

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

**GEORGE DIAS**

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**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.

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## 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 through 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

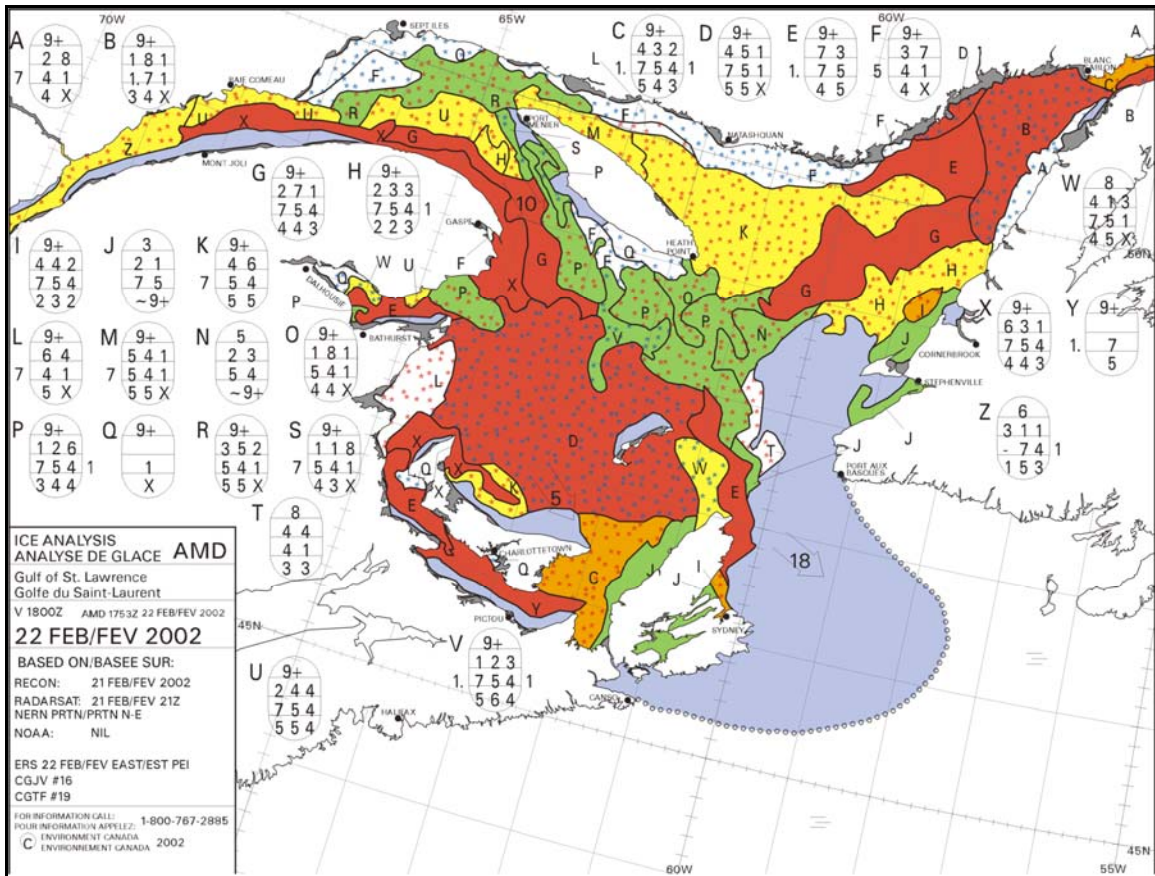


Figure 2.1. CIS's February 22, 2002, daily ice chart for the Gulf of St. Lawrence.

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.

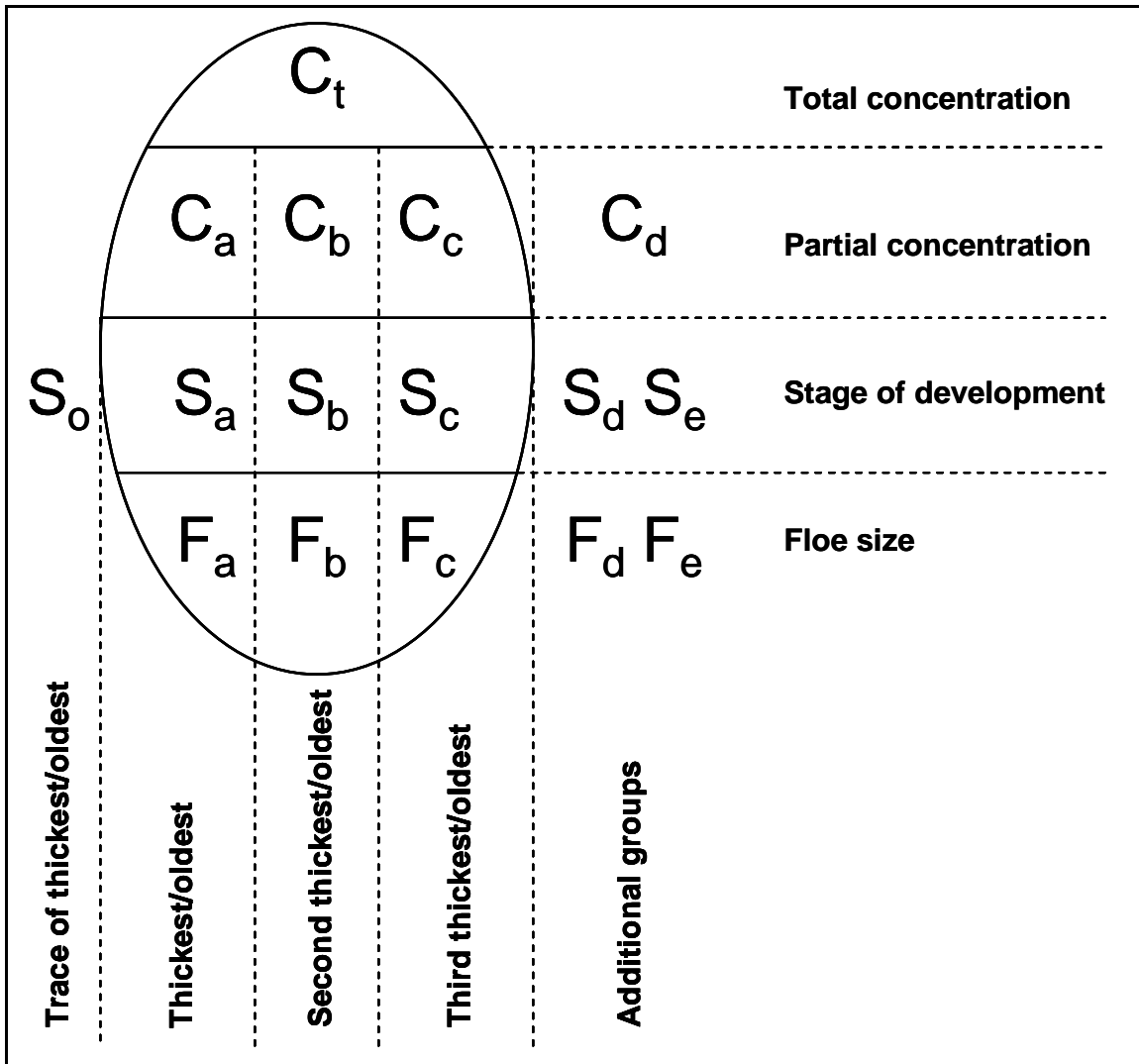


Figure 2.2. The Egg Code [after CIS 2002].

$C_t$  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.

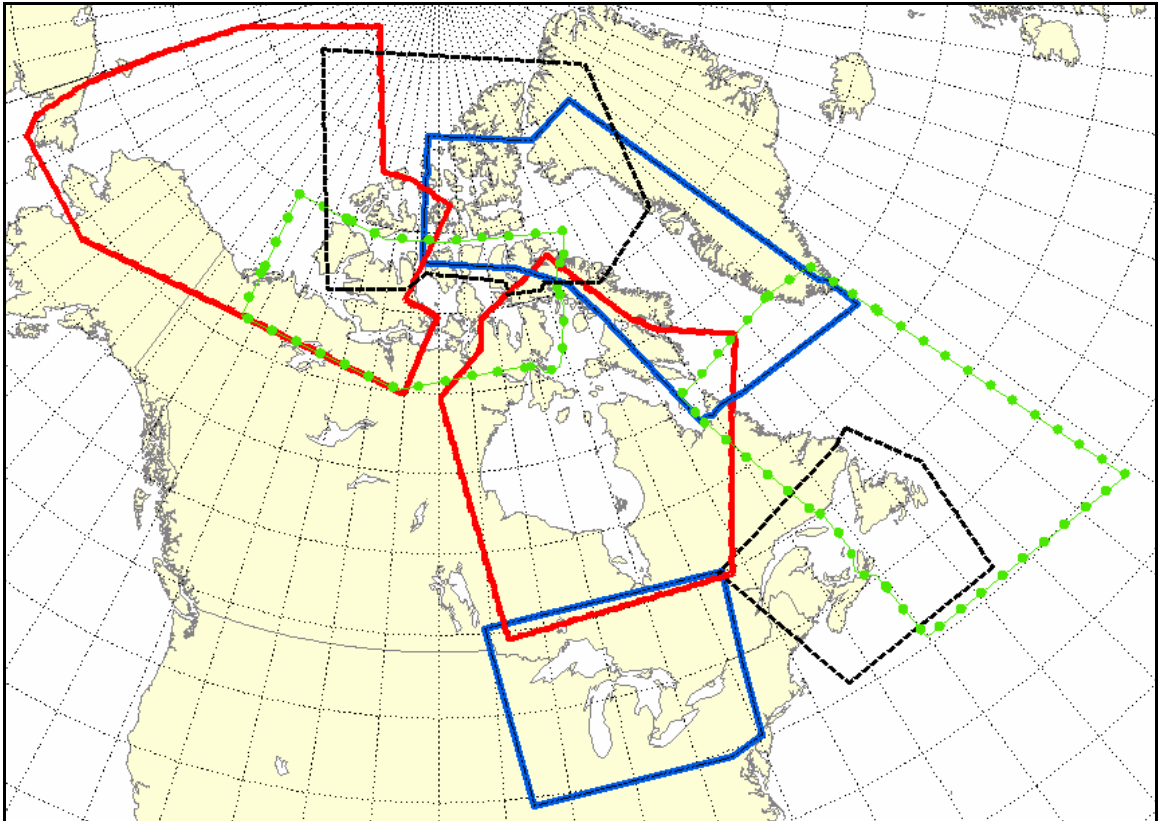


Figure 2.3. Areas covered by CIS daily ice charts. Styles and colours are used only to distinguish daily chart areas from each other.

### 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.

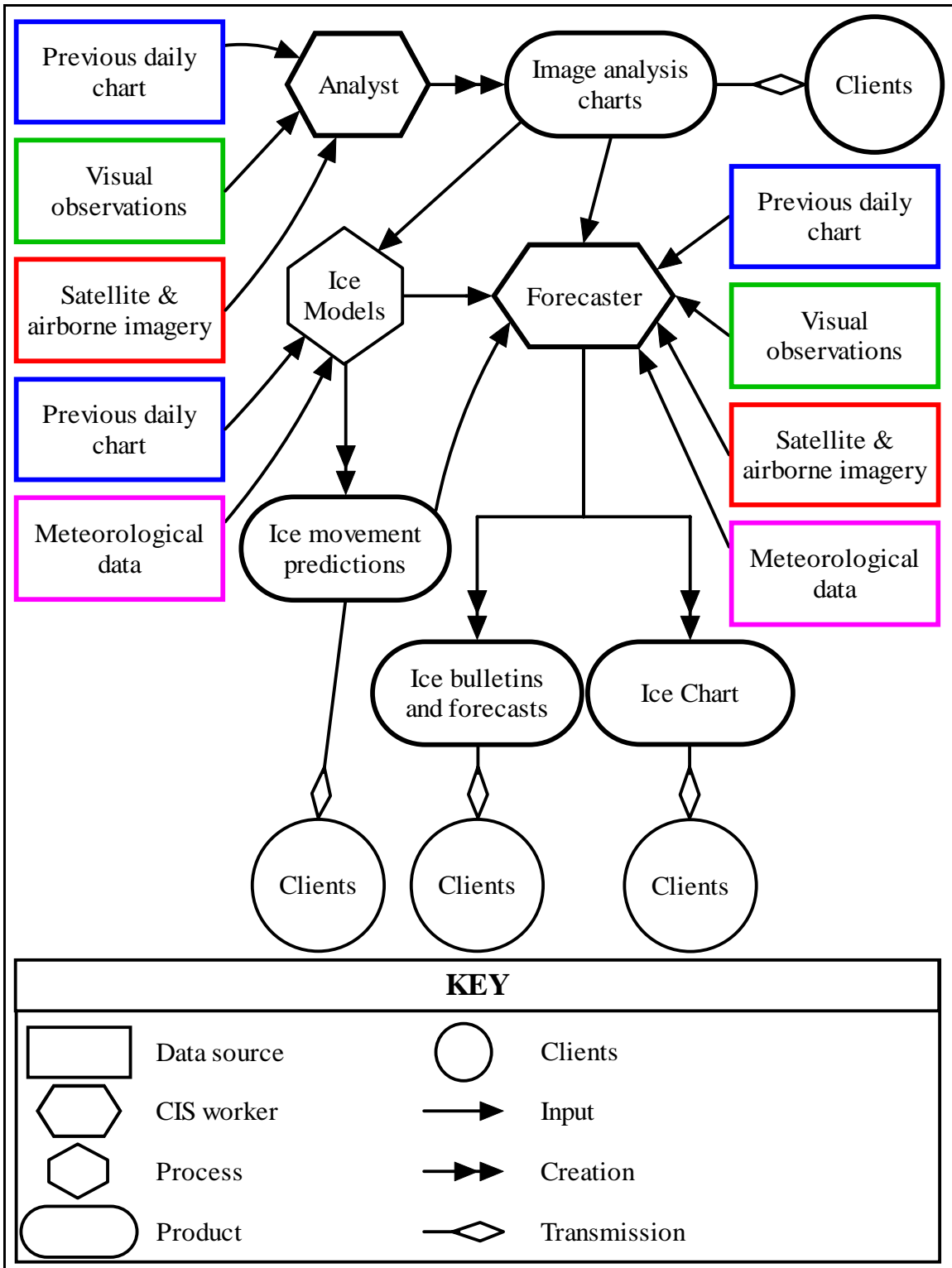


Figure 2.4. CIS daily production workflow (after Falkingham [2003]).

## 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.

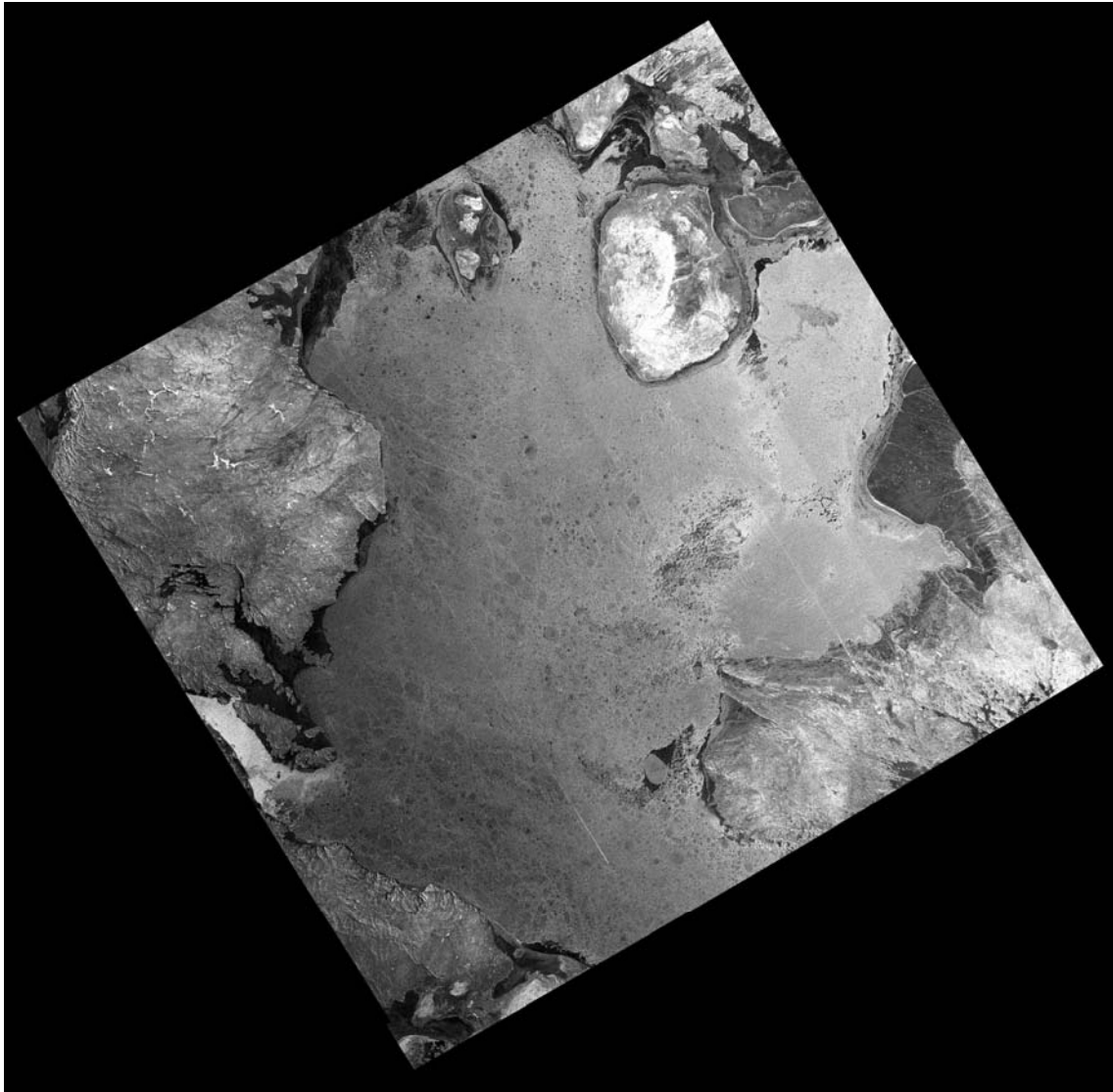


Figure 2.5. RADARSAT imagery of Foxe Basin, from May 13, 2005. Data © Canadian Space Agency (2005) and distributed by Radarsat International Ltd.

**(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.

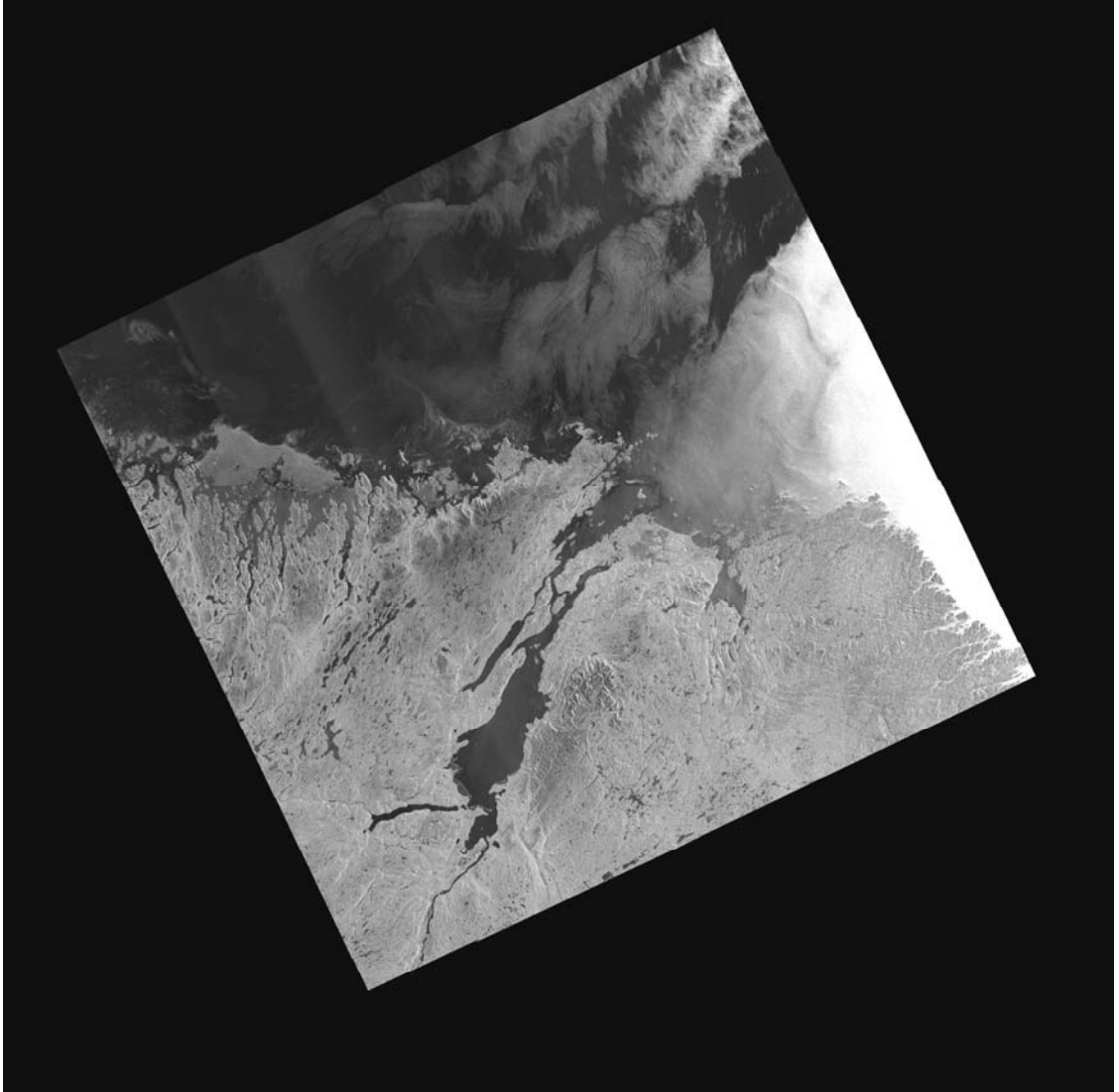


Figure 2.6. Envisat ASAR imagery of Hamilton Inlet and Goose Bay, on the Labrador coast, from May 21, 2005. Data provided by European Space Agency.

(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.

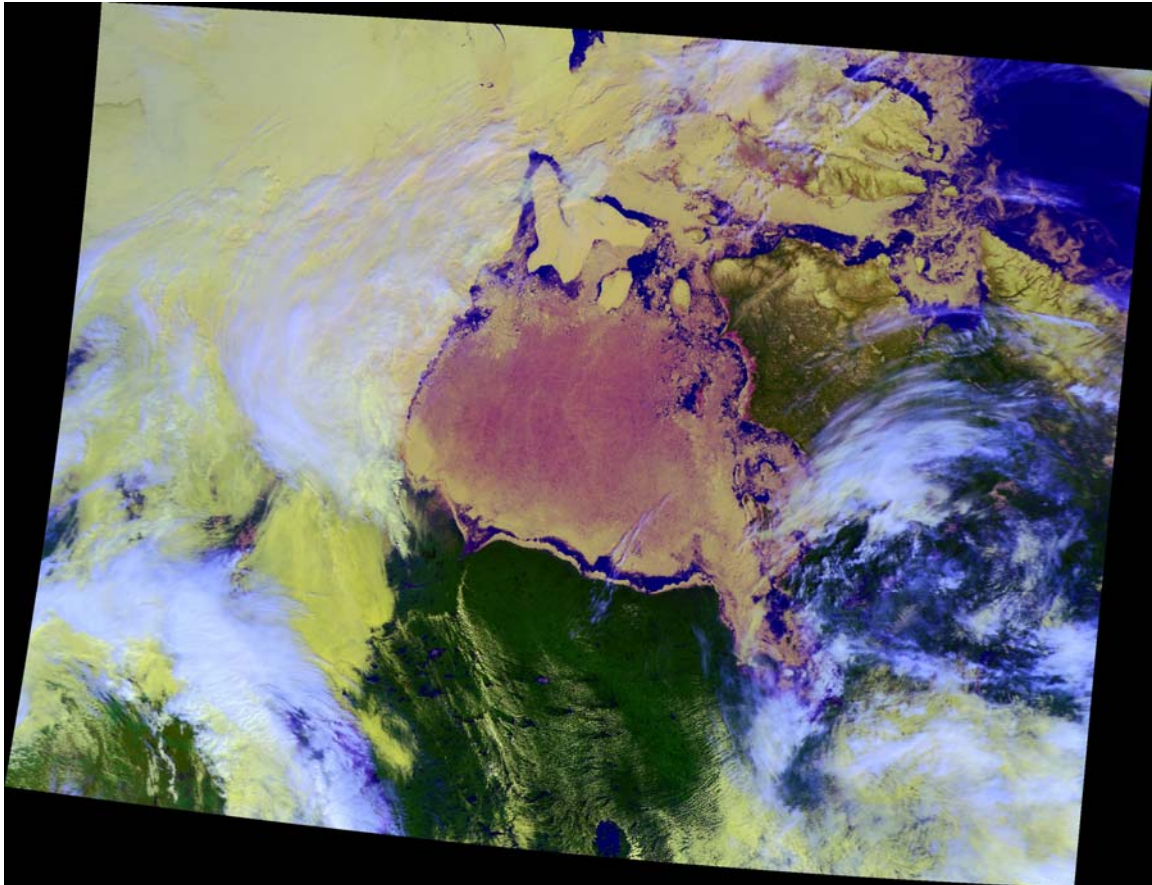


Figure 2.7. AVHRR imagery of Hudson Bay, from May 23, 2005. Data provided by NOAA.

**(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.

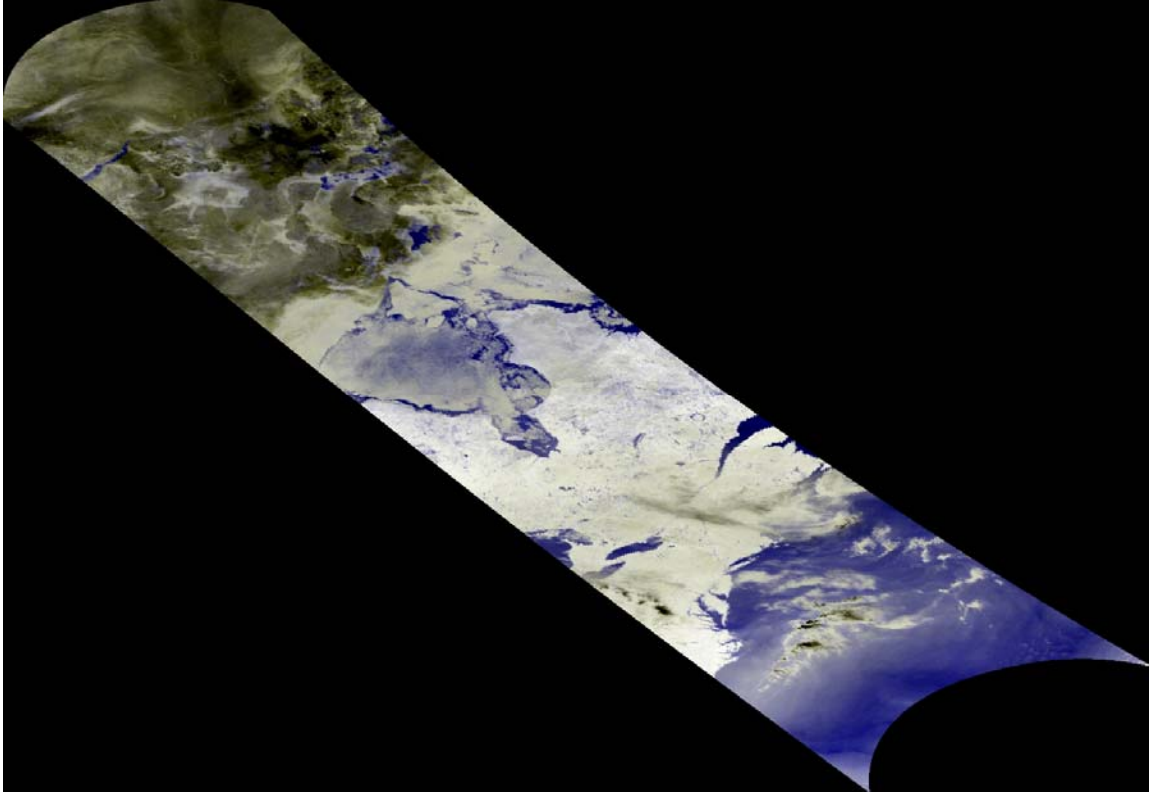


Figure 2.8. AMSR-E imagery covering Nunavut to the Atlantic Ocean, crossing Hudson Bay, Quebec, New Brunswick, and Maine, from May 23, 2005. Data provided by NASA.

(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.

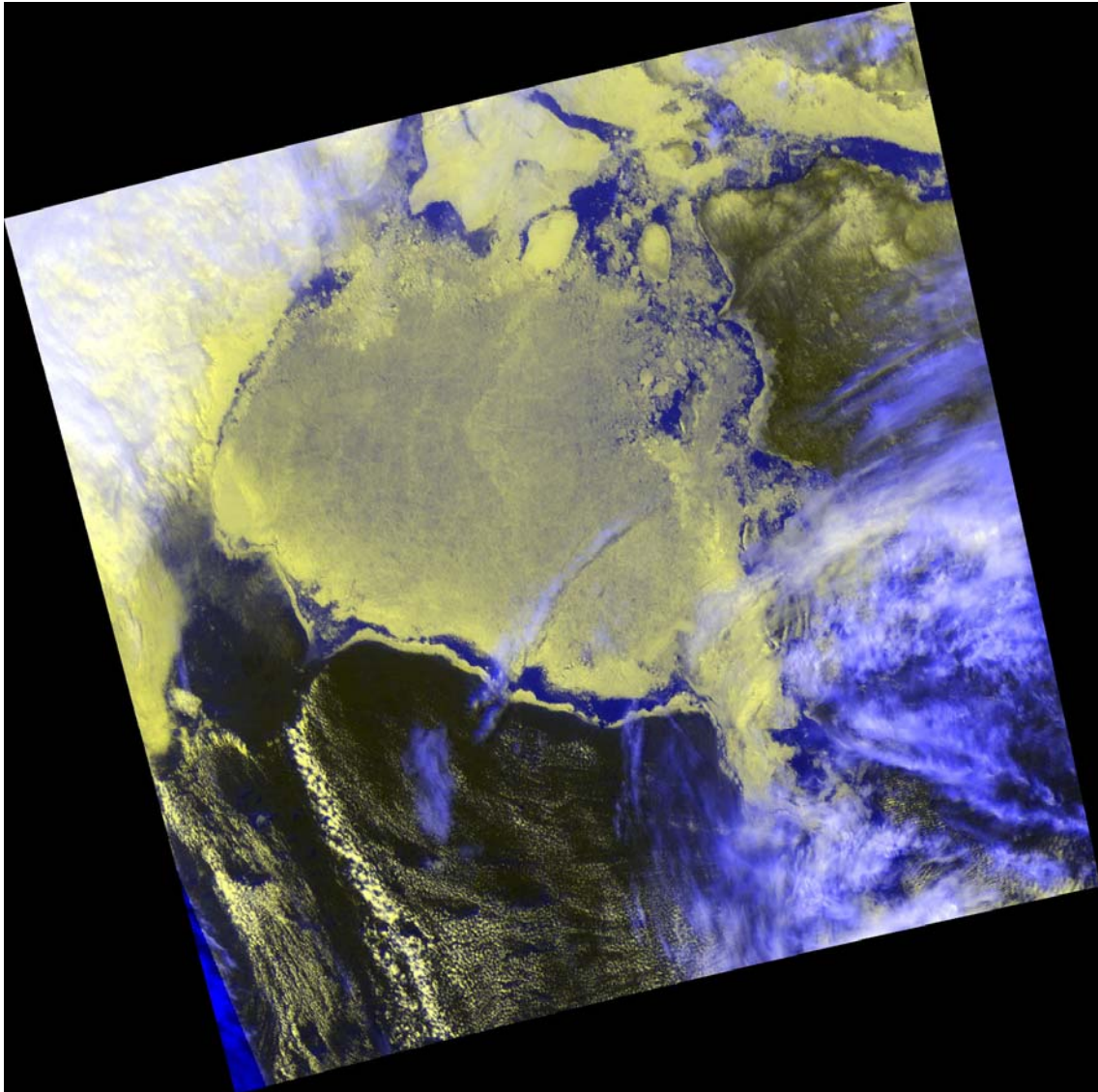


Figure 2.9. GOES imagery of Hudson Bay, from May 23, 2005.

**(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 non-

georeferenced imagery off the World Wide Web daily [Fequet, 2004]. A sample of MODIS imagery is shown in Figure 2.10.

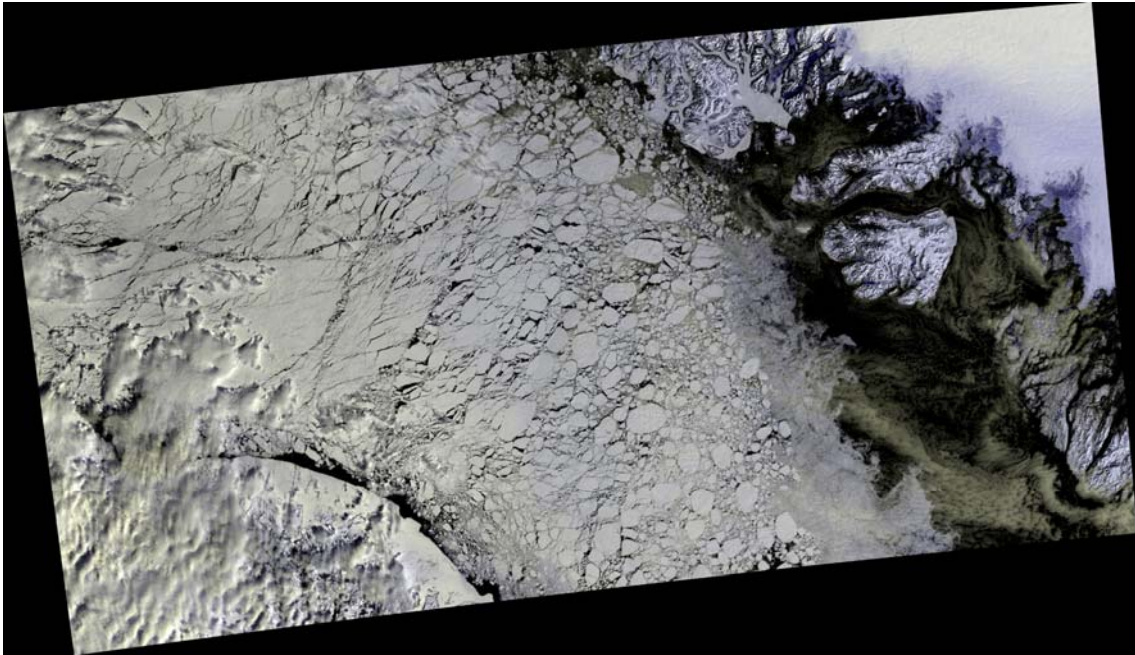


Figure 2.10. MODIS imagery of Baffin Bay, between Baffin Island and Greenland, from May 19, 2005. Data provided by NASA.

**(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.

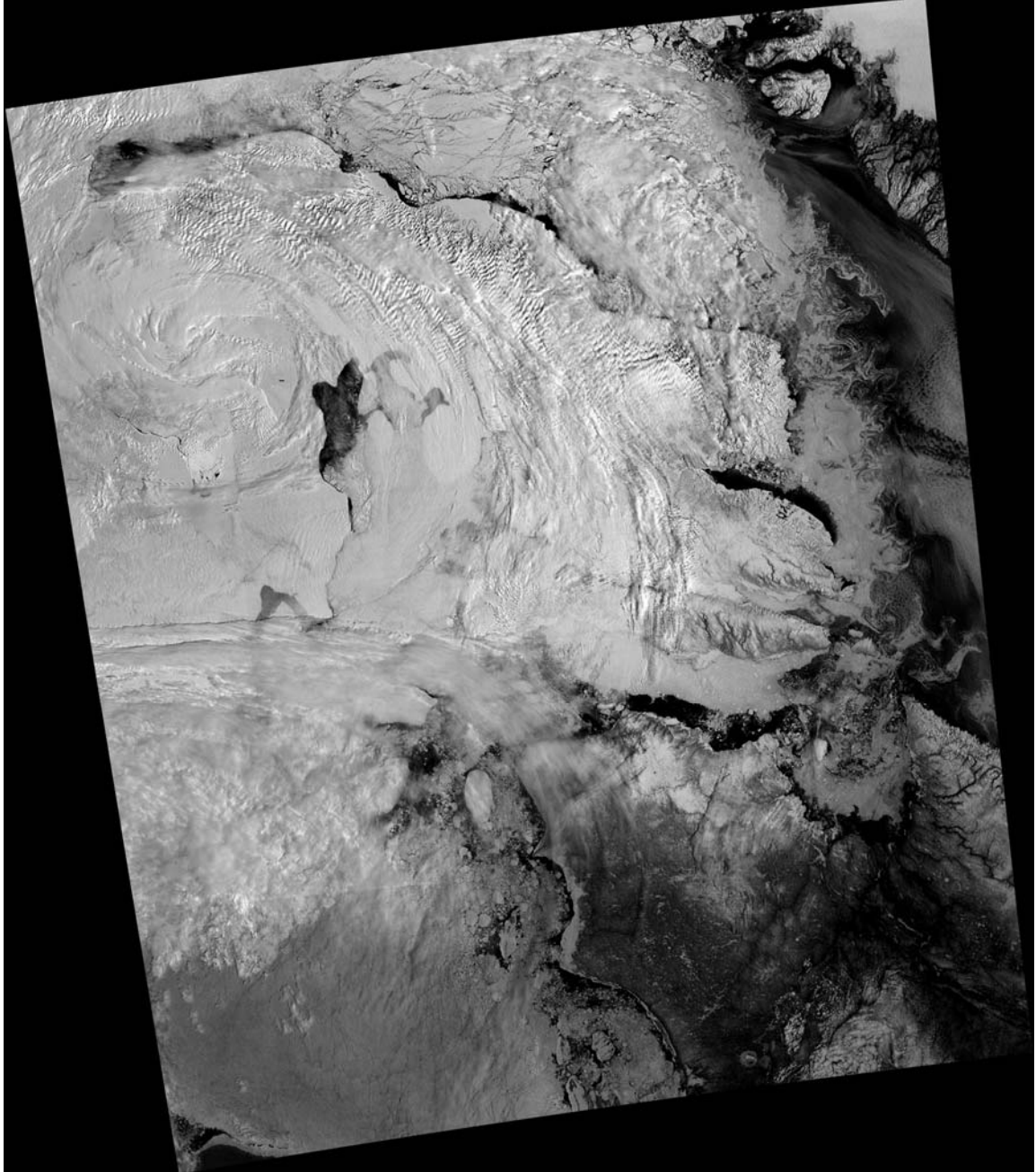


Figure 2.11. DMSP OLS imagery of Hudson Bay, Nunavut, and Quebec, from May 20, 2005.

**(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.

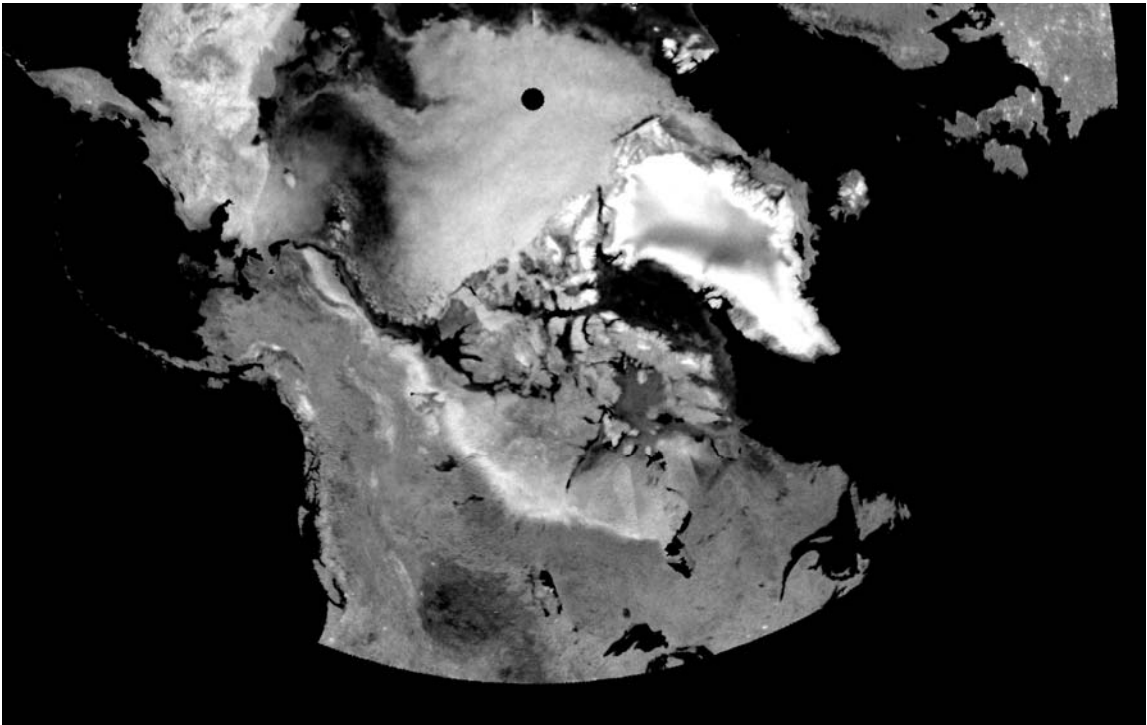


Figure 2.12. QuikSCAT SeaWinds imagery of Canada, from May 23, 2005. Data provided by NASA.

(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 imagery is used only one to three times per week [Fequet, 2003]. A sample of SSM/I imagery is shown in Figure 2.13.

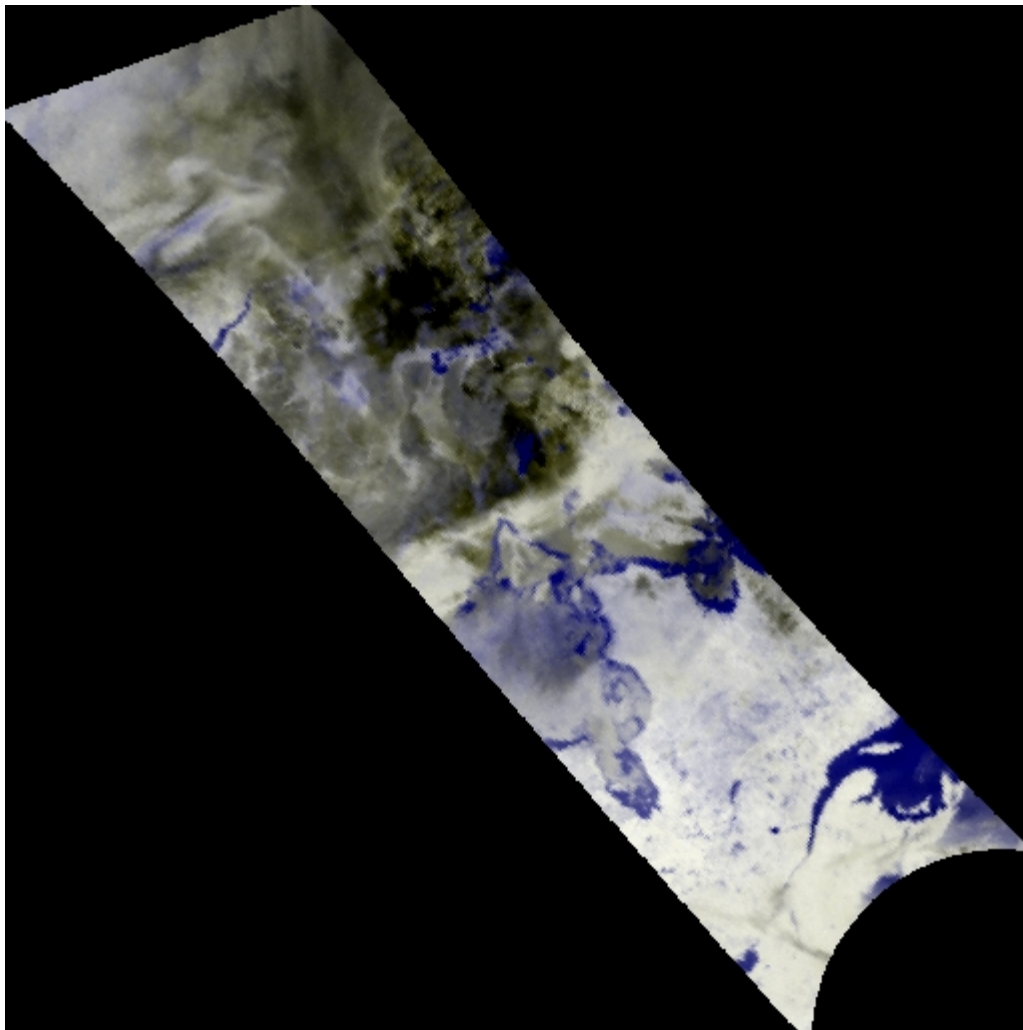


Figure 2.13. DMSP SSM/I imagery of Nunavut, Hudson Bay, Quebec, and the Maritime provinces, from May 24, 2005.

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

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

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

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.

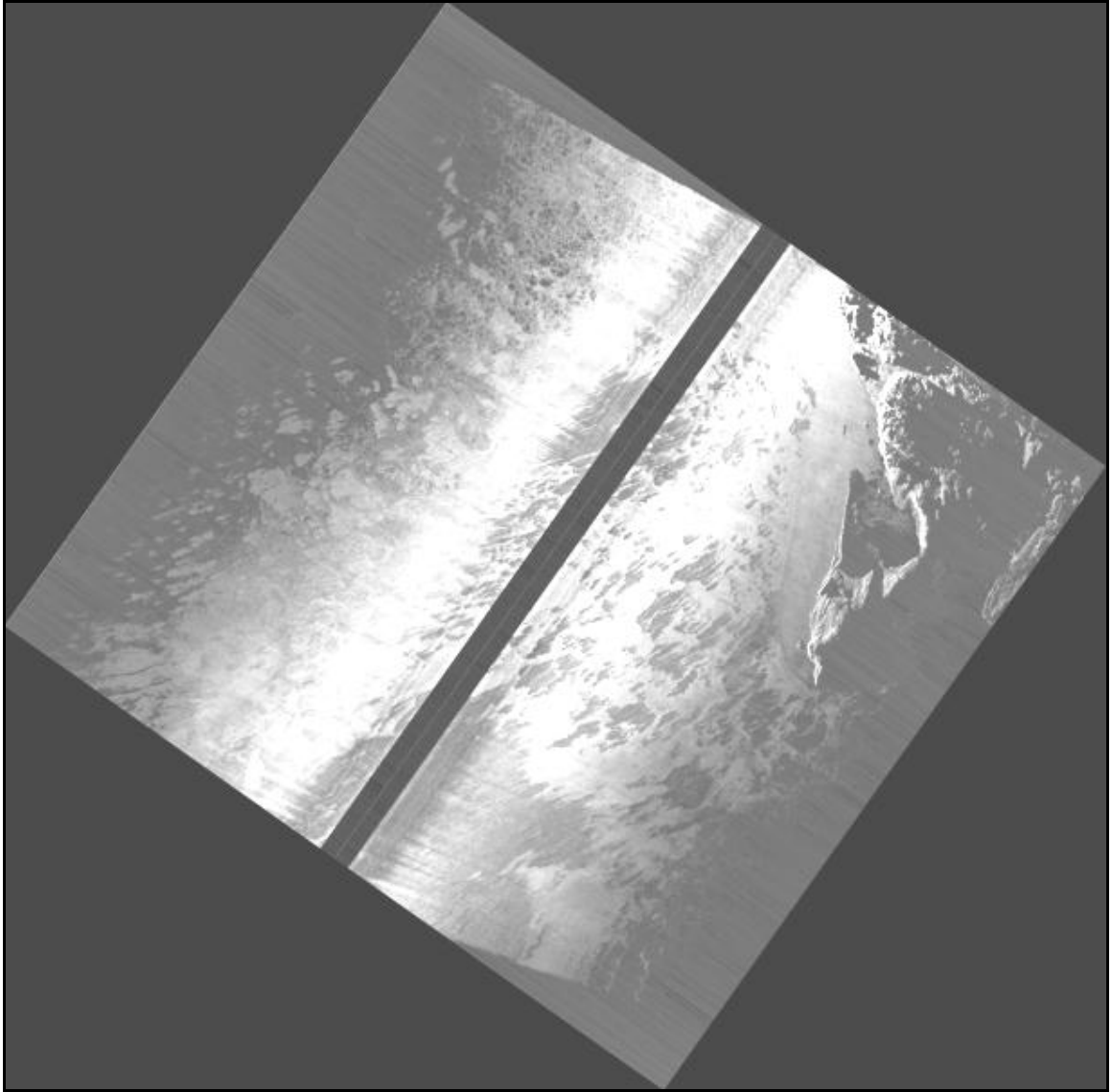


Figure 2.14. SLAR imagery of part of the Gulf of St. Lawrence, from March 4, 2003.  
Data provided by Canadian Ice Service.

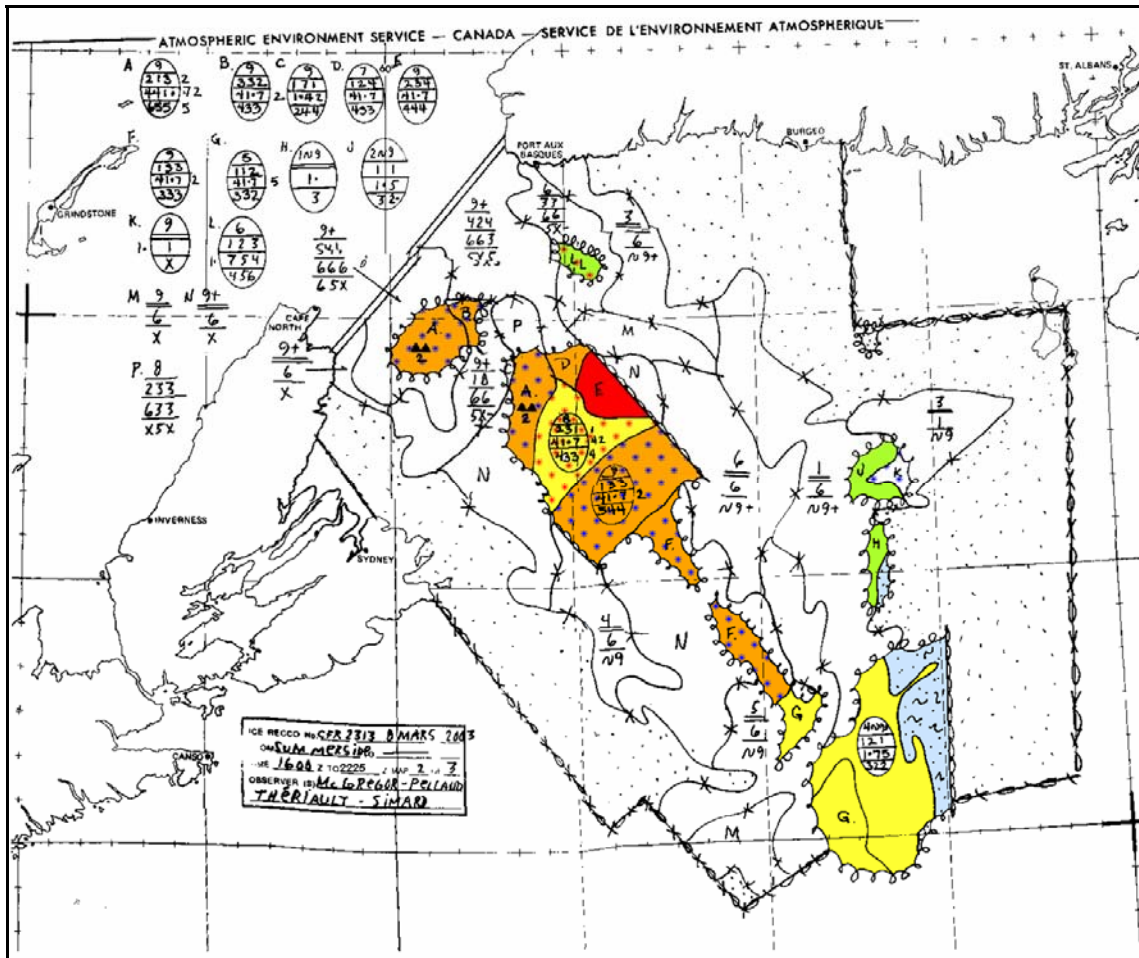


Figure 2.15. Airborne observed chart combining visual and SLAR observations.

### 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.

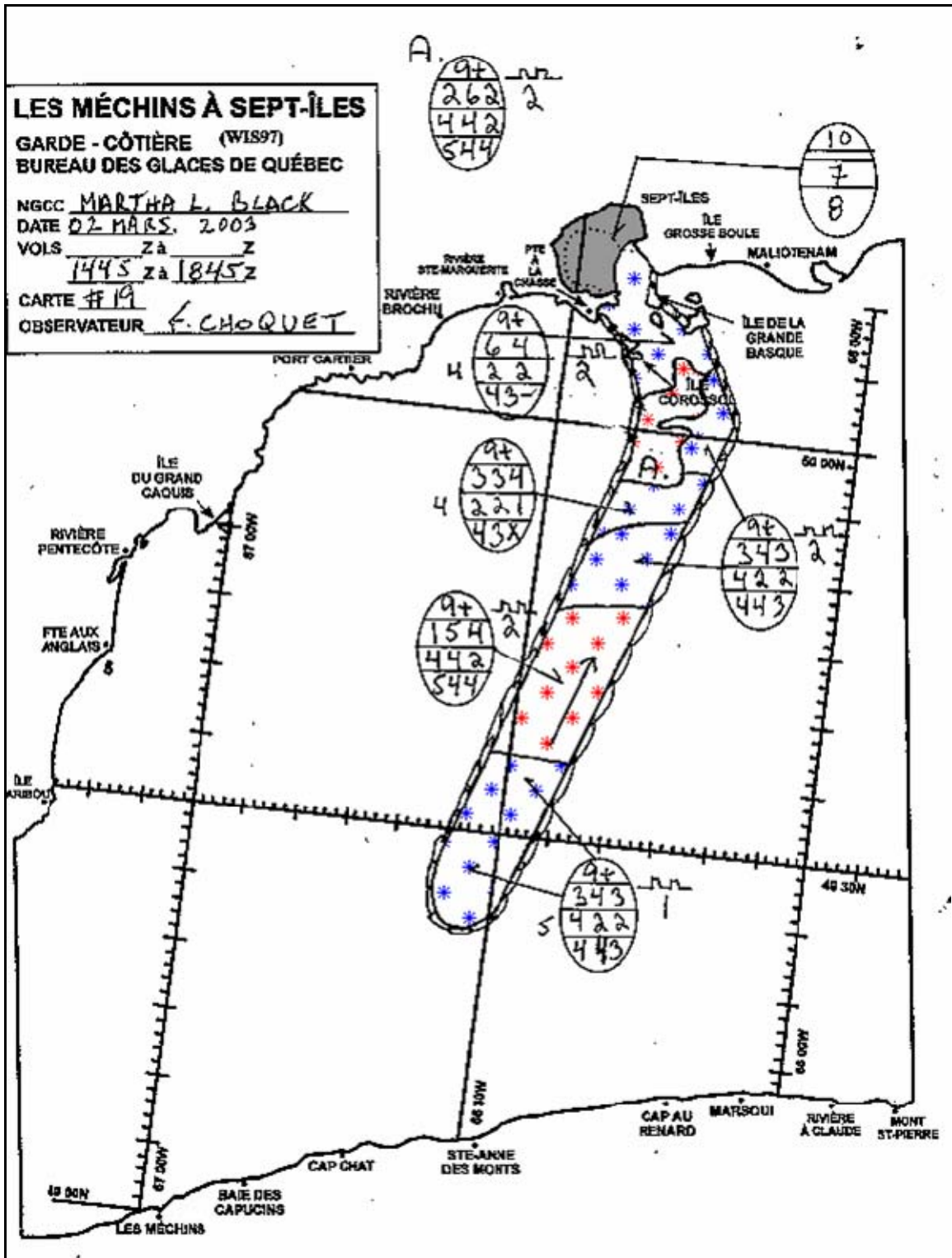


Figure 2.16. Ship-borne visual observation chart.

#### **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.

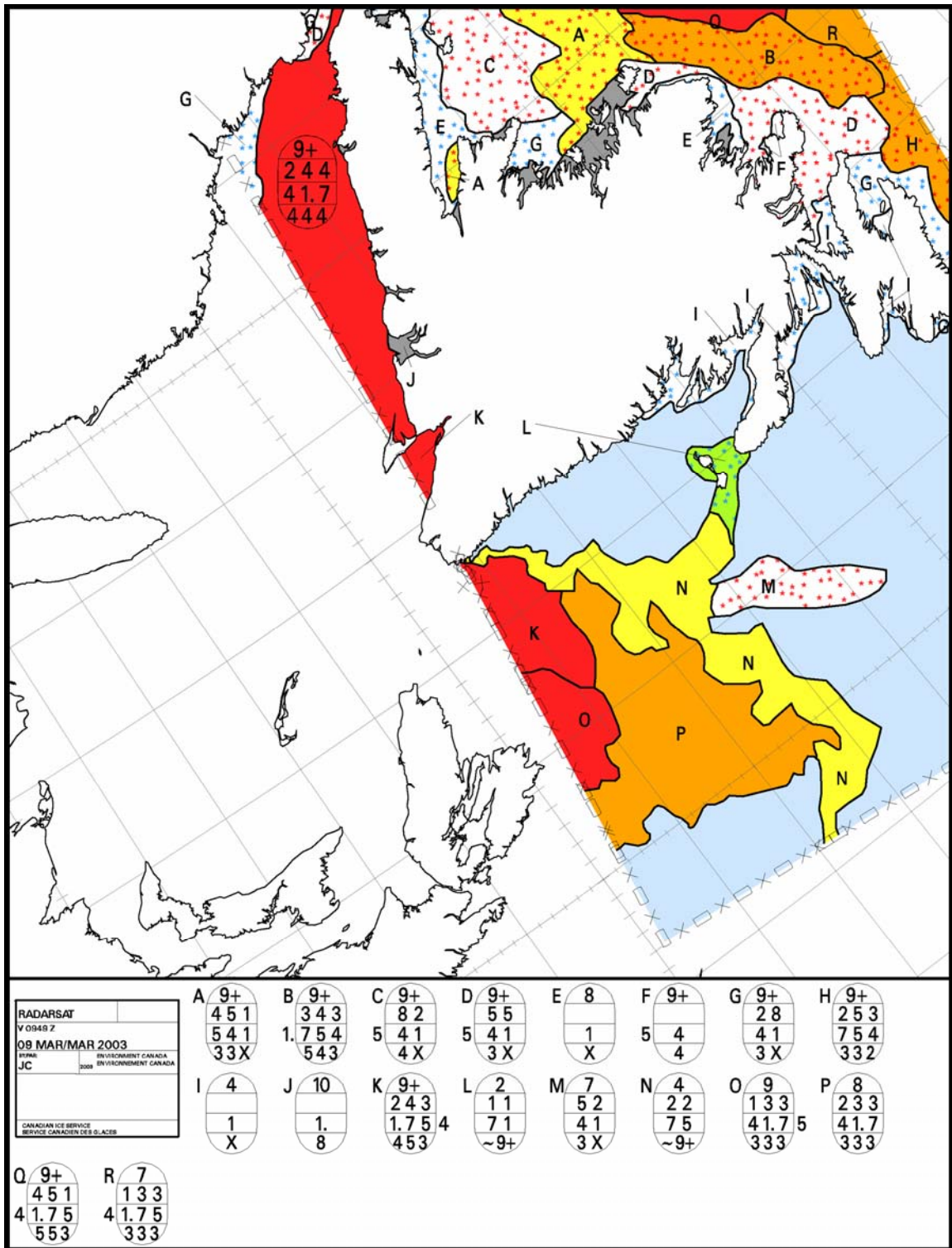


Figure 2.17. RADARSAT-based image analysis chart for the Cabot Strait.

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>.

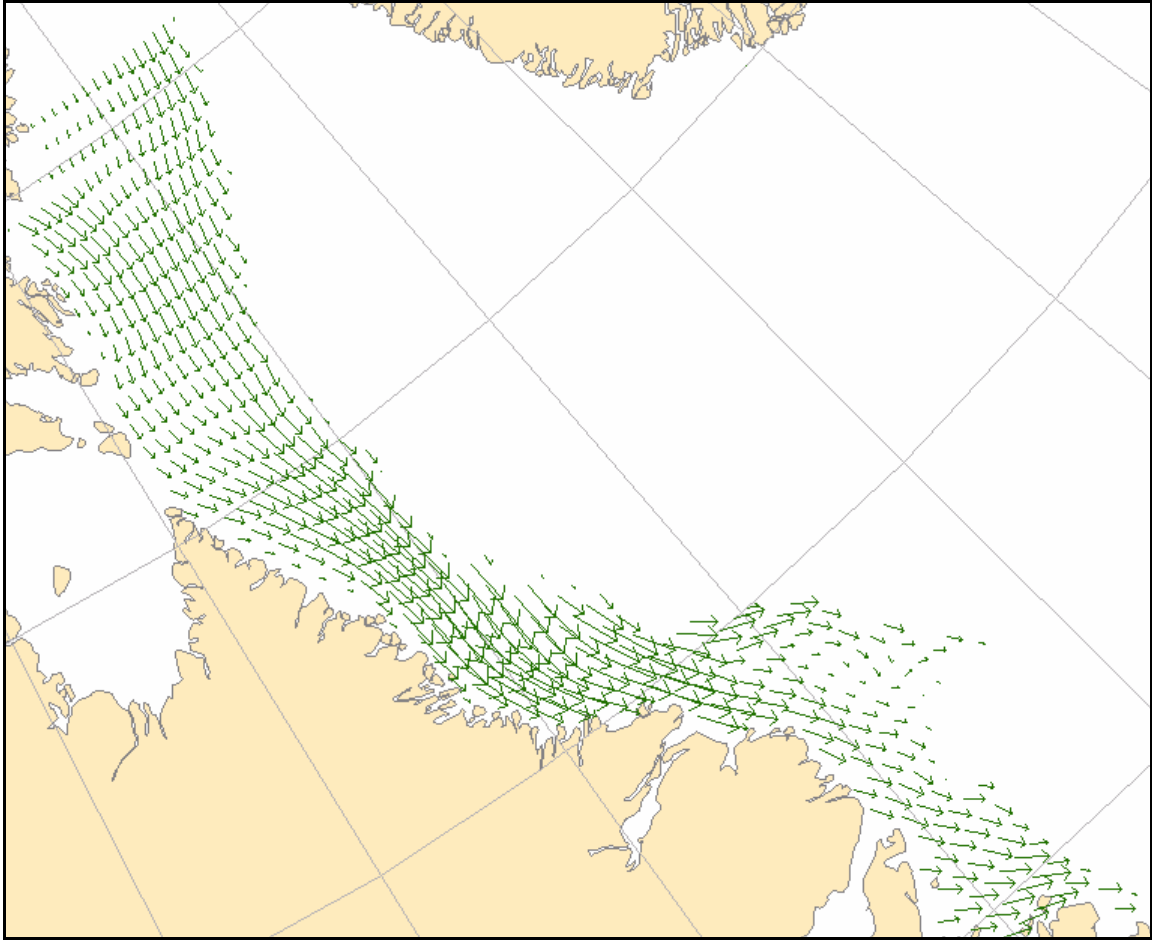


Figure 2.18. Ice trajectory map: the output of ice models.

### **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 it 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 data. 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].

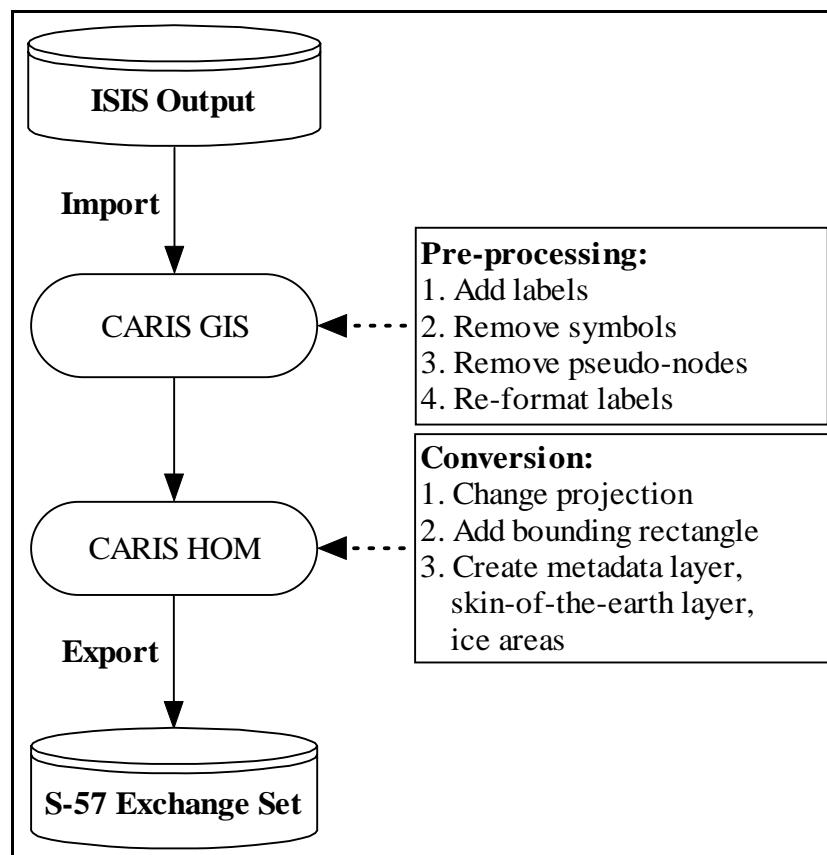


Figure 2.19. Flow chart of Lapointe's methodology (after Lapointe [2001]).

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 indicators, 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.

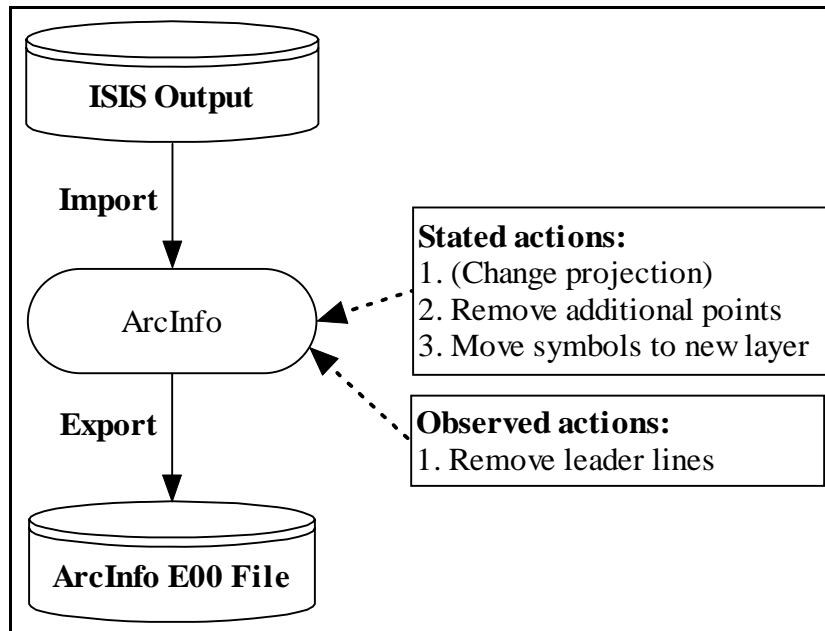


Figure 2.20. Flow chart of Diarbakerly's methodology (after Diarbakerly [2002]).

#### 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.

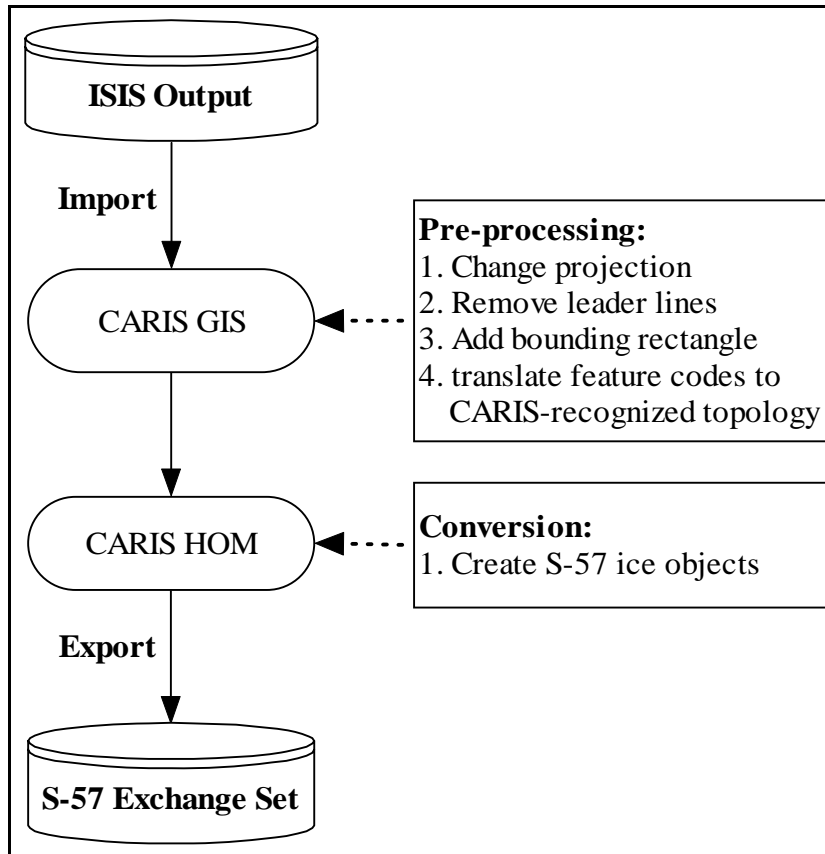


Figure 2.21. Flow chart of Agi's methodology (after Agi [2003]).

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

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

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<sup>1</sup> ArcInfo, ArcView, and ESRI are registered trademarks of the Environmental Systems Research Institute, Redlands, CA, USA.

<sup>2</sup> EASY-ENC is a trademark of CARIS, Fredericton, NB, Canada.

<sup>3</sup> CARIS is a registered trademark of CARIS, Fredericton, NB, Canada.

<sup>4</sup> EasyEdit Lite and PNGIS are trademarks of PNGIS, Vancouver, BC, Canada.

<sup>5</sup> dKart is a trademark of dKart

<sup>6</sup> TRANSAS is a trademark of TRANSAS

<sup>7</sup> SeeMyDEnc and SevenCs are trademarks of SevenCs, Germany.

Table 3.2. Daily Ice Charts Provided by the CIS

| <b>File Name</b>        | <b>Region</b>             | <b>Date</b>      |
|-------------------------|---------------------------|------------------|
| 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.

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<sup>8</sup> 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])

| <b>ArcInfo Geometry</b> |   | <b>S-57 Vector Record</b> |
|-------------------------|---|---------------------------|
| Point                   | ⇒ | Isolated node             |
| Node                    | ⇒ | Connected node            |
| Line                    | ⇒ | Edge                      |
| Polygon                 | ⇒ | 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])

| <b>S-57 Feature Record</b> |   | <b>ArcInfo Geometry</b> |
|----------------------------|---|-------------------------|
| Feature point              | ⇒ | Point                   |
| Feature node               | ⇒ | Node                    |
| Feature line               | ⇒ | Route                   |
| Feature area               | ⇒ | 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])

| <b>ArcInfo</b> |   | <b>S-57 Vector Record</b> | <b>S-57 Feature Record</b> |
|----------------|---|---------------------------|----------------------------|
| Point          | ⇒ | Isolated node             | Feature point              |
| Node           | ⇒ | Connected node            | Feature node               |

| <b>ArcInfo</b> |   | <b>S-57 Vector Record</b> | <b>S-57 Feature Record</b> |
|----------------|---|---------------------------|----------------------------|
| 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

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

| PNT_TYPE          | Description                | Object                 | Attribute(s) | Value(s) |
|-------------------|----------------------------|------------------------|--------------|----------|
| 140               | Ice area (with attributes) | SEAICE<br>or<br>LACICE | ICEACT       |          |
| 143<br>144<br>145 | Ice area (no attributes)   | SEAICE<br>or<br>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.

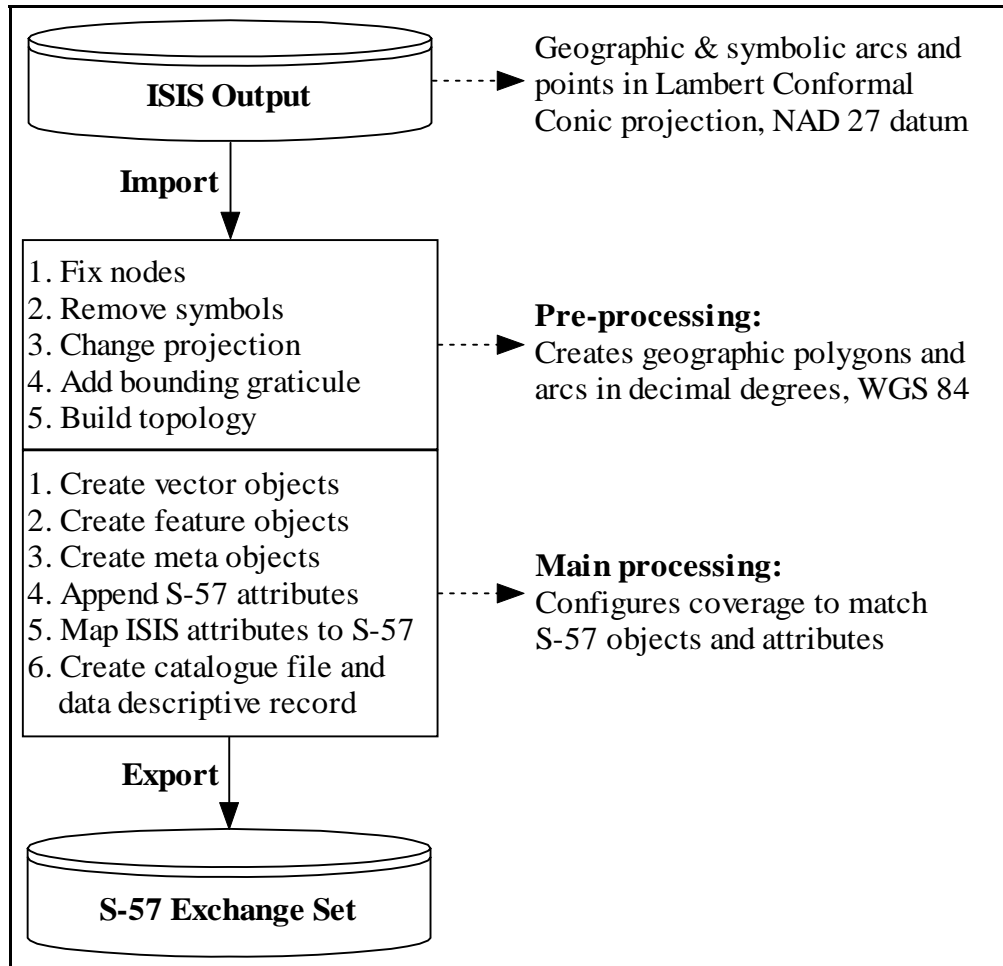


Figure 3.1. Application workflow of the developed solution.

### 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.

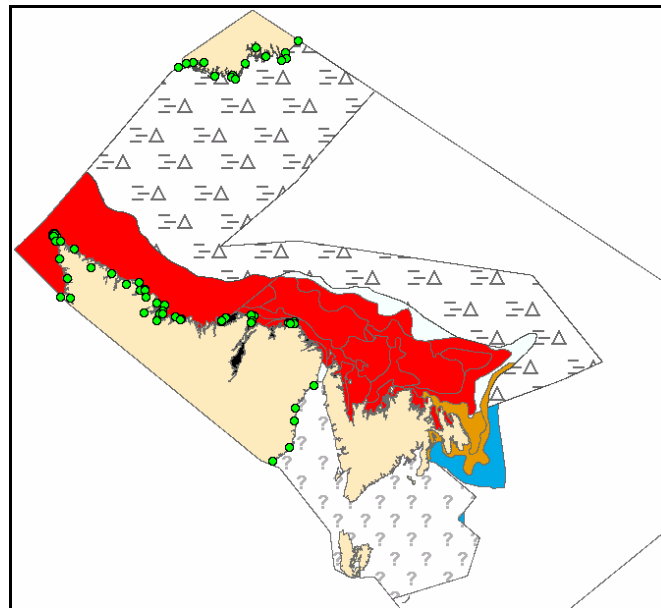


Figure 3.2. Ice chart of Newfoundland and Labrador with missing nodes (shown as green circles). Nodes are found only on some shorelines, not on any other arc.

### 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.

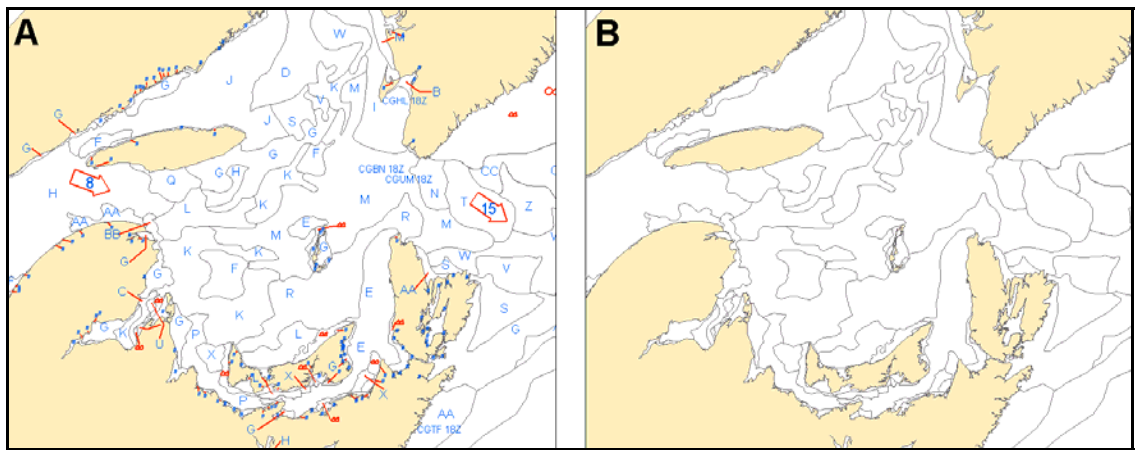


Figure 3.3. Ice chart with symbology removed. Land is shown in beige to assist viewing. (A) shows all arcs and annotations (text in blue) in the input coverage. Arcs to be deleted are in red. (B) shows the coverage after deletion.

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).

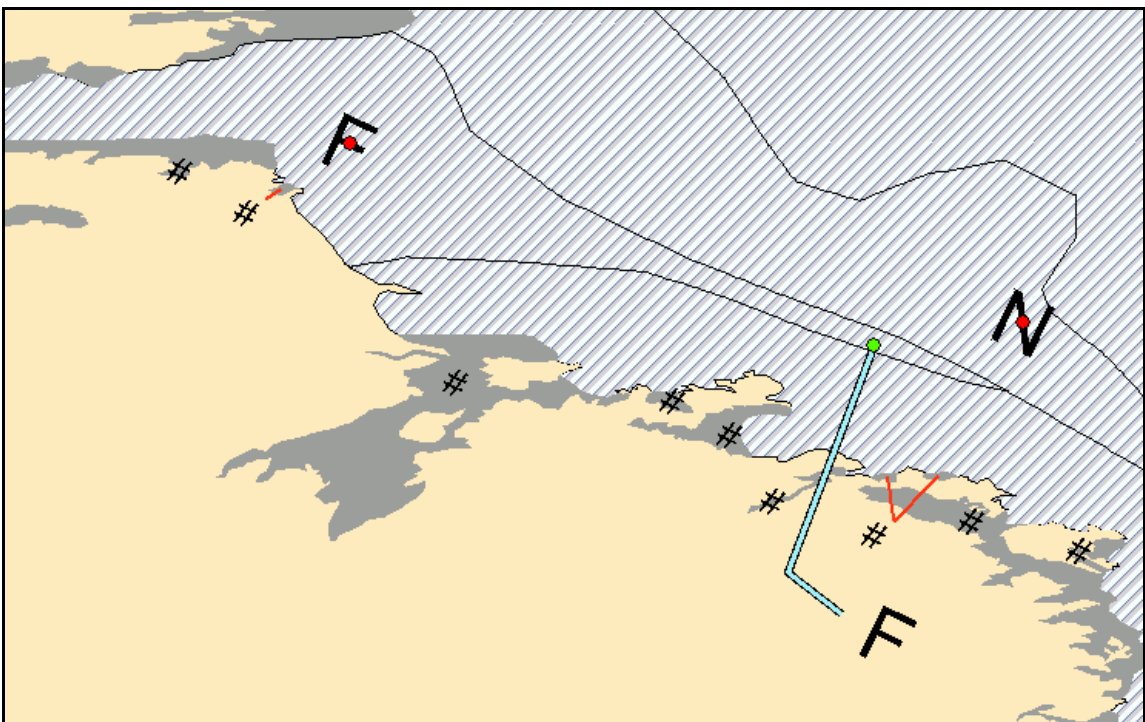


Figure 3.4. Example of two points, both labelled “F”, in one polygon. The point whose label is inside the polygon has a PNT\_TYPE value of 118, the other’s value is 120.

#### 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 ENC's 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.

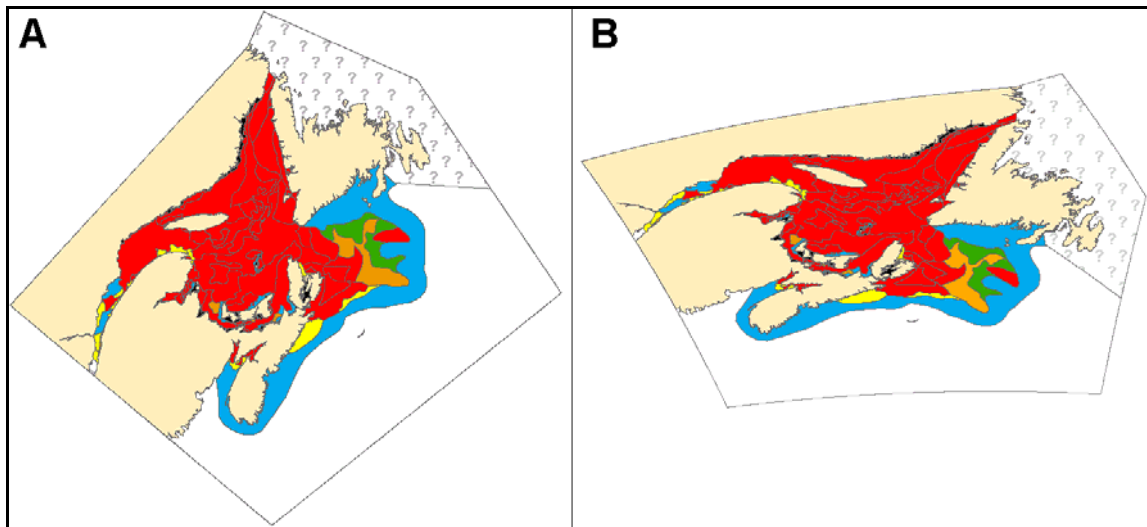


Figure 3.5. Ice chart's projection changed from Lambert Conformal Conic, NAD 27 (A) to decimal degrees, WGS 84 (Mercator projection used for display) (B).

### 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  $0.01^\circ$  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.

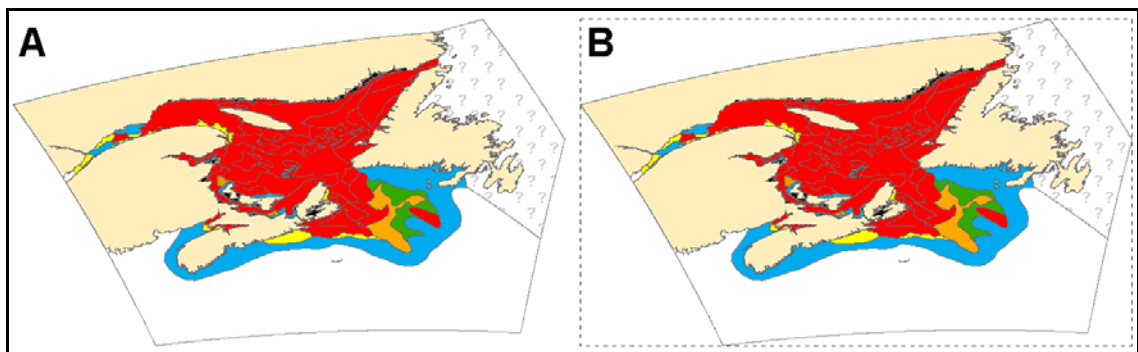


Figure 3.6. Ice chart with bounding graticule added. (A) shows the chart before the graticule is added, (B) shows the graticule as a dashed line.

### 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 placed 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.

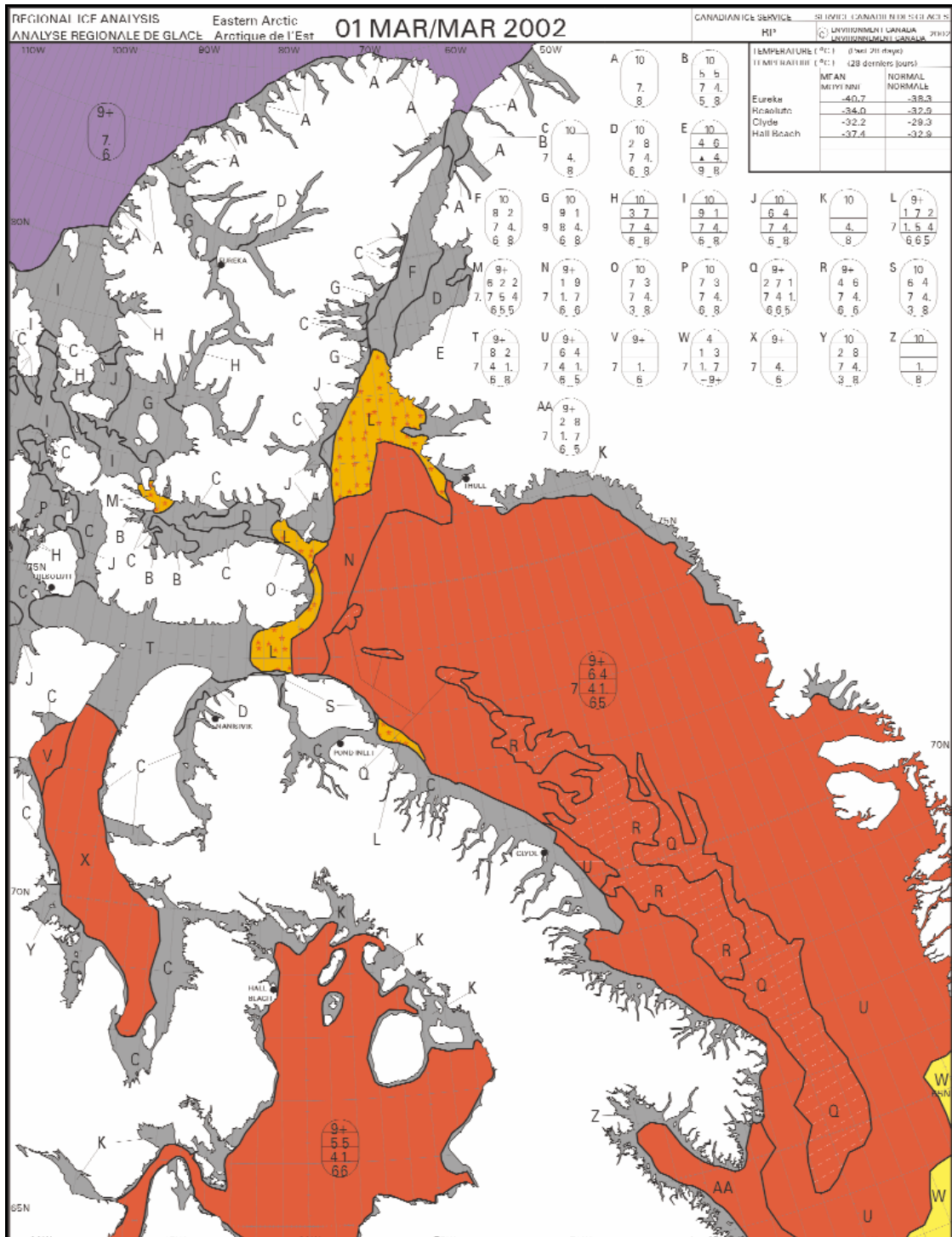


Figure 3.7. Egg Code placement on charts. Large polygons contain their Egg Codes. Some polygons only contain the letter of their Egg Code (which is in the upper-right of the chart). Small polygons only have lines pointing from their Egg Code letter to them.

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.

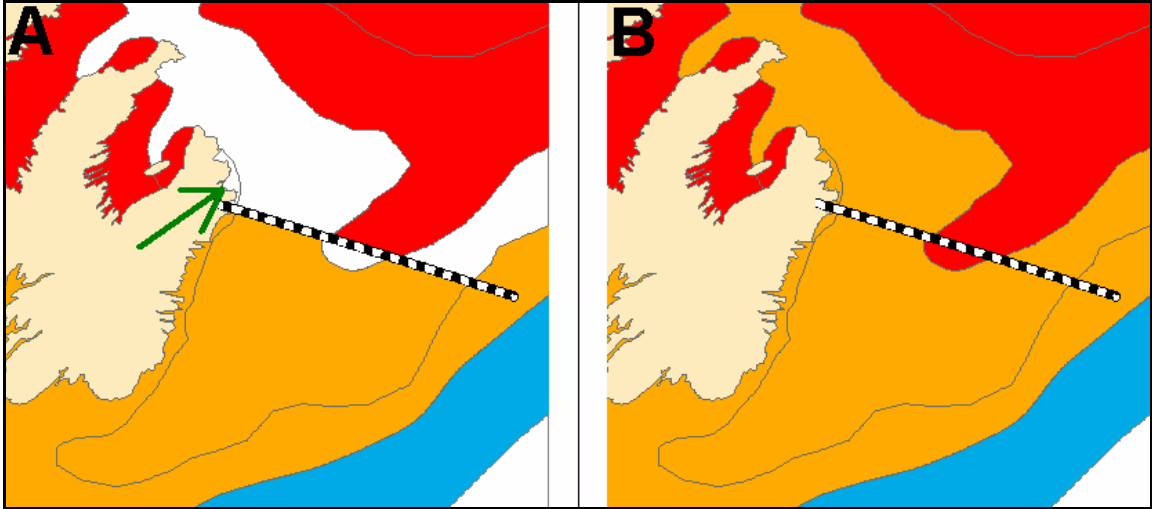


Figure 3.8. Non-topological LINE\_TYPE 151. This is the thick line that alternates between black and white. (A) shows how polygon attributes are lost after building topology (in white). (B) shows the fixed polygons.

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 ARCRROUTE and then edited in ArcEdit. They must be edited because ARCRROUTE 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 ARCRROUTE, 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.

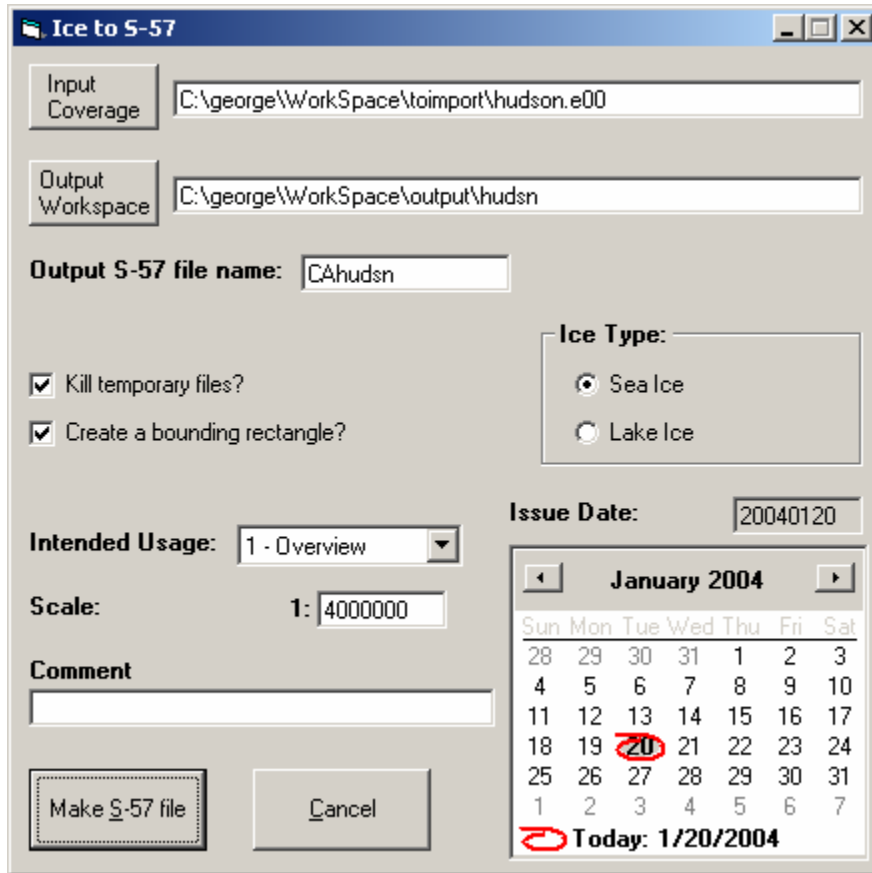


Figure 3.9. The tool's graphical user interface (GUI).

### 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 entirety 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 include 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.

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**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].












| <b>Ice coverage in tenths</b>   |  |
|---|--|
| <i>Ice thicker than 15 cm</i>   |  |
|    | Open or bergy water<br>(less than 1/10) LIGHT BLUE |
|    | 1 to 3/10 GREEN                                    |
|   | 4 to 6/10 YELLOW                                   |
|    | 7 to 8/10 ORANGE                                   |
|    | 9 to 10/10 RED                                     |
|   | Fast ice BLACK, GREY                               |
| <b>Predominant Ice – 15 cm or less</b>  |  |
|   | Less than 10 cm (new ice) BLUE                     |
|    | 10 to 15 cm (grey ice) RED                         |
| <b>Old Ice</b>  |  |
|   | 1 to 4/10 PURPLE LINES                             |
|   | 5 to 10/10 PURPLE                                  |

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

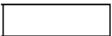


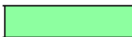





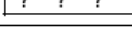


| Colour  |   | RGB colour model | Total concentration (definition from WMO Nomenclature) | Number from WMO Nomenclature |
|---|---|------------------|--|------------------------------|
| alternative   | prime   |                  |  |                              |
|  |    | 000-100-255      | Ice free   | 4.2.8                        |
|   |    | 150-200-255      | Less than one tenth (open water)                       | 4.2.6                        |
|   |    | 140-255-160      | 1/10 - 3/10 (very open ice)                            | 4.2.5                        |
|   |    | 255-255-000      | 4/10 - 6/10 (open ice)                                 | 4.2.4                        |
|   |    | 255-125-007      | 7/10 - 8/10 (close ice)                                | 4.2.3                        |
|   |    | 255-000-000      | 9/10 - 10/10 (very close ice)                          | 4.2.2                        |
|   |    | 150-150-150      | Fast ice   | 1.1.1                        |
|   |    | 210-210-210      | Ice shelf  | 10.3                         |
|   |    | 255-255-255      | Undefined ice  | -                            |
| <hr style="border-top: 1px dashed black;"/>                                       |   |                  |  |                              |
| <b>Optional</b>   |   | 255-175-255      | 7/10-10/10 new ice                                     | 2.1                          |
|   |  | 255-100-255      | 9/10-10/10 nilas, grey ice (mainly on leads)           | 2.2, 2.4                     |
| <b>Areas of No Information are annotated accordingly</b>                          |   |                  |  |                              |

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










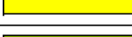









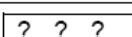











| Colour  |   | RGB colour model | Stage of development (SoD)                | Number from WMO Sea Ice Nomenclature |
|---|---|------------------|---|--------------------------------------|
| alternative   | prime   |                  |   |                                      |
|  |    | 000-100-255      | 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                               |
| <b>Areas of No Information are annotated accordingly</b>                          |   |                  |   |                                      |

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

| <b>Open or Bergy Water</b>  |   |
|---|---|
|    | Open water                              |
|    | Bergy waters                            |
| <b>New and Open Ice</b>   |   |
|    | New ice                                 |
|    | Open ice                                |
|    | Very open ice                           |
| <b>Level and More Compact Ice</b>   |   |
|   | Level ice                               |
|  | Close ice                               |
|  | Consolidated, compact or very close ice |
| <b>Fast Ice</b>   |   |
|  | 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].

| <b>PNT_TYPE</b> | <b>PNT_NAME</b>  | <b>Full Name</b>          | <b>“Real” Feature</b> | <b>Description</b>                               |
|-----------------|------------------|---------------------------|-----------------------|--|
| 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                     |

| <b>PNT_TYPE</b> | <b>PNT_NAME</b>   | <b>Full Name</b>                 | <b>“Real”<br/>Feature</b> | <b>Description</b>                               |
|-----------------|-------------------|----------------------------------|---------------------------|--|
| 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_glance        | IceGlance Egg                    | X                         | Polygon label for a “ice/glance” 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 |

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

| <b>PNT_TYPE</b> | <b>PNT_NAME</b> | <b>Full Name</b>                    | <b>“Real”<br/>Feature</b> | <b>Description</b>                        |
|-----------------|-----------------|-------------------------------------|---------------------------|---|
| 934             | inside_eggedge  | TEMPORARY                           |                           | temporary label for inside egg edge       |
| 935             | outside_eggedge | TEMPORARY                           |                           | temporary label for outside egg edge      |
| 950             | sym_centroid    | TEMPORARY<br>Symbol Centre<br>Point |                           | temporary label for symbology centroid    |
| 951             | sym_pivot       | TEMPORARY<br>Symbol Pivot<br>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].

| <b>LINE_TYPE</b> | <b>LINE_NAME</b>  | <b>Full Name</b>                          | <b>“Real”<br/>Feature</b> | <b>Description</b>                                    |
|------------------|-------------------|---|---------------------------|---|
| 8                | neat              | Analysis<br>Neatline<br>Boundary          | X                         | line for edge of<br>analysis                          |
| 8                | chartt_neat       | Chart Template<br>Neatline<br>Boundary    |                           | line for Chart<br>Template Neatline<br>Boundary       |
| 9                | chartt_construct  | Chart Template<br>Construction<br>Line    |                           | line for Chart<br>Template<br>Construction Line       |
| 10               | chartt_rem_eggs   | Chart Template<br>Remote Eggs             |                           | line for Chart<br>Template Remote<br>Eggs             |
| 11               | chartt_legend     | Chart Template<br>Legend Line             |                           | line for Chart<br>Template Legend<br>Line             |
| 12               | chartt_twnd       | Chart Template<br>Temperature<br>Boundary |                           | line for Chart<br>Template<br>Temperature<br>Boundary |
| 13               | chartt_tline      | Chart Template<br>Temperature<br>Line     |                           | line for Chart<br>Template<br>Temperature Line        |
| 14               | chartt_legend_int | Chart Template<br>Legend Interior<br>Line |                           | line for Chart<br>Template Legend<br>Interior Line    |
| 15               | chartt_erase      | Chart Template<br>Erase Polyline          |                           | line for Chart<br>Template Erase<br>Polyline          |
| 16               | chartt_shadebox   | Chart Template<br>Legend<br>Polyline      |                           | line for Chart<br>Template Legend<br>Polyline         |
| 17               | chartt_dashed     | Chart Template<br>Dashed Line             |                           | line for Chart<br>Template Dashed<br>Line             |

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

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

| <b>LINE_TYPE</b> | <b>LINE_NAME</b> | <b>Full Name</b>                                  | <b>“Real”<br/>Feature</b> | <b>Description</b>   |
|------------------|------------------|---|---------------------------|--|
| 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<br>for clipping<br>analysis extent |                           | line for Temporary<br>line for clipping<br>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].

| <b>Object Code</b> | <b>Object Class</b> | <b>Description</b>   |
|--------------------|---------------------|--|
| 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].

| <b>Attribute Code</b> | <b>Ice Attribute</b>               | <b>Description</b>  |
|-----------------------|------------------------------------|---|
| 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. |

| <b>Attribute Code</b> | <b>Ice Attribute</b>          | <b>Description</b>  |
|-----------------------|-------------------------------|---|
| 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**

```

1.    &SETVAR myspace = [SHOW &WORKSPACE]

2.    /* (re)import ice INFO files
3.    &IF [EXISTS %ARHOME%\template\s57\s57.objl_ice -INFO] = .TRUE.
    &THEN
4.    KILLINFO %ARHOME%\template\s57\s57.objl_ice
5.    &IF [EXISTS %ARHOME%\template\s57\s57.attl_ice -INFO] = .TRUE.
    &THEN
6.    KILLINFO %ARHOME%\template\s57\s57.attl_ice
7.    &IF [EXISTS %ARHOME%\template\s57\s57.o2a_ice -INFO] = .TRUE.
    &THEN
8.    KILLINFO %ARHOME%\template\s57\s57.o2a_ice

9.    DBASEINFO objl_ice.dbf %ARHOME%\template\s57\s57.objl_ice DEFINE
10.   nocode nocode 4 6 B
11.   colabel colabel 6 6 C
12.   codesc codesc 100 100 C
13.   END

14.   DBASEINFO attl_ice.dbf %ARHOME%\template\s57\s57.attl_ice DEFINE
15.   nocode nocode 4 6 B
16.   calabel calabel 6 6 C
17.   ctype ctype 1 1 C
18.   cadesc cadesc 100 100 C
19.   info_type info_type 1 1 C
20.   info_lengt info_length 2 4 B
21.   END

22.   DBASEINFO o2a_ice.dbf %ARHOME%\template\s57\s57.o2a_ice DEFINE
23.   nocode nocode 4 6 B
24.   nocode nocode 4 6 B
25.   cset cset 1 1 C
26.   END

27.   &WORKSPACE %ARHOME%\template\s57

28.   /* merge ice records into rest of S-57 records
29.   &DATA ARC INFO
30.   ARC
31.   /* add or replace objects
32.   SELECT S57.OBJL
33.   RESELECT NOCODE GE 201 AND NOCODE LE 218
34.   PURGE
35.   YES
36.   SELECT S57.OBJL_ICE
37.   MERGE INTO S57.OBJL ON NOCODE
38.   /* add or replace attributes
39.   SELECT S57.ATTL
40.   RESELECT NACODE GE 201 AND NACODE LE 234
41.   PURGE
42.   YES
43.   SELECT S57.ATTL_ICE
44.   MERGE INTO S57.ATTL ON NACODE
45.   /* add or replace object to attribute link
46.   SELECT S57.O2A
47.   RESELECT NOCODE GE 201 AND NOCODE LE 218
48.   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**

```

1.  /*****
    *****/
2.  /*   Program: ICE2S57.AML
3.  /*   Purpose: Convert a CIS ice chart to S-57 format.
4.  /*-----
    -----
5.  /*
6.  /*   Usage: ICE2S57 <in_cover> <out_workspace> <out_cover>
    <SEAICE | LACICE> {TEMPS | NOTEMPS}
7.  /*                   {BOX | NOBOX} {intended_usage}
    {issue_date} {scale} {comment}
8.  /*
9.  /*   Arguments: INE00 - input e00 file from CIS
10. /*              OUTSPACE - output workspace - safer if it doesn't
    exist
11. /*              OUTCOV - output coverage name - also will be name
    of output S-57 file
12. /*              ICETYPE - sea ice or lake ice
13. /*              KILLTEMPS - kill temporary coverages or not
14. /*              BOUNDBOX - create a bounding rectangle or not -
    necessary unless one exists
15. /*              INTU - intended usage code (1 to 6)
16. /*              ISDT - issue date in format YYYYMMDD
17. /*              CSCL - compilation scale - (1:4000000 is entered
    simply as 4000000)
18. /*              COMT - comment, up to 70 characters
19. /*
20. /*   Routines: INPUTS - verify inputs are legal
21. /*              IMPORTER - import e00
22. /*              SYMBOLOLOGY - remove non-geography features
23. /*              FIXPROJECTION - reproject to lat-long WGS84
24. /*              BOUNDBOX - add bounding rectangle
25. /*              TOPOLOGY - build topology
26. /*              ROUTE_REGION - create S-57 meta and feature
    objects (routes and regions in ARC)
27. /*              VRID - adds attributes to VENAME, AAT, and NAT
    which become VRID in S-57 file
28. /*              POP_RCID - adds unique RCID value to each object
29. /*              POP_REGION - populates meta and feature object
    attribute values
30. /*              ATTR - populates table containing S-57 B-level and
    C-level attributes
31. /*              CATD - create CATD field
32. /*              DSID - create DSID field
33. /*              DSSI - create DSSI field
34. /*              DSPM - create DSPM field
35. /*              MULTIPOINTS - create a list of polygons with
    different-valued points
36. /*              KILLTEMPS - kills temporary coverages, if
    requested
37. /*              MAKES57 - converts processed coverage to S-57
38. /*
39. /*   Globals: none
40. /*

```

```

41.  /*-----
-----
42.  /*      Calls: none
43.  /*-----
-----
44.  /*      Notes: Sometimes this AML fails for no apparent reason
when it enters tables.  It just
45.  /*          needs to be run again - things almost always work
out.
46.  /*
47.  /*          If a bounding rectangle already exists, it must
contain a value of 'xx' for the
48.  /*          'region' field.
49.  /*
50.  /*          DSHT and DSAC cannot be exported for some unknown
reason.  It seems to be a
51.  /*          problem with the ARCS57 command.
52.  /*
53.  /*-----
-----

54.  /* Created by: George Dias
55.  /* Created on: November 1, 2003
56.  /******
*****
57.  &ARGS ine00 outspace outcov icetype killtemps boundbox intu isdt
cscl comt
58.  &SEVERITY &ERROR &ROUTINE bailout
59.  &TERMINAL 9999
60.  &PT

61.  /*DEFINE PRECISION OF OUTPUT DATASETS
62.  PRECISION DOUBLE DOUBLE
63.  &MESSAGES &OFF &ALL

64.  &CALL inputs
65.  &CALL importer
66.  &CALL symbology
67.  &CALL fixprojection
68.  &IF %boundbox% = 'box' &THEN
69.  &CALL boundbox
70.  &CALL topology
71.  &CALL route_region
72.  &CALL vrid
73.  &CALL pop_rcid
74.  &CALL pop_region
75.  &CALL attr
76.  TABLES
77.  &CALL catd
78.  &CALL dsid
79.  &CALL dssi
80.  &CALL dspm
81.  QUIT
82.  &CALL multipoints
83.  &IF %killtemps% = 'notemps' &THEN
84.  &CALL killtemps

```

```

85.    &CALL makes57
86.    &MESSAGES &POPUP
87.    &TYPE 'Mission: accomplished in: '['TRUNCATE [CALC %timed% / 60]]'
minutes and '['MOD %timed% 60]' second(s).'
```

```

88.    &WORKSPACE %startspace%
89.    &PT &OFF
90.    &MESSAGES &ON
91.    &RETURN

92.    &ROUTINE inputs
93.    /*****
94.    /* CHECK IF INPUTS ARE CORRECT
95.    *****/
96.    &MESSAGES &POPUP
97.    /*INE00
98.    &SETVAR %ine00% = [QUOTE [UNQUOTE %ine00%]]
99.    &IF [NULL %ine00%] = .TRUE. &THEN
100.   &RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace>
<out_cover> <SEAICE | LACICE> ~
101.   /&                {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage}
~
102.   /&                {issue_date} {scale} {comment}
103.   &IF [EXISTS %ine00% -FILE] = .FALSE. &THEN
104.   &RETURN &WARNING Error: Exchange file %ine00% does not exist.

105.   /*OUTSPACE
106.   &SETVAR %outspace% = [QUOTE [UNQUOTE %outspace%]]
107.   &IF [NULL %outspace%] = .TRUE. &THEN
108.   &SETVAR %outspace% = &WORKSPACE
109.   &IF [EXISTS %outspace% -WORKSPACE] = .FALSE. &THEN
110.   CREATEWORKSPACE %outspace%

111.   /*OUTCOV
112.   &SETVAR %outcov% = [QUOTE [UNQUOTE %outcov%]]
113.   &IF [NULL %outcov%] = .TRUE. &THEN
114.   &RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace>
<out_cover> <SEAICE | LACICE> ~
115.   /&                {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage}
~
116.   /&                {issue_date} {scale} {comment}
117.   &IF [EXISTS %outspace%\%outcov% -COVER] = .TRUE. &THEN
118.   &DO
119.   &SETVAR killit = [QUERY 'Output coverage '%outspace%\'%outcov%'
exists. Do you want to replace it' .FALSE]
120.   &IF %killit% = .TRUE. &THEN
121.   &DO
122.   &MESSAGES &OFF &ALL
123.   KILL %outspace%\%outcov% ALL
124.   &MESSAGES &POPUP
125.   &END
126.   &ELSE
127.   &RETURN
128.   &END
129.   &SETVAR outcov = [UPCASE %outcov%]
```

```

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

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

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

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

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

```

```

168. &RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace>
    <out_cover> <SEAICE | LACICE> ~
169. /&                {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage}
    ~
170. /&                {issue_date} {scale} {comment} ~
171. /&-> {issue_date} must be an 8-character number in the form of
    YYYYMMDD. ~
172. /&-> the YYYY value entered is outlandish.
173. &IF [TYPE %isd%] <> -1 OR [LENGTH %isd%] <> 8 &THEN
174. &RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace>
    <out_cover> <SEAICE | LACICE> ~
175. /&                {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage}
    ~
176. /&                {issue_date} {scale} {comment} ~
177. /&-> {issue_date} must be an 8-character number in the form of
    YYYYMMDD.
178. &IF [SUBSTR %isd% 5 2] > 12 &THEN
179. &RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace>
    <out_cover> <SEAICE | LACICE> ~
180. /&                {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage}
    ~
181. /&                {issue_date} {scale} {comment} ~
182. /&-> {issue_date} must be an 8-character number in the form of
    YYYYMMDD. ~
183. /&-> the MM value entered is illegal.
184. &DO i &LIST 01 03 05 07 08 10 12
185. &IF [SUBSTR %isd% 5 2] = %i% &THEN
186. &IF [SUBSTR %isd% 7 2] > 31 &THEN
187. &RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace>
    <out_cover> <SEAICE | LACICE> ~
188. /&                {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage}
    ~
189. /&                {issue_date} {scale} {comment} ~
190. /&-> {issue_date} must be an 8-character number in the form of
    YYYYMMDD. ~
191. /&-> the DD value entered is illegal for the month given.
192. &END
193. &DO i &LIST 04 06 09 11
194. &IF [SUBSTR %isd% 5 2] = %i% &THEN
195. &IF [SUBSTR %isd% 7 2] > 30 &THEN
196. &RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace>
    <out_cover> <SEAICE | LACICE> ~
197. /&                {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage}
    ~
198. /&                {issue_date} {scale} {comment} ~
199. /&-> {issue_date} must be an 8-character number in the form of
    YYYYMMDD. ~
200. /&-> the DD value entered is illegal for the month given.
201. &END
202. &IF [SUBSTR %isd% 5 2] = 02 &THEN
203. &IF [SUBSTR %isd% 7 2] > 29 &THEN
204. &RETURN &WARNING Usage: ICE2S57 <in_cover> <out_workspace>
    <out_cover> <SEAICE | LACICE> ~
205. /&                {TEMPS | NOTEMPS} {BOX | NOBOX} {intended_usage}
    ~

```

```

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

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

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

225. &MESSAGES &OFF &ALL
226. &RETURN

227. &ROUTINE importer
228. /*****
229. /* IMPORT EXCHANGE FILE
230. /*****
231. &TYPE 'Importing file...'
232. &SETVAR startspace = [SHOW &WORKSPACE]
233. &WORKSPACE %outspace%

234. /*GET FILE NAME WITHOUT PATH
235. &SETVAR incov = [AFTER %ine00% \]
236. &DO &UNTIL [SEARCH %incov% \] = 0
237. &SETVAR incov = [AFTER %incov% \]
238. &END
239. /*REMOVE EXTENSION
240. &SETVAR incov = [BEFORE %incov% .]
241. /*LIMIT TO MAX 10 CHARACTERS
242. &SETVAR incov = [SUBSTR %incov% 1 10]

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

```

```

247. &IF %killit% = .TRUE. &THEN
248. &DO
249. &MESSAGES &OFF &ALL
250. KILL %incov% ALL
251. &MESSAGES &POPUP
252. &END
253. &ELSE
254. &RETURN &WARNING 'Coverage %incov% was not imported.'
255. &END

256. &MESSAGES &OFF &ALL
257. IMPORT COVER %ine00% %incov%

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

261. /*TEMPORARY COVERAGE NAMES
262. &SETVAR cov_poly = temp_pol
263. &SETVAR cov_dis = temp_dis
264. &SETVAR cov_int = temp_int
265. &SETVAR cov_densify = temp_dens
266. &SETVAR cov_tempproj = temp_prj
267. &SETVAR cov_reproj = temp_reprj
268. &SETVAR lt151 = temp_151
269. &SETVAR outcov_p = %outcov%_

270. /*KILL COVERAGES IF THEY ALREADY EXIST
271. &IF [EXISTS %cov_poly% -COVER] = .TRUE. &THEN
272. KILL %cov_poly% ALL
273. &IF [EXISTS %cov_dis% -COVER] = .TRUE. &THEN
274. KILL %cov_dis% ALL
275. &IF [EXISTS %cov_int% -COVER] = .TRUE. &THEN
276. KILL %cov_int% ALL
277. &IF [EXISTS %cov_densify% -COVER] = .TRUE. &THEN
278. KILL %cov_densify% ALL
279. &IF [EXISTS %cov_tempproj% -COVER] = .TRUE. &THEN
280. KILL %cov_tempproj% ALL
281. &IF [EXISTS %cov_reproj% -COVER] = .TRUE. &THEN
282. KILL %cov_reproj% ALL
283. &IF [EXISTS %lt151% -COVER] = .TRUE. &THEN
284. KILL %lt151% ALL
285. &IF [EXISTS %outcov_p% -COVER] = .TRUE. &THEN
286. KILL %outcov_p% ALL
287. &IF [EXISTS %outcov%.stat -INFO] = .TRUE. &THEN
288. KILLINFO %outcov%.stat
289. &RETURN

290. &ROUTINE symbology
291. /*****
292. /* remove symbology, duplicate points, clean up
293. /*****
294. /* remove annotation
295. DROPFEATURES %incov% ANNO.egg GEOMETRY
296. DROPFEATURES %incov% ANNO.sym GEOMETRY

```

```

297.  /* NODES MAY BE MISSING
298.  BUILD %incov% NODE

299.  &TYPE 'Removing symbology...'
300.  ARCEDIT
301.  EDITCOVER %incov%

302.  /* remove symbol arcs (egg_id <> 0)
303.  EDITFEATURE ARC
304.  SELECT egg_id <> 0
305.  &IF [SHOW NUMBER SELECTED] > 0 &THEN
306.  DELETE
307.  /* remove points asociated with symbol arcs
308.  EDITFEATURE POINT
309.  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
310.  &IF [SHOW NUMBER SELECTED] > 0 &THEN
311.  DELETE
312.  SAVE ALL YES
313.  QUIT

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

319.  &ROUTINE fixprojection
320.  /*****
321.  /* REPROJECT TO WGS84
322.  /*****
323.  &TYPE 'Reprojecting data to WGS84, lat-long...'
324.  /*Add NAD27 to projection definition because it may be missing
325.  PROJECTDEFINE COVER %cov_dis%
326.  DATUM NAD27
327.  PARAMETERS
328.  ~
329.  ~
330.  ~
331.  ~
332.  ~
333.  ~

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

```

```

339. &IF %PRJ$DATUM% = 'NAD27' &THEN
340. &DO
341. /*IF NAD27, FIRST PROJECT TO NAD83 DECIMAL DEGREES
342. PROJECT COVER %cov_densify% %cov_tempproj%
343. OUTPUT
344. PROJECTION GEOGRAPHIC
345. UNITS DD
346. DATUM NAD83
347. SPHEROID GRS80
348. PARAMETERS
349. END

350. /*REDEFINE DATUM TO NAR_C SO CONVERSION TO WGS84 IS POSSIBLE
351. PROJECTDEFINE COVER %cov_tempproj%
352. PROJECTION GEOGRAPHIC
353. UNITS DD
354. DATUM NAR_C
355. SPHEROID GRS80
356. PARAMETERS
357. &END
358. &ELSE
359. /*if not NAD27, set new varname to orig input
360. &SETVAR cov_tempproj = %cov_densify%

361. /*REPROJECT TO WGS84 DECIMAL DEGREES
362. PROJECT COVER %cov_tempproj% %outcov%
363. OUTPUT
364. PROJECTION GEOGRAPHIC
365. UNITS DD
366. DATUM WGS84
367. SPHEROID WGS84
368. PARAMETERS
369. END
370. &END
371. &ELSE
372. &SETVAR outcov = %cov_dis%
373. &RETURN

374. &ROUTINE bbox
375. /*****
376. /* DRAW BOUNDING POLYGON
377. /*****
378. &TYPE 'Adding a rectangular boundary...'
379. /*FIRST REMOVE TICS OUTSIDE OF TRUE COVERAGE EXTENT
380. REBOX %outcov%
381. ARCEDIT
382. &DESCRIBE %outcov%
383. EDITCOVER %outcov%
384. EDITFEATURE ARC
385. COORDINATE KEYBOARD
386. ADD
387. 2, [CALC %DSC$XMIN% - 0.01], [CALC %DSC$YMAX% + 0.01]
388. 1, [CALC %DSC$XMIN% - 0.01], [CALC %DSC$YMIN% - 0.01]
389. 1, [CALC %DSC$XMAX% + 0.01], [CALC %DSC$YMIN% - 0.01]
390. 1, [CALC %DSC$XMAX% + 0.01], [CALC %DSC$YMAX% + 0.01]

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391. 2, [CALC %DSC$XMIN% - 0.01], [CALC %DSC$YMAX% + 0.01]
392. 9
393. SAVE ALL YES
394. &RETURN

395. &ROUTINE topology
396. /*****
397. /* Build polygon topology / get feature codes from points
398. /*****
399. &TYPE 'Building topology...'
400. /* check for LINE_TYPE 151 before exiting AE
401. ASELECT ALL
402. SELECT LINE_TYPE = 151
403. &SETVAR lt151 = [SHOW NUMBER SELECTED]
404. QUIT

405. /* Create point-only coverage
406. COPY %outcov% %outcov_p%
407. DROPFEATURES %outcov_p% NODE GEOMETRY
408. DROPFEATURES %outcov_p% LINE GEOMETRY
409. BUILD %outcov_p% POINT
410. /* Lose extra fields from coverage
411. DROPITEM %outcov_p%.pat %outcov_p%.pat egg_id aegg_id egg_name
egg_scale user_attr rotation /* egg_attr
412. /* Build polygon topology
413. BUILD %outcov% POLY
414. /* Lose extra fields from coverage
415. DROPITEM %outcov%.pat %outcov%.pat aegg_id egg_id egg_name
egg_scale user_attr rotation

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

423. /* COPY PNT_TYPE TO NEW POLYGONS WITH NO ID VALUES
424. TABLES
425. SELECT %outcov%.aat
426. RESELECT line_type = 151 AND lpol//%outcov%-id = 0
427. CALCULATE lpol//pnt_type = rpol//pnt_type
428. CALCULATE lpol//egg_attr = rpol//egg_attr
429. ASELECT
430. RESELECT line_type = 151 AND rpol//%outcov%-id = 0
431. CALCULATE rpol//pnt_type = lpol//pnt_type
432. CALCULATE rpol//egg_attr = lpol//egg_attr
433. QUIT
434. RELATE DROP $ALL
435. &END

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

```

```

438.  /* rebuild to store labels for next build
439.  BUILD %outcov% POLY
440.  &RETURN

441.  &ROUTINE route_region
442.  /*****
443.  /* CREATE ROUTES AND REGIONS (S-57 FEATURE OBJECTS)
444.  /*****
445.  &TYPE 'Creating feature and meta objects...'
446.  /*first drop routes and regions if they exist
447.  &IF [EXISTS %outcov% -SECTION.vename] = .TRUE. &THEN
448.  DROPFEATURES %outcov% SECTION.vename
449.  &IF [EXISTS %outcov% -SECTION.icelin] = .TRUE. &THEN
450.  DROPFEATURES %outcov% SECTION.icelin
451.  &IF [EXISTS %outcov% -SECTION.icefra] = .TRUE. &THEN
452.  DROPFEATURES %outcov% SECTION.icefra
453.  &IF [EXISTS %outcov% -SECTION.icelea] = .TRUE. &THEN
454.  DROPFEATURES %outcov% SECTION.icelea
455.  &IF [EXISTS %outcov% -REGION.m_covr] = .TRUE. &THEN
456.  DROPFEATURES %outcov% REGION.m_covr
457.  &IF [EXISTS %outcov% -REGION.m_qual] = .TRUE. &THEN
458.  DROPFEATURES %outcov% REGION.m_qual
459.  &IF [EXISTS %outcov% -REGION.lndare] = .TRUE. &THEN
460.  DROPFEATURES %outcov% REGION.lndare
461.  &IF [EXISTS %outcov% -REGION.depare] = .TRUE. &THEN
462.  DROPFEATURES %outcov% REGION.depare
463.  &IF [EXISTS %outcov% -REGION.seaice] = .TRUE. &THEN
464.  DROPFEATURES %outcov% REGION.seaice
465.  &IF [EXISTS %outcov% -REGION.lacice] = .TRUE. &THEN
466.  DROPFEATURES %outcov% REGION.lacice
467.  &IF [EXISTS %outcov% -REGION.brgare] = .TRUE. &THEN
468.  DROPFEATURES %outcov% REGION.brgare
469.  &IF [EXISTS %outcov% -REGION.seaare] = .TRUE. &THEN
470.  DROPFEATURES %outcov% REGION.seaare

471.  /*"vename" is the required for each arc
472.  ARCRROUTE %outcov% vename %outcov%#

473.  /*icelin is the ice limit line
474.  ARCRROUTE %outcov% icelin line_type line_type
475.  /*icefra is an ice fracture line
476.  ARCRROUTE %outcov% icefra line_type line_type
477.  /*icelea is an ice lead
478.  ARCRROUTE %outcov% icelea line_type line_type
479.  /*metadata for coverage and extent of spatial objects within the
cell
480.  POLYREGION %outcov% %outcov% m_covr

481.  ARCEDIT
482.  EDITCOVER %outcov%
483.  EDITFEATURE ROUTE.icelin
484.  SELECT line_type <> 133 AND line_type <> 150 AND line_type <> 151
AND line_type <> 162
485.  DELETE
486.  EDITFEATURE ROUTE.icefra

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487. SELECT line_type <> 171
488. DELETE
489. EDITFEATURE ROUTE.icelea
490. SELECT line_type <> 183 AND line_type <> 190
491. DELETE
492. EDITFEATURE REGION.m_covr
493. SELECT pnt_type <> 0
494. MERGE SELECT
495. CALCULATE pnt_type = 999
496. CALCULATE m_covr-id = 2
497. QUIT YES

498. &MESSAGES &OFF
499. /*required metadata for showing that a uniform quality of data
exists
500. REGIONQUERY %outcov% # m_qual # CONTIGUOUS
501. RESELECT pnt_type <> 0 /*region <> 'xx'
502. ~
503. N
504. N

505. /*land area
506. REGIONQUERY %outcov% # lndare # CONTIGUOUS
507. RESELECT pnt_type = 400
508. ~
509. N
510. N

511. /*depth area
512. REGIONQUERY %outcov% # depare # CONTIGUOUS
513. RESELECT pnt_type <> 400 AND pnt_type <> 0 /*region <> 'xx'
514. ~
515. N
516. N

517. /*SEAICE or LACICE area
518. REGIONQUERY %outcov% # %icetype% # CONTIGUOUS pnt_type egg_attr
519. RESELECT pnt_type <> 115 AND pnt_type <> 400 AND pnt_type <> 0
/*region <> 'xx' AND pnt_type <> 101
520. ~
521. N
522. N

523. /*brgare area
524. REGIONQUERY %outcov% # brgare # CONTIGUOUS pnt_type egg_attr
525. RESELECT pnt_type = 101
526. ~
527. N
528. N

529. /*sea area
530. REGIONQUERY %outcov% # seaare # CONTIGUOUS
531. RESELECT pnt_type = 115
532. ~
533. N

```

```

534. N
535. &MESSAGES &OFF &ALL
536. &RETURN

537. &ROUTINE vrid
538. &TYPE 'Setting up RCID field...'
539. TABLES
540. /*WILL FORM PART OF VRID
541. ADDITEM %outcov%.ratvename name 12 12 C
542. ADDITEM %outcov%.ratvename rver 2 6 B
543. ADDITEM %outcov%.ratvename ruin 1 1 C
544. ADDITEM %outcov%.ratvename hordat 2 6 B
545. ADDITEM %outcov%.ratvename posacc 4 8 F 2
546. ADDITEM %outcov%.ratvename quapos 2 6 B
547. ADDITEM %outcov%.ratvename usag 1 1 C

548. &SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -ROUTE.vename
name -FULLDEF]]
549. SELECT %outcov%.ratvename
550. REDEFINE
551. %starcol% rcnm 2 2 C /*13
552. [CALC %starcol% + 2] rcid 10 10 C /*15
553. ~

554. SELECT %outcov%.ratvename
555. CALCULATE rcnm = "VE"
556. CALCULATE rcid = ""
557. CALCULATE rver = 1
558. CALCULATE ruin = "I"
559. CALCULATE hordat = 2 /* this is WGS84
560. CALCULATE posacc = -9998
561. CALCULATE quapos = -9998
562. CALCULATE usag = "E"

563. /*WORK THE NAT
564. ADDITEM %outcov%.nat name 12 12 C
565. ADDITEM %outcov%.nat rver 2 6 B
566. ADDITEM %outcov%.nat ruin 1 1 C
567. ADDITEM %outcov%.nat hordat 2 6 B
568. ADDITEM %outcov%.nat posacc 4 8 F 2
569. ADDITEM %outcov%.nat quapos 2 6 B
570. ADDITEM %outcov%.nat temp 10 10 I

571. &SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -NODE name -
FULLDEF]]
572. SELECT %outcov%.nat
573. REDEFINE
574. %starcol% rcnm 2 2 C /*14
575. [CALC %starcol% + 2] rcid 10 10 C /*16
576. ~

577. SELECT %outcov%.nat
578. CALCULATE rcnm = "VC"
579. CALCULATE rcid = ""
580. CALCULATE rver = 1

```

```

581. CALCULATE ruin = "I"
582. CALCULATE hordat = 2 /* this is WGS84
583. CALCULATE posacc = -9998
584. CALCULATE quapos = -9998
585. CALCULATE temp = %outcov%#
586. QUIT
587. &RETURN

588. &ROUTINE pop_rcid
589. &TYPE 'Populating RCID field...'
590. &SETVAR idval = 1
591. /*ROUTE
592. CURSOR uid DECLARE %outcov%.ratvename INFO RW
593. CURSOR uid OPEN
594. &DO &WHILE %:uid.aml$next% = .TRUE.
595. &SETVAR :uid.rcid = %idval%
596. &DO &WHILE [LENGTH %:uid.rcid%] < 10
597. &SETVAR :uid.rcid = 0%:uid.rcid%
598. &END
599. &SETVAR idval = %idval% + 1
600. CURSOR uid NEXT
601. &END
602. CURSOR uid CLOSE
603. CURSOR uid REMOVE

604. /*NAT
605. CURSOR uid DECLARE %outcov%.nat INFO RW
606. CURSOR uid OPEN
607. &DO &WHILE %:uid.aml$next% = .TRUE.
608. &SETVAR :uid.rcid = %:uid.temp%
609. &DO &WHILE [LENGTH %:uid.rcid%] < 10
610. &SETVAR :uid.rcid = 0%:uid.rcid%
611. &END
612. CURSOR uid NEXT
613. &END
614. CURSOR uid CLOSE
615. CURSOR uid REMOVE

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

618. &ROUTINE pop_region
619. &TYPE 'Adding attributes to feature and meta objects...'
620. TABLES
621. /*M_COVR
622. ADDITEM %outcov%.patm_covr lnam 17 17 C
623. ADDITEM %outcov%.patm_covr name 12 12 C
624. ADDITEM %outcov%.patm_covr rver 2 6 B
625. ADDITEM %outcov%.patm_covr ruin 1 1 C
626. ADDITEM %outcov%.patm_covr grup 2 6 B
627. ADDITEM %outcov%.patm_covr catcov 2 6 B

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

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```

630. REDEFINE
631. %starcol% agen 2 2 C /*25
632. [CALC %starcol% + 2] fidn 10 10 C /*27
633. [CALC %starcol% + 12] fids 5 5 C /*37
634. [CALC %starcol% + 17] rcnm 2 2 C /*42
635. [CALC %starcol% + 19] rcid 10 10 C /*44
636. ~

637. CALCULATE agen = "CA"
638. CALCULATE fidn = ""
639. CALCULATE fids = "00000"
640. CALCULATE rcnm = "FE"
641. CALCULATE rcid = ""
642. CALCULATE rver = 1
643. CALCULATE ruin = "I"
644. CALCULATE grup = 2

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

647. NSELECT
648. CALCULATE catcov = 2

649. /*M_QUAL
650. ADDITEM %outcov%.patm_qual lnam 17 17 C
651. ADDITEM %outcov%.patm_qual name 12 12 C
652. ADDITEM %outcov%.patm_qual rver 2 6 B
653. ADDITEM %outcov%.patm_qual ruin 1 1 C
654. ADDITEM %outcov%.patm_qual grup 2 6 B
655. /* ADDITEM %outcov%.patm_qual catqua 2 6 B
656. ADDITEM %outcov%.patm_qual catzoc 2 6 B
657. ADDITEM %outcov%.patm_qual drval1 4 8 F 2
658. ADDITEM %outcov%.patm_qual drval2 4 8 F 2
659. ADDITEM %outcov%.patm_qual posacc 4 8 F 2
660. ADDITEM %outcov%.patm_qual souacc 4 8 F 2
661. ADDITEM %outcov%.patm_qual surend 8 8 C
662. ADDITEM %outcov%.patm_qual sursta 8 8 C
663. ADDITEM %outcov%.patm_qual tecsou 70 70 C
664. ADDITEM %outcov%.patm_qual verdat 2 6 B

665. &SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -REGION.m_qual
lnam -FULLDEF]]
666. SELECT %outcov%.patm_qual
667. REDEFINE
668. %starcol% agen 2 2 C /*25
669. [CALC %starcol% + 2] fidn 10 10 C /*27
670. [CALC %starcol% + 12] fids 5 5 C /*37
671. [CALC %starcol% + 17] rcnm 2 2 C /*42
672. [CALC %starcol% + 19] rcid 10 10 C /*44
673. ~

674. CALCULATE agen = "CA"
675. CALCULATE fidn = ""
676. CALCULATE fids = "00000"
677. CALCULATE rcnm = "FE"

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```

678. CALCULATE rcid = ""
679. CALCULATE rver = 1
680. CALCULATE ruin = "I"
681. CALCULATE grup = 2
682. /* CALCULATE catqua = 5
683. CALCULATE catzoc = 6
684. CALCULATE drvall = -9998
685. CALCULATE drval2 = -9998
686. CALCULATE posacc = -9998
687. CALCULATE souacc = -9998
688. CALCULATE surend = "[SUBSTR [DATE -YEAR] 1 2][DATE -TAG]"
689. CALCULATE sursta = "[SUBSTR [DATE -YEAR] 1 2][DATE -TAG]"
690. CALCULATE tecsou = "IGNORED"
691. CALCULATE verdat = -9998

692. /*LAND
693. ADDITEM %outcov%.patlndare lnam 17 17 C
694. ADDITEM %outcov%.patlndare name 12 12 C
695. ADDITEM %outcov%.patlndare rver 2 6 B
696. ADDITEM %outcov%.patlndare ruin 1 1 C
697. ADDITEM %outcov%.patlndare grup 2 6 B
698. ADDITEM %outcov%.patlndare condtn 2 6 B
699. ADDITEM %outcov%.patlndare objnam 70 70 C
700. ADDITEM %outcov%.patlndare nobjnm 70 70 C
701. ADDITEM %outcov%.patlndare status 70 70 C

702. &SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -REGION.lndare
lnam -FULLDEF]]
703. SELECT %outcov%.patlndare
704. REDEFINE
705. %starcol% agen 2 2 C /*25
706. [CALC %starcol% + 2] fidn 10 10 C /*27
707. [CALC %starcol% + 12] fids 5 5 C /*37
708. [CALC %starcol% + 17] rcnm 2 2 C /*42
709. [CALC %starcol% + 19] rcid 10 10 C /*44
710. ~

711. CALCULATE agen = "CA"
712. CALCULATE fidn = ""
713. CALCULATE fids = "00000"
714. CALCULATE rcnm = "FE"
715. CALCULATE rcid = ""
716. CALCULATE rver = 1
717. CALCULATE ruin = "I"
718. CALCULATE grup = 1
719. CALCULATE condtn = -9998
720. CALCULATE objnam = "IGNORED"
721. CALCULATE nobjnm = "IGNORED"
722. CALCULATE status = "1"

723. /*DEEP
724. ADDITEM %outcov%.patdepare lnam 17 17 C
725. ADDITEM %outcov%.patdepare name 12 12 C
726. ADDITEM %outcov%.patdepare rver 2 6 B
727. ADDITEM %outcov%.patdepare ruin 1 1 C

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728. ADDITEM %outcov%.patdepare grup 2 6 B
729. ADDITEM %outcov%.patdepare drvall 4 8 F 2
730. ADDITEM %outcov%.patdepare drval2 4 8 F 2
731. ADDITEM %outcov%.patdepare quasou 70 70 C
732. ADDITEM %outcov%.patdepare souacc 4 8 F 2
733. ADDITEM %outcov%.patdepare verdat 2 6 B

734. &SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -REGION.depare
lnam -FULLDEF]]
735. SELECT %outcov%.patdepare
736. REDEFINE
737. %starcol% agen 2 2 C /*25
738. [CALC %starcol% + 2] fidn 10 10 C /*27
739. [CALC %starcol% + 12] fids 5 5 C /*37
740. [CALC %starcol% + 17] rcnm 2 2 C /*42
741. [CALC %starcol% + 19] rcid 10 10 C /*44
742. ~

743. CALCULATE agen = "CA"
744. CALCULATE fidn = ""
745. CALCULATE fids = "00000"
746. CALCULATE rcnm = "FE"
747. CALCULATE rcid = ""
748. CALCULATE rver = 1
749. CALCULATE ruin = "I"
750. CALCULATE grup = 1
751. CALCULATE drvall = 0
752. CALCULATE drval2 = 10000
753. CALCULATE quasou = "IGNORED"
754. CALCULATE souacc = -9998
755. CALCULATE verdat = -9998

756. /*SEAICE or LACICE
757. ADDITEM %outcov%.pat%icetype% lnam 17 17 C
758. ADDITEM %outcov%.pat%icetype% name 12 12 C
759. ADDITEM %outcov%.pat%icetype% rver 2 6 B
760. ADDITEM %outcov%.pat%icetype% ruin 1 1 C
761. ADDITEM %outcov%.pat%icetype% grup 2 6 B
762. ADDITEM %outcov%.pat%icetype% nobjnm 70 70 C
763. ADDITEM %outcov%.pat%icetype% objnam 70 70 C
764. ADDITEM %outcov%.pat%icetype% iceact 2 6 B
765. ADDITEM %outcov%.pat%icetype% iceapc 70 70 C
766. &IF [LOCASE %icetype%] = 'seaice' &THEN
767. ADDITEM %outcov%.pat%icetype% icesod 70 70 C
768. &ELSE
769. ADDITEM %outcov%.pat%icetype% icelso 70 70 C
770. ADDITEM %outcov%.pat%icetype% iceflz 70 70 C
771. ADDITEM %outcov%.pat%icetype% icecvt 2 6 B
772. ADDITEM %outcov%.pat%icetype% icemax 4 8 F 2
773. ADDITEM %outcov%.pat%icetype% icemin 4 8 F 2
774. ADDITEM %outcov%.pat%icetype% icemlt 2 6 B
775. ADDITEM %outcov%.pat%icetype% icescv 2 6 B
776. ADDITEM %outcov%.pat%icetype% icerdv 2 6 B
777. ADDITEM %outcov%.pat%icetype% icercn 2 6 B
778. ADDITEM %outcov%.pat%icetype% icedos 2 6 B

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779. &SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -REGION.%icetype%
lnam -FULLDEF]]
780. SELECT %outcov%.pat%icetype%
781. REDEFINE
782. %starcol% agen 2 2 C /*25
783. [CALC %starcol% + 2] fidn 10 10 C /*27
784. [CALC %starcol% + 12] fids 5 5 C /*37
785. [CALC %starcol% + 17] rcnm 2 2 C /*42
786. [CALC %starcol% + 19] rcid 10 10 C /*44
787. ~

788. CALCULATE agen = "CA"
789. CALCULATE fidn = ""
790. CALCULATE fids = "00000"
791. CALCULATE rcnm = "FE"
792. CALCULATE rcid = ""
793. CALCULATE rver = 1
794. CALCULATE ruin = "I"
795. CALCULATE grup = 2
796. CALCULATE objnam = "IGNORED"
797. CALCULATE nobjnm = "IGNORED"
798. /* iceact, iceapc, icesod, icelso, iceflz are extracted from the
egg code
799. CALCULATE icecvt = -9998
800. CALCULATE icemax = -9998
801. CALCULATE icemin = -9998
802. CALCULATE icemlt = -9998
803. CALCULATE icescv = -9998
804. CALCULATE icerdv = -9998
805. CALCULATE icercn = -9998
806. CALCULATE icedos = -9998

807. /*SEA
808. ADDITEM %outcov%.patseaare lnam 17 17 C
809. ADDITEM %outcov%.patseaare name 12 12 C
810. ADDITEM %outcov%.patseaare rver 2 6 B
811. ADDITEM %outcov%.patseaare ruin 1 1 C
812. ADDITEM %outcov%.patseaare grup 2 6 B
813. ADDITEM %outcov%.patseaare objnam 70 70 C
814. ADDITEM %outcov%.patseaare nobjnm 70 70 C
815. ADDITEM %outcov%.patseaare catsea 2 6 B

816. &SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -REGION.seaare
lnam -FULLDEF]]
817. SELECT %outcov%.patseaare
818. REDEFINE
819. %starcol% agen 2 2 C /*25
820. [CALC %starcol% + 2] fidn 10 10 C /*27
821. [CALC %starcol% + 12] fids 5 5 C /*37
822. [CALC %starcol% + 17] rcnm 2 2 C /*42
823. [CALC %starcol% + 19] rcid 10 10 C /*44
824. ~

825. CALCULATE agen = "CA"

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826. CALCULATE fidn = ""
827. CALCULATE fids = "00000"
828. CALCULATE rcnm = "FE"
829. CALCULATE rcid = ""
830. CALCULATE rver = 1
831. CALCULATE ruin = "I"
832. CALCULATE grup = 2
833. CALCULATE objnam = "IGNORED"
834. CALCULATE nobjnm = "IGNORED"
835. CALCULATE catsea = 2

836. /*BRGARE
837. ADDITEM %outcov%.patbrgare lnam 17 17 C
838. ADDITEM %outcov%.patbrgare name 12 12 C
839. ADDITEM %outcov%.patbrgare rver 2 6 B
840. ADDITEM %outcov%.patbrgare ruin 1 1 C
841. ADDITEM %outcov%.patbrgare grup 2 6 B
842. ADDITEM %outcov%.patbrgare objnam 70 70 C
843. ADDITEM %outcov%.patbrgare nobjnm 70 70 C
844. ADDITEM %outcov%.patbrgare icebnm 4 8 F 2

845. &SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -REGION.brgare
lnam -FULLDEF]]
846. SELECT %outcov%.patbrgare
847. REDEFINE
848. %starcol% agen 2 2 C /*25
849. [CALC %starcol% + 2] fidn 10 10 C /*27
850. [CALC %starcol% + 12] fids 5 5 C /*37
851. [CALC %starcol% + 17] rcnm 2 2 C /*42
852. [CALC %starcol% + 19] rcid 10 10 C /*44
853. ~

854. CALCULATE agen = "CA"
855. CALCULATE fidn = ""
856. CALCULATE fids = "00000"
857. CALCULATE rcnm = "FE"
858. CALCULATE rcid = ""
859. CALCULATE rver = 1
860. CALCULATE ruin = "I"
861. CALCULATE grup = 2
862. CALCULATE objnam = "IGNORED"
863. CALCULATE nobjnm = "IGNORED"
864. CALCULATE icebnm = -9998

865. /*ICELIN
866. ADDITEM %outcov%.raticelin lnam 17 17 C
867. ADDITEM %outcov%.raticelin name 12 12 C
868. ADDITEM %outcov%.raticelin rver 2 6 B
869. ADDITEM %outcov%.raticelin ruin 1 1 C
870. ADDITEM %outcov%.raticelin grup 2 6 B
871. ADDITEM %outcov%.raticelin objnam 70 70 C
872. ADDITEM %outcov%.raticelin nobjnm 70 70 C
873. ADDITEM %outcov%.raticelin icelnc 2 6 B

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874. &SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -ROUTE.icelin
      lnam -FULLDEF]]
875. SELECT %outcov%.raticelin
876. REDEFINE
877. %starcol% agen 2 2 C /*25
878. [CALC %starcol% + 2] fidn 10 10 C /*27
879. [CALC %starcol% + 12] fids 5 5 C /*37
880. [CALC %starcol% + 17] rcnm 2 2 C /*42
881. [CALC %starcol% + 19] rcid 10 10 C /*44
882. ~

883. CALCULATE agen = "CA"
884. CALCULATE fidn = ""
885. CALCULATE fids = "00000"
886. CALCULATE rcnm = "FE"
887. CALCULATE rcid = ""
888. CALCULATE rver = 1
889. CALCULATE ruin = "I"
890. CALCULATE grup = 2
891. CALCULATE objnam = "IGNORED"
892. CALCULATE nobjnm = "IGNORED"

893. RESELECT line_type = 133
894. CALCULATE icelnc = 5

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

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

901. /*ICEFRA
902. ADDITEM %outcov%.raticefra lnam 17 17 C
903. ADDITEM %outcov%.raticefra name 12 12 C
904. ADDITEM %outcov%.raticefra rver 2 6 B
905. ADDITEM %outcov%.raticefra ruin 1 1 C
906. ADDITEM %outcov%.raticefra grup 2 6 B
907. ADDITEM %outcov%.raticefra objnam 70 70 C
908. ADDITEM %outcov%.raticefra nobjnm 70 70 C
909. ADDITEM %outcov%.raticefra icefty 2 6 B

910. &SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -ROUTE.icefra
      lnam -FULLDEF]]
911. SELECT %outcov%.raticefra
912. REDEFINE
913. %starcol% agen 2 2 C /*25
914. [CALC %starcol% + 2] fidn 10 10 C /*27
915. [CALC %starcol% + 12] fids 5 5 C /*37
916. [CALC %starcol% + 17] rcnm 2 2 C /*42
917. [CALC %starcol% + 19] rcid 10 10 C /*44
918. ~

919. CALCULATE agen = "CA"

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920. CALCULATE fidn = ""
921. CALCULATE fids = "00000"
922. CALCULATE rcnm = "FE"
923. CALCULATE rcid = ""
924. CALCULATE rver = 1
925. CALCULATE ruin = "I"
926. CALCULATE grup = 2
927. CALCULATE objnam = "IGNORED"
928. CALCULATE nobjnm = "IGNORED"
929. CALCULATE icefty = 8

930. /*ICELEA
931. ADDITEM %outcov%.raticelea lnam 17 17 C
932. ADDITEM %outcov%.raticelea name 12 12 C
933. ADDITEM %outcov%.raticelea rver 2 6 B
934. ADDITEM %outcov%.raticelea ruin 1 1 C
935. ADDITEM %outcov%.raticelea grup 2 6 B
936. ADDITEM %outcov%.raticelea objnam 70 70 C
937. ADDITEM %outcov%.raticelea nobjnm 70 70 C
938. ADDITEM %outcov%.raticelea icelty 2 6 B
939. ADDITEM %outcov%.raticelea icelst 2 6 B

940. &SETVAR starcol = [EXTRACT 1 [ITEMINFO %outcov% -ROUTE.icelea
lnam -FULLDEF]]
941. SELECT %outcov%.raticelea
942. REDEFINE
943. %starcol% agen 2 2 C /*25
944. [CALC %starcol% + 2] fidn 10 10 C /*27
945. [CALC %starcol% + 12] fids 5 5 C /*37
946. [CALC %starcol% + 17] rcnm 2 2 C /*42
947. [CALC %starcol% + 19] rcid 10 10 C /*44
948. ~

949. CALCULATE agen = "CA"
950. CALCULATE fidn = ""
951. CALCULATE fids = "00000"
952. CALCULATE rcnm = "FE"
953. CALCULATE rcid = ""
954. CALCULATE rver = 1
955. CALCULATE ruin = "I"
956. CALCULATE grup = 2
957. CALCULATE objnam = "IGNORED"
958. CALCULATE nobjnm = "IGNORED"
959. CALCULATE icelty = 1
960. CALCULATE icelst = 1
961. QUIT

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

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

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969. &SETVAR :uid.fidn = %idval%
970. &DO &WHILE [LENGTH %:uid.rcid%] < 10
971. &SETVAR :uid.rcid = 0%:uid.rcid%
972. &SETVAR :uid.fidn = 0%:uid.fidn%
973. &END
974. &SETVAR idval = %idval% + 1
975. CURSOR uid NEXT
976. &END
977. CURSOR uid CLOSE
978. CURSOR uid REMOVE

979. /*UNIQUE IDs FOR M_QUAL
980. CURSOR uid DECLARE %outcov%.patm_qual INFO RW
981. CURSOR uid OPEN
982. &DO &WHILE %:uid.aml$next% = .TRUE.
983. &SETVAR :uid.rcid = %idval%
984. &SETVAR :uid.fidn = %idval%
985. &DO &WHILE [LENGTH %:uid.rcid%] < 10
986. &SETVAR :uid.rcid = 0%:uid.rcid%
987. &SETVAR :uid.fidn = 0%:uid.fidn%
988. &END
989. &SETVAR idval = %idval% + 1
990. CURSOR uid NEXT
991. &END
992. CURSOR uid CLOSE
993. CURSOR uid REMOVE

994. /*UNIQUE IDs FOR LNDARE
995. CURSOR uid DECLARE %outcov%.patlndare INFO RW
996. CURSOR uid OPEN
997. &DO &WHILE %:uid.aml$next% = .TRUE.
998. &SETVAR :uid.rcid = %idval%
999. &SETVAR :uid.fidn = %idval%
1000. &DO &WHILE [LENGTH %:uid.rcid%] < 10
1001. &SETVAR :uid.rcid = 0%:uid.rcid%
1002. &SETVAR :uid.fidn = 0%:uid.fidn%
1003. &END
1004. &SETVAR idval = %idval% + 1
1005. CURSOR uid NEXT
1006. &END
1007. CURSOR uid CLOSE
1008. CURSOR uid REMOVE

1009. /*UNIQUE IDs FOR DEPARE
1010. CURSOR uid DECLARE %outcov%.patdepare INFO RW
1011. CURSOR uid OPEN
1012. &DO &WHILE %:uid.aml$next% = .TRUE.
1013. &SETVAR :uid.rcid = %idval%
1014. &SETVAR :uid.fidn = %idval%
1015. &DO &WHILE [LENGTH %:uid.rcid%] < 10
1016. &SETVAR :uid.rcid = 0%:uid.rcid%
1017. &SETVAR :uid.fidn = 0%:uid.fidn%
1018. &END
1019. &SETVAR idval = %idval% + 1
1020. CURSOR uid NEXT

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```

1021. &END
1022. CURSOR uid CLOSE
1023. CURSOR uid REMOVE

1024. /*UNIQUE IDs FOR SEAICE
1025. /*ALSO EXTRACT EGG CODES HERE
1026. CURSOR uid DECLARE %outcov%.pat%icetype% INFO RW
1027. CURSOR uid OPEN
1028. &DO &WHILE %:uid.aml$next% = .TRUE.
1029. &SETVAR :uid.rcid = %idval%
1030. &SETVAR :uid.fidn = %idval%
1031. &DO &WHILE [LENGTH %:uid.rcid%] < 10
1032. &SETVAR :uid.rcid = 0%:uid.rcid%
1033. &SETVAR :uid.fidn = 0%:uid.fidn%
1034. &END

1035. &IF [NULL %:uid.egg_attr%] = .FALSE. &THEN
1036. &DO
1037. &SETVAR egg_string = [SUBST %:uid.egg_attr% '_' ',']
1038. /* ICEACT (Ct)
1039. &SELECT [EXTRACT 1 %egg_string%]
1040. &WHEN 1
1041. &SETVAR :uid.iceact = 1
1042. &WHEN 2
1043. &SETVAR :uid.iceact = 2
1044. &WHEN 3
1045. &SETVAR :uid.iceact = 3
1046. &WHEN 4
1047. &SETVAR :uid.iceact = 4
1048. &WHEN 5
1049. &SETVAR :uid.iceact = 5
1050. &WHEN 6
1051. &SETVAR :uid.iceact = 6
1052. &WHEN 7
1053. &SETVAR :uid.iceact = 7
1054. &WHEN 8
1055. &SETVAR :uid.iceact = 8
1056. &WHEN 9
1057. &SETVAR :uid.iceact = 9
1058. &WHEN 9+
1059. &SETVAR :uid.iceact = 15
1060. &WHEN 10
1061. &SETVAR :uid.iceact = 16
1062. &WHEN @
1063. &SETVAR :uid.iceact = 17
1064. &END

1065. /* ICEAPC (Ca)
1066. &SELECT [EXTRACT 2 %egg_string%]
1067. &WHEN 1
1068. &SETVAR :uid.iceapc = 1
1069. &WHEN 2
1070. &SETVAR :uid.iceapc = 2
1071. &WHEN 3
1072. &SETVAR :uid.iceapc = 3

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```

1073. &WHEN 4
1074. &SETVAR :uid.iceapc = 4
1075. &WHEN 5
1076. &SETVAR :uid.iceapc = 5
1077. &WHEN 6
1078. &SETVAR :uid.iceapc = 6
1079. &WHEN 7
1080. &SETVAR :uid.iceapc = 7
1081. &WHEN 8
1082. &SETVAR :uid.iceapc = 8
1083. &WHEN 9
1084. &SETVAR :uid.iceapc = 9
1085. &WHEN 9+
1086. &SETVAR :uid.iceapc = 10
1087. &WHEN 10
1088. &SETVAR :uid.iceapc = 11
1089. &WHEN @
1090. &SETVAR :uid.iceapc = 13
1091. &END

1092. /* ICEAPC (Cb,Cc,Cd)
1093. &DO i = 3 &TO 5
1094. &SELECT [EXTRACT %i% %egg_string%]
1095. &WHEN 1
1096. &SETVAR :uid.iceapc = %:uid.iceapc%,1
1097. &WHEN 2
1098. &SETVAR :uid.iceapc = %:uid.iceapc%,2
1099. &WHEN 3
1100. &SETVAR :uid.iceapc = %:uid.iceapc%,3
1101. &WHEN 4
1102. &SETVAR :uid.iceapc = %:uid.iceapc%,4
1103. &WHEN 5
1104. &SETVAR :uid.iceapc = %:uid.iceapc%,5
1105. &WHEN 6
1106. &SETVAR :uid.iceapc = %:uid.iceapc%,6
1107. &WHEN 7
1108. &SETVAR :uid.iceapc = %:uid.iceapc%,7
1109. &WHEN 8
1110. &SETVAR :uid.iceapc = %:uid.iceapc%,8
1111. &WHEN 9
1112. &SETVAR :uid.iceapc = %:uid.iceapc%,9
1113. &WHEN 9+
1114. &SETVAR :uid.iceapc = %:uid.iceapc%,10
1115. &WHEN 10
1116. &SETVAR :uid.iceapc = %:uid.iceapc%,11
1117. &WHEN @
1118. &SETVAR :uid.iceapc = %:uid.iceapc%,13
1119. &END
1120. &END

1121. &IF [LOCASE %icetype%] = 'seaice' &THEN
1122. &DO
1123. /* ICESOD (So)
1124. &SELECT [EXTRACT 6 %egg_string%]
1125. &WHEN @

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```

1126. &SETVAR :uid.icesod = 0
1127. &WHEN 1
1128. &SETVAR :uid.icesod = 1
1129. &WHEN 2
1130. &SETVAR :uid.icesod = 2
1131. &WHEN 3
1132. &SETVAR :uid.icesod = 3
1133. &WHEN 4
1134. &SETVAR :uid.icesod = 4
1135. &WHEN 5
1136. &SETVAR :uid.icesod = 5
1137. &WHEN 6
1138. &SETVAR :uid.icesod = 6
1139. &WHEN 7
1140. &SETVAR :uid.icesod = 7
1141. &WHEN 8
1142. &SETVAR :uid.icesod = 7
1143. &WHEN 9
1144. &SETVAR :uid.icesod = 7
1145. &WHEN 1.
1146. &SETVAR :uid.icesod = 8
1147. &WHEN 4.
1148. &SETVAR :uid.icesod = 9
1149. &WHEN 7.
1150. &SETVAR :uid.icesod = 10
1151. &WHEN 8.
1152. &SETVAR :uid.icesod = 11
1153. &WHEN 9.
1154. &SETVAR :uid.icesod = 12
1155. &WHEN ^.
1156. &SETVAR :uid.icesod = 13
1157. &WHEN X
1158. &SETVAR :uid.icesod = 14
1159. &END

1160. /* ICESOD (Sa,Sb,Sc,Sd,Se)
1161. &DO i = 7 &TO 11
1162. &SELECT [EXTRACT %i% %egg_string%]
1163. &WHEN @
1164. &SETVAR :uid.icesod = %:uid.icesod%,0
1165. &WHEN 1
1166. &SETVAR :uid.icesod = %:uid.icesod%,1
1167. &WHEN 2
1168. &SETVAR :uid.icesod = %:uid.icesod%,2
1169. &WHEN 3
1170. &SETVAR :uid.icesod = %:uid.icesod%,3
1171. &WHEN 4
1172. &SETVAR :uid.icesod = %:uid.icesod%,4
1173. &WHEN 5
1174. &SETVAR :uid.icesod = %:uid.icesod%,5
1175. &WHEN 6
1176. &SETVAR :uid.icesod = %:uid.icesod%,6
1177. &WHEN 7
1178. &SETVAR :uid.icesod = %:uid.icesod%,7
1179. &WHEN 8

```

```

1180. &SETVAR :uid.icesod = %:uid.icesod%,7
1181. &WHEN 9
1182. &SETVAR :uid.icesod = %:uid.icesod%,7
1183. &WHEN 1.
1184. &SETVAR :uid.icesod = %:uid.icesod%,8
1185. &WHEN 4.
1186. &SETVAR :uid.icesod = %:uid.icesod%,9
1187. &WHEN 7.
1188. &SETVAR :uid.icesod = %:uid.icesod%,10
1189. &WHEN 8.
1190. &SETVAR :uid.icesod = %:uid.icesod%,11
1191. &WHEN 9.
1192. &SETVAR :uid.icesod = %:uid.icesod%,12
1193. &WHEN ^.
1194. &SETVAR :uid.icesod = %:uid.icesod%,13
1195. &WHEN X
1196. &SETVAR :uid.icesod = %:uid.icesod%,14
1197. &END
1198. &END
1199. &END
1200. &ELSE
1201. &DO
1202. /* ICESLO (So)
1203. &SELECT [EXTRACT 6 %egg_string%]
1204. &WHEN @
1205. &SETVAR :uid.icelso = 0
1206. &WHEN 1
1207. &SETVAR :uid.icelso = 1
1208. &WHEN 4
1209. &SETVAR :uid.icelso = 2
1210. &WHEN 5
1211. &SETVAR :uid.icelso = 3
1212. &WHEN 7
1213. &SETVAR :uid.icelso = 4
1214. &WHEN 1.
1215. &SETVAR :uid.icelso = 5
1216. &WHEN X
1217. &SETVAR :uid.icelso = 6
1218. &END

1219. /* ICESLO (Sa,Sb,Sc,Sd,Se)
1220. &DO i = 7 &TO 11
1221. &SELECT [EXTRACT %i% %egg_string%]
1222. &WHEN @
1223. &SETVAR :uid.icelso = %:uid.icelso%,0
1224. &WHEN 1
1225. &SETVAR :uid.icelso = %:uid.icelso%,1
1226. &WHEN 4
1227. &SETVAR :uid.icelso = %:uid.icelso%,2
1228. &WHEN 5
1229. &SETVAR :uid.icelso = %:uid.icelso%,3
1230. &WHEN 7
1231. &SETVAR :uid.icelso = %:uid.icelso%,4
1232. &WHEN 1.
1233. &SETVAR :uid.icelso = %:uid.icelso%,5

```

```

1234. &WHEN X
1235. &SETVAR :uid.icelso = %:uid.icelso%,6
1236. &END
1237. &END
1238. &END

1239. /* ICEFLZ (Fa)
1240. &SELECT [EXTRACT 12 %egg_string%]
1241. &WHEN 0
1242. &SETVAR :uid.iceflz = 1
1243. &WHEN 1
1244. &SETVAR :uid.iceflz = 2
1245. &WHEN 2
1246. &SETVAR :uid.iceflz = 3
1247. &WHEN 3
1248. &SETVAR :uid.iceflz = 4
1249. &WHEN 4
1250. &SETVAR :uid.iceflz = 5
1251. &WHEN 5
1252. &SETVAR :uid.iceflz = 6
1253. &WHEN 6
1254. &SETVAR :uid.iceflz = 7
1255. &WHEN 7
1256. &SETVAR :uid.iceflz = 8
1257. &WHEN 8
1258. &SETVAR :uid.iceflz = 9
1259. &WHEN 9
1260. &SETVAR :uid.iceflz = 10
1261. &WHEN @
1262. &SETVAR :uid.iceflz = 11
1263. &WHEN X
1264. &SETVAR :uid.iceflz = 12
1265. &END

1266. /* ICEFLZ (Fb,Fc,Fd,Fe)
1267. &DO i = 13 &TO 16
1268. &SELECT [EXTRACT %i% %egg_string%]
1269. &WHEN 0
1270. &SETVAR :uid.iceflz = %:uid.iceflz%,1
1271. &WHEN 1
1272. &SETVAR :uid.iceflz = %:uid.iceflz%,2
1273. &WHEN 2
1274. &SETVAR :uid.iceflz = %:uid.iceflz%,3
1275. &WHEN 3
1276. &SETVAR :uid.iceflz = %:uid.iceflz%,4
1277. &WHEN 4
1278. &SETVAR :uid.iceflz = %:uid.iceflz%,5
1279. &WHEN 5
1280. &SETVAR :uid.iceflz = %:uid.iceflz%,6
1281. &WHEN 6
1282. &SETVAR :uid.iceflz = %:uid.iceflz%,7
1283. &WHEN 7
1284. &SETVAR :uid.iceflz = %:uid.iceflz%,8
1285. &WHEN 8
1286. &SETVAR :uid.iceflz = %:uid.iceflz%,9

```

```

1287. &WHEN 9
1288. &SETVAR :uid.iceflz = %:uid.iceflz%,10
1289. &WHEN @
1290. &SETVAR :uid.iceflz = %:uid.iceflz%,12
1291. &WHEN X
1292. &SETVAR :uid.iceflz = %:uid.iceflz%,12
1293. &END
1294. &END

1295. &END

1296. &ELSE
1297. /* bergy water not in egg code
1298. &IF %:uid.pnt_type% = 101 &THEN
1299. &SETVAR :uid.iceact = 17

1300. /* fast ice not in egg code
1301. &IF %:uid.pnt_type% = 106 &THEN
1302. &SETVAR :uid.iceact = 16

1303. /* open water not in egg code
1304. &IF %:uid.pnt_type% = 107 &THEN
1305. &SETVAR :uid.iceact = 17

1306. &SETVAR idval = %idval% + 1
1307. CURSOR uid NEXT
1308. &END
1309. CURSOR uid CLOSE
1310. CURSOR uid REMOVE

1311. /*UNIQUE IDs FOR BRGARE
1312. CURSOR uid DECLARE %outcov%.patbrgare INFO RW
1313. CURSOR uid OPEN
1314. &DO &WHILE %:uid.aml$next% = .TRUE.
1315. &SETVAR :uid.rcid = %idval%
1316. &SETVAR :uid.fidn = %idval%
1317. &DO &WHILE [LENGTH %:uid.rcid%] < 10
1318. &SETVAR :uid.rcid = 0%:uid.rcid%
1319. &SETVAR :uid.fidn = 0%:uid.fidn%
1320. &END
1321. &SETVAR idval = %idval% + 1
1322. CURSOR uid NEXT
1323. &END
1324. CURSOR uid CLOSE
1325. CURSOR uid REMOVE

1326. /*UNIQUE IDs FOR SEAARE
1327. CURSOR uid DECLARE %outcov%.patseaare INFO RW
1328. CURSOR uid OPEN
1329. &DO &WHILE %:uid.aml$next% = .TRUE.
1330. &SETVAR :uid.rcid = %idval%
1331. &SETVAR :uid.fidn = %idval%
1332. &DO &WHILE [LENGTH %:uid.rcid%] < 10
1333. &SETVAR :uid.rcid = 0%:uid.rcid%
1334. &SETVAR :uid.fidn = 0%:uid.fidn%

```

```

1335. &END
1336. &SETVAR idval = %idval% + 1
1337. CURSOR uid NEXT
1338. &END
1339. CURSOR uid CLOSE
1340. CURSOR uid REMOVE

1341. /*UNIQUE IDs FOR ICELIN
1342. CURSOR uid DECLARE %outcov%.raticelin INFO RW
1343. CURSOR uid OPEN
1344. &DO &WHILE %:uid.aml$next% = .TRUE.
1345. &SETVAR :uid.rcid = %idval%
1346. &SETVAR :uid.fidn = %idval%
1347. &DO &WHILE [LENGTH %:uid.rcid%] < 10
1348. &SETVAR :uid.rcid = 0%:uid.rcid%
1349. &SETVAR :uid.fidn = 0%:uid.fidn%
1350. &END
1351. &SETVAR idval = %idval% + 1
1352. CURSOR uid NEXT
1353. &END
1354. CURSOR uid CLOSE
1355. CURSOR uid REMOVE

1356. /*UNIQUE IDs FOR ICEFRA
1357. CURSOR uid DECLARE %outcov%.raticefra INFO RW
1358. CURSOR uid OPEN
1359. &DO &WHILE %:uid.aml$next% = .TRUE.
1360. &SETVAR :uid.rcid = %idval%
1361. &SETVAR :uid.fidn = %idval%
1362. &DO &WHILE [LENGTH %:uid.rcid%] < 10
1363. &SETVAR :uid.rcid = 0%:uid.rcid%
1364. &SETVAR :uid.fidn = 0%:uid.fidn%
1365. &END
1366. &SETVAR idval = %idval% + 1
1367. CURSOR uid NEXT
1368. &END
1369. CURSOR uid CLOSE
1370. CURSOR uid REMOVE

1371. /*UNIQUE IDs FOR ICELEA
1372. CURSOR uid DECLARE %outcov%.raticelea INFO RW
1373. CURSOR uid OPEN
1374. &DO &WHILE %:uid.aml$next% = .TRUE.
1375. &SETVAR :uid.rcid = %idval%
1376. &SETVAR :uid.fidn = %idval%
1377. &DO &WHILE [LENGTH %:uid.rcid%] < 10
1378. &SETVAR :uid.rcid = 0%:uid.rcid%
1379. &SETVAR :uid.fidn = 0%:uid.fidn%
1380. &END
1381. &SETVAR idval = %idval% + 1
1382. CURSOR uid NEXT
1383. &END
1384. CURSOR uid CLOSE
1385. CURSOR uid REMOVE
1386. &RETURN

```

```

1387. &ROUTINE attr
1388. &TYPE 'Adding B-level and C-level attributes to feature
      objects...'
1389. &IF [EXISTS %outcov%.attr -INFO] = .TRUE. &THEN
1390. KILLINFO %outcov%.attr
1391. &DO i &LIST A B C D E F G H
1392. &IF [EXISTS %outcov%.attr_%i% -INFO] = .TRUE. &THEN
1393. KILLINFO %outcov%.attr_%i%
1394. &END

1395. /*ATTR
1396. PULLITEMS %outcov%.pat%icetype% %outcov%.attr lnam
1397. PULLITEMS %outcov%.pat%icetype% %outcov%.attr_a lnam egg_attr
1398. PULLITEMS %outcov%.pat%ndare %outcov%.attr_b lnam
1399. PULLITEMS %outcov%.pat%depare %outcov%.attr_c lnam
1400. PULLITEMS %outcov%.pat%seaare %outcov%.attr_d lnam
1401. PULLITEMS %outcov%.pat%bgare %outcov%.attr_e lnam
1402. PULLITEMS %outcov%.rat%icelin %outcov%.attr_f lnam
1403. PULLITEMS %outcov%.rat%icefra %outcov%.attr_g lnam
1404. PULLITEMS %outcov%.rat%icelea %outcov%.attr_h lnam

1405. &DATA ARC INFO
1406. &MESSAGES &OFF &ALL
1407. ARC
1408. SELECT [UPCASE %outcov%].ATTR_B
1409. MERGE INTO [UPCASE %outcov%].ATTR ON LNAM
1410. SELECT [UPCASE %outcov%].ATTR_C
1411. MERGE INTO [UPCASE %outcov%].ATTR ON LNAM
1412. SELECT [UPCASE %outcov%].ATTR_D
1413. MERGE INTO [UPCASE %outcov%].ATTR ON LNAM
1414. SELECT [UPCASE %outcov%].ATTR_E
1415. MERGE INTO [UPCASE %outcov%].ATTR ON LNAM
1416. SELECT [UPCASE %outcov%].ATTR_F
1417. MERGE INTO [UPCASE %outcov%].ATTR ON LNAM
1418. SELECT [UPCASE %outcov%].ATTR_G
1419. MERGE INTO [UPCASE %outcov%].ATTR ON LNAM
1420. SELECT [UPCASE %outcov%].ATTR_H
1421. MERGE INTO [UPCASE %outcov%].ATTR ON LNAM
1422. Q STOP
1423. &END

1424. JOINITEM %outcov%.attr %outcov%.attr_a %outcov%.attr lnam

1425. TABLES
1426. ADDITEM %outcov%.attr inform 70 70 C
1427. ADDITEM %outcov%.attr ninfom 70 70 C
1428. ADDITEM %outcov%.attr ntxtds 70 70 C
1429. ADDITEM %outcov%.attr picrep 70 70 C
1430. ADDITEM %outcov%.attr scamax 4 12 B
1431. ADDITEM %outcov%.attr scamin 4 12 B
1432. ADDITEM %outcov%.attr txt dsc 70 70 C
1433. ADDITEM %outcov%.attr pubref 70 70 C
1434. ADDITEM %outcov%.attr recdat 8 8 C
1435. ADDITEM %outcov%.attr recind 70 70 C

```

```

1436. ADDITEM %outcov%.attr sordat 8 8 C
1437. ADDITEM %outcov%.attr sorind 70 70 C

1438. SELECT %outcov%.attr
1439. CALCULATE inform = egg_attr
1440. CALCULATE ninfom = "IGNORED"
1441. CALCULATE ntxtsds = "IGNORED"
1442. CALCULATE picrep = "IGNORED"
1443. CALCULATE scamax = -9998
1444. CALCULATE scamin = -9998
1445. CALCULATE txttdsc = "IGNORED"
1446. CALCULATE pubref = "IGNORED"
1447. CALCULATE recdat = "IGNORED"
1448. CALCULATE recind = "IGNORED"
1449. /* CALCULATE recdat = "[SUBSTR [DATE -YEAR] 1 2][DATE -TAG]"
1450. /* CALCULATE recind = "CA,C1,digi"
1451. CALCULATE sordat = "[SUBSTR [DATE -YEAR] 1 2][DATE -TAG]"
1452. CALCULATE sorind = "IGNORED"

1453. DROPITEM %outcov%.attr egg_attr

1454. QUIT

1455. &DO i &LIST A B C D E F G H
1456. &IF [EXISTS %outcov%.attr_%i% -INFO] = .TRUE. &THEN
1457. KILLINFO %outcov%.attr_%i%
1458. &END
1459. &RETURN

1460. /*****
1461. /* CATALOGUE DIRECTORY RECORD
1462. /* - CATD
1463. /*****
1464. &ROUTINE catd
1465. /*****
1466. /*CATALOG DIRECTORY FIELD
1467. /*****
1468. &TYPE 'Creating catalog file...'
1469. &DESCRIBE %outcov%
1470. &IF [EXISTS catd -INFO] &THEN
1471. KILL catd

1472. DEFINE catd
1473. rcnm 2 2 C
1474. rcid 10 10 C
1475. file 70 70 C
1476. lfil 70 70 C
1477. volm 70 70 C
1478. impl 3 3 C
1479. slat 4 8 F 2
1480. wlon 4 8 F 2
1481. nlat 4 8 F 2
1482. elon 4 8 F 2
1483. crcs 70 70 C
1484. comt 70 70 C

```

```

1485. ~

1486. SELECT catd
1487. ADD
1488. /*Catalog File
1489. "CD"
1490. 0000000001
1491. "CATALOG.031"
1492. ~
1493. "V01X01"
1494. "ASC"
1495. -9998
1496. -9998
1497. -9998
1498. -9998
1499. ~
1500. "Exchange Set Catalog file..."

1501. /*Coverage
1502. "CD"
1503. 0000000002
1504. [UPCASE %outcov%].000
1505. ~
1506. "V01X01"
1507. "BIN"
1508. [CALC %DSC$YMIN% - 0.01]
1509. [CALC %DSC$XMIN% - 0.01]
1510. [CALC %DSC$YMAX% + 0.01]
1511. [CALC %DSC$XMAX% + 0.01]
1512. "00000000" /*JUST TEMPORARY
1513. "Ice objects"
1514. ~
1515. &RETURN

1516. /*****
1517. /* DATA SET GENERAL INFORMATION RECORD
1518. /* - DSID
1519. /* - DSSI
1520. /*****
1521. &ROUTINE dsid
1522. &TYPE 'Adding data set information fields...'
1523. /*****
1524. /* DATA SET IDENTIFICATION FIELD
1525. /*****
1526. &IF [EXISTS %outcov%.dsid -INFO] = .TRUE. &THEN
1527. KILL %outcov%.dsid

1528. DEFINE %outcov%.dsid
1529. rcnm 2 2 C
1530. rcid 10 10 C
1531. expp 1 1 C
1532. intu 2 6 B
1533. dsnm 70 70 C
1534. edtn 70 70 C
1535. updn 70 70 C

```

```

1536. uadt 8 8 C
1537. isdt 8 8 C
1538. sted 4 4 C
1539. prsp 3 3 C
1540. psdn 70 70 C
1541. pred 70 70 C
1542. prof 2 2 C
1543. agen 2 2 C
1544. comt 70 70 C
1545. ~

1546. SELECT %outcov%.dsid
1547. ADD
1548. "DS"
1549. "0000000001"
1550. "N"
1551. 1
1552. [UPCASE %outcov%].000
1553. "1"
1554. "0"
1555. %isdt% /*from user input, UADT is same as ISDT for new data
sets
1556. %isdt% /*from user input
1557. "03.1"
1558. "ENC"
1559. ~
1560. "2.0"
1561. "EN"
1562. "CA"
1563. %comt% /*from user input
1564. ~
1565. &RETURN

1566. &ROUTINE dssi
1567. /*****
1568. /* DATA SET STRUCTURE INFORMATION FIELD
1569. /*****
1570. &IF [EXISTS %outcov%.dssi -INFO] = .TRUE. &THEN
1571. KILL %outcov%.dssi

1572. DEFINE %outcov%.dssi
1573. dstr 2 2 C
1574. aall 1 1 C
1575. nall 1 1 C
1576. nomr 4 12 B
1577. nocr 4 12 B
1578. nogr 4 12 B
1579. nolr 4 12 B
1580. noin 4 12 B
1581. nocn 4 12 B
1582. noed 4 12 B
1583. nofa 4 12 B
1584. ~

1585. /*count meta records

```

```

1586. SELECT %outcov%.patm_covr
1587. &SETVAR metas = [SHOW NUMBER SELECT]
1588. SELECT %outcov%.patm_qual
1589. &SETVAR metas = %metas% + [SHOW NUMBER SELECT]

1590. /*count geo records
1591. SELECT %outcov%.patlndare
1592. &SETVAR geos = [SHOW NUMBER SELECT]
1593. SELECT %outcov%.patdepare
1594. &SETVAR geos = %geos% + [SHOW NUMBER SELECT]
1595. &IF [LOCASE %icetype%] = 'seaice' &THEN
1596. SELECT %outcov%.patseaice
1597. &ELSE
1598. SELECT %outcov%.patlacice
1599. &SETVAR geos = %geos% + [SHOW NUMBER SELECT]
1600. SELECT %outcov%.patbgare
1601. &SETVAR geos = %geos% + [SHOW NUMBER SELECT]
1602. SELECT %outcov%.patseaare
1603. &SETVAR geos = %geos% + [SHOW NUMBER SELECT]
1604. SELECT %outcov%.raticelin
1605. &SETVAR geos = %geos% + [SHOW NUMBER SELECT]

1606. SELECT %outcov%.dssi
1607. ADD
1608. "CN"
1609. "1"          /* ATTF lexical level
1610. "1"          /* NATF lexical level
1611. %metas%      /* meta records
1612. /* cartographic records not allowed
1613. %geos%      /* geo records
1614. /* collection records
1615. /* isolated node records (points)
1616. %DSC$MAX_NODE% /* connected node records
1617. %DSC$ARCS%   /* edge records
1618. /* face records not allowed
1619. ~
1620. &RETURN

1621. /*****
1622. /* DATA SET GEOGRAPHICAL REFERENCE RECORD
1623. /* - DSPM
1624. /*****
1625. &ROUTINE dspm
1626. /*****
1627. /* DATA SET PARAMETER FIELD
1628. /*****
1629. &IF [EXISTS %outcov%.dspm -INFO] = .TRUE. &THEN
1630. KILL %outcov%.dspm

1631. &IF [EXISTS %incov%.lut -INFO] = .TRUE. &THEN
1632. &DO
1633. SELECT %incov%.lut
1634. &SETVAR cscl = [SHOW RECORD 1 SCALE]
1635. &END

```

```

1636. SELECT %outcov%.patlndare
1637. &SETVAR geos = [SHOW NUMBER SELECT]

1638. DEFINE %outcov%.dspm
1639. rcnm 2 2 C
1640. rcid 10 10 C
1641. hdat 2 6 B
1642. vdat 2 6 B
1643. sdat 2 6 B
1644. cscl 4 12 B
1645. duni 2 6 B
1646. huni 2 6 B
1647. puni 2 6 B
1648. coun 2 2 C
1649. comf 4 12 B
1650. somf 4 12 B
1651. comt 70 70 C
1652. ~

1653. SELECT %outcov%.dspm
1654. ADD
1655. "DP"
1656. "0000000001"
1657. /* must be '2' - WGS84
1658. /* mean sea level
1659. /* mean sea level
1660. %cscl% /* scale from user input OR LUT, if it exists
1661. /* must be '1' - metres
1662. /* must be '1' - metres
1663. /* must be '1' - metres
1664. "LL" /* must be 'll' - lat/long
1665. 10000000 /* 10000000 ensures cell is at best accurate to
0.000001 degrees
1666. /* must be '10'
1667. %comt% /* comment from user input
1668. ~
1669. &RETURN

1670. &ROUTINE multipoints
1671. /*****
1672. /* FIND POLYS WITH MUTIPLE DIFFERENT-VALUED POINTS
1673. /*****
1674. INTERSECT %outcov_p% %outcov% %cov_int% POINT
1675. STATISTICS %cov_int%.pat %outcov%.stat %outcov%#
1676. MINIMUM pnt_type
1677. MAXIMUM pnt_type
1678. END

1679. TABLES
1680. SELECT %outcov%.stat
1681. RESELECT min-pnt_type = max-pnt_type
1682. PURGE
1683. YES
1684. SORT frequency %outcov%#
1685. QUIT

```

```

1686. &RETURN

1687. &ROUTINE killtemps
1688. /*****
1689. /* CLEAN-UP TEMP FILES
1690. /*****
1691. &TYPE 'Killing temporary files...'
1692. &IF [EXISTS %incov% -COVER] = .TRUE. &THEN
1693. KILL %incov% ALL
1694. &IF [EXISTS %cov_poly% -COVER] = .TRUE. &THEN
1695. KILL %cov_poly% ALL
1696. &IF [EXISTS %cov_dis% -COVER] = .TRUE. &THEN
1697. KILL %cov_dis% ALL
1698. &IF [EXISTS %cov_int% -COVER] = .TRUE. &THEN
1699. KILL %cov_int% ALL
1700. &IF [EXISTS %cov_densify% -COVER] = .TRUE. &THEN
1701. KILL %cov_densify% ALL
1702. &IF [EXISTS %cov_reproj% -COVER] = .TRUE. &THEN
1703. KILL %cov_reproj% ALL
1704. &IF [EXISTS %cov_tempproj% -COVER] = .TRUE. &THEN
1705. KILL %cov_tempproj% ALL
1706. &IF [EXISTS %lt151% -COVER] = .TRUE. &THEN
1707. KILL %lt151% ALL
1708. &RETURN

1709. &ROUTINE makes57
1710. /*****
1711. /* CONVERT TO S-57
1712. /*****
1713. &TYPE 'Making S-57 file...'
1714. &IF [EXISTS %outcov%_log.txt -FILE] = .TRUE. &THEN
1715. &SYSTEM DEL %outcov%_log.txt
1716. &IF [EXISTS 'c:\temp' -DIRECTORY] = .FALSE. &THEN
1717. &SYSTEM MKDIR c:\temp

1718. /* Make the S-57
1719. ARCS57 [SHOW &WORKSPACE] %outcov%_log.txt

1720. /* export catalog to create proper CRC
1721. &IF [EXISTS %outcov%_log2.txt -FILE] = .TRUE. &THEN
1722. &SYSTEM DEL %outcov%_log2.txt
1723. ENCREVISION EXPORTCATALOG [SHOW &WORKSPACE] %outcov%_log2.txt
1724. &IF [EXISTS %outcov%_log2.txt -FILE] = .TRUE. &THEN
1725. &SYSTEM DEL %outcov%_log2.txt
1726. &IF [EXISTS catd -INFO] = .TRUE. &THEN
1727. KILLINFO catd
1728. /* import catalog with proper CRC
1729. ENCREVISION IMPORTCATALOG catalog.030 [SHOW &WORKSPACE]

1730. /* rename catalog to 031, this is version 3.1
1731. &IF [EXISTS CATALOG.031 -FILE] = .TRUE. &THEN
1732. &SYSTEM DEL CATALOG.031
1733. &SYSTEM RENAME CATALOG.030 CATALOG.031

1734. &SETVAR timed = [TRUNCATE [SHOW &PT TIME]]

```

```

1735. /* APPEND PROCESSING TIME TO REPORT
1736. &SETVAR logopen = [OPEN [SHOW &WORKSPACE]\%outcov%_log.txt
      logstatus -APPEND]
1737. &SETVAR record = 'Total Processing time: '[TRUNCATE [CALC %timed%
      / 60]]' minutes and '[MOD %timed% 60]' second(s).'
```

```

1738. /* &SETVAR record = ''
1739. &IF [WRITE %logopen% %record%] = 0 &THEN
1740. &SETVAR closelog = [CLOSE -ALL]

1741. /* APPEND DUPLICATE POINT LIST TO REPORT
1742. LISTOUTPUT [SHOW &WORKSPACE]\%outcov%_log.txt APPEND
1743. LIST %outcov%.stat

1744. &SYSTEM NOTEPAD.EXE %outcov%_log.txt
1745. &RETURN

1746. /*****
1747. &ROUTINE BAILOUT
1748. /*****
1749. &SEVERITY &ERROR &IGNORE
1750. &DELVAR .*
1751. &PT &OFF
1752. &MESSAGES &POPUP
1753. &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";
    "Mscmct2.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        = "CAxxxxxxx"
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
57. End
58. 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
59. End
60. End
61. Attribute VB_Name = "frmS57"
62. Attribute VB_GlobalNameSpace = False
63. Attribute VB_Creatable = False
64. Attribute VB_PredeclaredId = True
65. Attribute VB_Exposed = False
66. Option Explicit
67. Dim thisPath As String

68. Private Sub Form_Load()
69. '*****
70. ' set initial values
71. '*****
72. cboIntu.AddItem "1 - Overview"
73. cboIntu.AddItem "2 - General"
74. cboIntu.AddItem "3 - Coastal"
75. cboIntu.AddItem "4 - Approach"
76. cboIntu.AddItem "5 - Harbour"
77. cboIntu.AddItem "6 - Berthing"
78. cboIntu.Text = "1 - Overview"
79. MonthView1.Value = Date
80. thisPath = App.Path
81. Call MonthView1_DateClick(Date)
82. End Sub

83. Private Sub MonthView1_DateClick(ByVal DateClicked As Date)
84. Dim month As String
85. Dim day As String
86. Dim isdt As String

87. '*****
88. ' add leading zero if month/day is 1 digit
89. '*****
90. If MonthView1.month < mvwOctober Then
91. month = 0 & MonthView1.month

```

```

92. Else
93. month = MonthView1.month
94. End If

95. If MonthView1.day < 10 Then
96. day = 0 & MonthView1.day
97. Else
98. day = MonthView1.day
99. End If

100. isdt = MonthView1.Year & month & day

101. MonthView1.DayBold(MonthView1.Value) = True

102. txtIsdt.Text = isdt
103. End Sub

104. Private Sub cmdIncov_Click()
105. '*****
106. ' launch file browser
107. '*****
108. CommonDialog1.Filter = "ArcInfo Interchange files (*.e00) |
*.e00"
109. CommonDialog1.ShowOpen
110. txtIncov.Text = CommonDialog1.FileName
111. End Sub

112. Private Sub cmdOutspace_Click()
113. '*****
114. ' Opens a Browse Folders Dialog Box
115. '*****
116. Dim lpIDList As Long
117. Dim sBuffer As String
118. Dim szTitle As String
119. Dim tBrowseInfo As BrowseInfo

120. '*****
121. ' Text in the gray area under the title bar
122. '*****
123. szTitle = "Select the folder to save the S-57 file:"

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

129. lpIDList = SHBrowseForFolder(tBrowseInfo)

130. If (lpIDList) Then
131. sBuffer = Space(MAX_PATH)
132. SHGetPathFromIDList lpIDList, sBuffer
133. sBuffer = Left(sBuffer, InStr(sBuffer, vbNullChar) - 1)
134. txtOutspace.Text = sBuffer

```

```

135. End If
136. End Sub

137. Private Sub MonthView1_SelChange(ByVal StartDate As Date, ByVal
    EndDate As Date, Cancel As Boolean)
138. Dim i As Integer
139. '*****
140. ' bold the selected day
141. '*****
142. For i = 1 To 42
143. MonthView1.DayBold(MonthView1.VisibleDays(i)) = False
144. Next
145. End Sub

146. Private Sub cmdRunAML_Click()
147. On Error GoTo ErrorHandler
148. Dim sealake As String
149. Dim killtemps As String
150. Dim boundbox As String
151. Dim crcs As String

152. '*****
153. ' get arguments to pass
154. '*****
155. If optSeaLake(0) = True Then
156. sealake = "seaice"
157. Else
158. sealake = "lacice"
159. End If

160. If chkKillTemps.Value = 1 Then
161. killtemps = "notemps"
162. Else
163. killtemps = "temps"
164. End If

165. If chkBoundingRectangle.Value = 1 Then
166. boundbox = "box"
167. Else
168. boundbox = "nobox"
169. End If

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

173. '*****
174. ' launch arc & run AML
175. '*****
176. 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)  
177. Exit Sub  
  
178. ErrorHandler:  
179. Call MsgBox("Hrmm.. something went terribly wrong." & vbCrLf &  
        vbCrLf & Err.Description, vbExclamation)  
180. End Sub  
181. Private Sub cmdCancel_Click()  
182. Unload Me  
183. End Sub
```

**Module: modWaitForShell.mod**

```
1. Private Type STARTUPINFO
2.   cb As Long
3.   lpReserved As String
4.   lpDesktop As String
5.   lpTitle As String
6.   dwX As Long
7.   dwY As Long
8.   dwXSize As Long
9.   dwYSize As Long
10.  dwXCountChars As Long
11.  dwYCountChars As Long
12.  dwFillAttribute As Long
13.  dwFlags As Long
14.  wShowWindow As Integer
15.  cbReserved2 As Integer
16.  lpReserved2 As Long
17.  hStdInput As Long
18.  hStdOutput As Long
19.  hStdError As Long
20. End Type

21. Private Type PROCESS_INFORMATION
22.   hProcess As Long
23.   hThread As Long
24.   dwProcessID As Long
25.   dwThreadID As Long
26. End Type

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

30. Declare Function CreateProcessA Lib "kernel32" _
31.   (ByVal lpApplicationName As Long, ByVal lpCommandLine As _
32.   String, ByVal lpProcessAttributes As Long, ByVal _
33.   lpThreadAttributes As Long, ByVal bInheritHandles As Long, _
34.   ByVal dwCreationFlags As Long, ByVal lpEnvironment As Long, _
35.   ByVal lpCurrentDirectory As Long, lpStartupInfo As _
36.   STARTUPINFO, lpProcessInformation As PROCESS_INFORMATION) _
37.   As Long

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

40. Private Const NORMAL_PRIORITY_CLASS = &H20&
41. Private Const INFINITE = -1&

42. Public Sub ExecCmd(cmdline$)
43.   Dim proc As PROCESS_INFORMATION
44.   Dim start As STARTUPINFO

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

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

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

**Module: modFolderBrowser.mod**

1. Option Explicit
2. Public Const BIF\_RETURNONLYFSDIRS = 1
3. Public Const BIF\_DONTGOBELOWDOMAIN = 2
4. Public Const MAX\_PATH = 260
5. Public Const BIF\_USENEWUI = &H40
6. Declare Function SHBrowseForFolder Lib "shell32" (lpbi As BrowseInfo) As Long
7. Declare Function SHGetPathFromIDList Lib \_  
"shell32" (ByVal pidList As Long, \_  
ByVal lpBuffer As String) As Long
8. Declare Function lstrcat Lib "kernel32" Alias "lstrcatA" \_  
(ByVal lpString1 As String, \_  
ByVal lpString2 As String) As Long
9. Type BrowseInfo
10. hWndOwner As Long
11. pIDLRoot As Long
12. pszDisplayName As Long
13. lpszTitle As Long
14. ulFlags As Long
15. lpfnCallback As Long
16. lParam As Long
17. iImage As Long
18. End Type

**APPENDIX VIII**  
**PROPOSED S-52 COLOURS AND SYMBOLS**

**Object: Sea Ice**















Code: SEAIICE  
 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:

| <b>ICELSO Value</b> | <b>Description</b>      | <b>Symbol</b>   |
|---------------------|-------------------------|---|
| 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:



|                |                 |
|----------------|-----------------|
| <b>Object:</b> | <b>Land Ice</b> |
| Code:          | LNDICE          |
| Geometry:      | Area            |
| Display Using: | Undetermined    |
| <br>           |                 |
| Symbol:        | Undetermined    |

**Object: Ice Line**

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

Symbols:

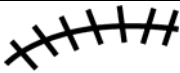
| Value | Description                     | Symbol |
|-------|---------------------------------|--------|
| 1     | Limit of undercast / data limit |        |
| 2     | Ice edge from radar             |        |
| 3     | Limit of radar observation      |        |
| 4     | Limit of visual observation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

|                |                  |
|----------------|------------------|
| <b>Object:</b> | <b>Ice Route</b> |
| 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

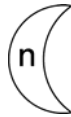
Code: ICETHK  
Geometry: Point  
Display Using: Single symbol  
Attributes: ICETCK and/or ICESCT  
Attribute Description: Ice thickness, snow thickness

Symbols:

ICETCK:



ICESCT:



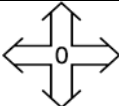

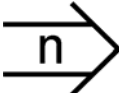


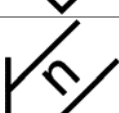
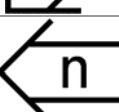


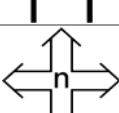
Note:

“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:

| <b>Value</b> | <b>Description</b>      | <b>Symbol</b>   |
|--------------|-------------------------|---|
| 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

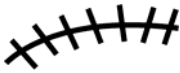


“h” is the value of ICERHT

“c” is the value of ICERCN, if ICERCN &lt; 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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1995 – 1999  
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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