbol
Attributes:	ICERCN, ICERHT, and ICEFRQ
Attribute Description:	Ice ridge concentration, ice ridge height, and ice ridge frequency
Attribute not represented:	Ice ridge development (ICERDV)
Symbol:	
Notes:	"f" is the value of ICEFRQ "h" is the value of ICERHT "c" is the value of ICERCN, if ICERCN < 11

Object: Ice Opening

Code: ICEOPN
Geometry: Point or area
Display Using: Unique value
Attribute: ICEOTY
Attribute Description: Ice opening type

Symbols:

Value	Description	Symbol
1	Crack	
2	Tide crack	
3	Flaw	
4	Very small fracture	
5	Small fracture	
6	Medium fracture	
7	Large fracture	
8	Non-recurring polynya	
9	Recurring polynya	
10	Open lead	
11	Frozen lead	
12	Undetermined or unknown	

Object: Ice Topography

Code: ICETOP
Geometry: Point or area
Display Using: Unique symbol
Attribute: ICETTY
Attribute Description: Ice topography type

Symbols:

Value	Description	Symbol
1	Rafted ice	
2	Jammed brash barrier	
3	Ridged ice	
4	Hummocked ice	
5	Undetermined or unknown	

CURRICULUM VITAE

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Journal Papers

Webster, T., and G. Dias (2006). "LIDAR Validation Using GIS: An Automated Procedure for Comparing GPS and Proximal LIDAR Ground Elevations." *Computers and Geoscience*, in press.

El-Rabbany, A., B. Agi, G. Dias, M. El-Diasty, and D. Coleman (2004). "On the Development of an Integrated Navigational Chart System for Marine Navigation in Ice Covered Waters." *Lighthouse*, Spring/Summer 2004, Canadian Hydrographic Association.

Conference and Workshop Presentations

Balram, S., S. Dragicevic, G. Dias, T. Meredith, and J. Lewis (2001). "Listening to the Community: Collaborative GIS for conservation planning in the West Island of Montreal." *Annual Conference of Canadian Association of Geographers*, Montreal, Canada, May 30 - June 3.

Dias, G. (2003). "Delineating Wetlands Using Multitemporal RADARSAT." *2003 Graduate Student Technical Conference*, Fredericton, New Brunswick, Canada, March 21 - March 24.

Dias, G., D. Coleman, A. El-Rabbany, and B. Agi (2003). "On the Integration of Sea Ice Information into ECDIS." *37th CMOS Congress – Atmosphere-Ocean Science: Impacts and Innovation*, Ottawa, Canada, June 2 - 5.

El-Rabbany, A., B. Agi, D. Coleman, and G. Dias (2003). "Automated Processing in the Integration of Ice Information in Electronic Navigational Chart System." *CRESTech's Innovation Network Workshop*, Toronto, Canada, 9 October.

Other Publications

Meredith, T., G. Dias, C. Ibrahim, R.Tipple, and T. Wilkinson (2000). Reaching Consensus on Biodiversity Conservation Priority Regions: *A Report on the Commission for Environmental Cooperation Strategic Directions for the Conservation of Biodiversity*. Montreal: The Commission for Environmental Cooperation