Bulletin: United States Coast Guard

U. S. Department
of Transportation
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Coast Guard

Report of the International Ice Patrol in the North Atlantic

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Bulletin No. 79

REPORT OF THE INTERNATIONAL ICE PATROL
IN THE NORTH ATLANTIC

Season of 1993

CG-188-48

Forwarded herewith is Bulletin No. 79 of the International Ice Patrol, describing the Patrol's services, ice observations and conditions during the 1993 season.

G. A. PENINGTON
Chief, Office of Navigation Safety
and Waterway Services

International Ice Patrol 1993 Annual Report

Contents

Introduction 3
Summary of Operations, 1993 5
Iceberg Reconnaissance and Communications 9
Discussion of Ice and Environmental Conditions 13
References 35
Acknowledgments 36
Appendix A: Nations Currently Supporting International Ice Patrol 37
Appendix B: Commanders of International Ice Patrol 39
Appendix C: Ship Reports 41
Appendix D: International Ice Patrol's Iceberg Sighting Data Base 49
Appendix E: Improvements in Ice Patrol's Drifter Program 81
Appendix F: IIP Iceberg Resights 1992 & 1993 Seasons 87

Introduction

This is the 79th annual report of the International Ice Patrol (IIP). It contains information on Ice Patrol operations, environmental conditions, and ice conditions for the 1993 IIP season. The U.S. Coast Guard conducts the Ice Patrol in the North Atlantic under the provisions of U.S. Code, Title 46, Sections 738, 738a through 738d, and the International Convention for the Safety of Life at Sea (SOLAS), 1974, regulations 5-8. The IIP is supported by 17 member nations (Appendix A). It was initiated shortly after the sinking of the RMS TITANIC on April 15, 1912 and has been provided seasonally since that time.

Commander, International Ice Patrol is under the operational control of Commander, Coast Guard Atlantic Area. He directs the IIP from its Operations Center in Groton, Connecticut. IIP analyzes ice and environmental data, prepares daily ice bulletins and facsimile charts, and responds to requests for ice information. IIP uses aerial Ice Reconnaissance Detachments (ICERECDETs) and, when necessary, surface patrol cutters to survey the southeastern, southern, and southwestern regions of the Grand Banks of Newfoundland for icebergs. In 1993, IIP's ICERECDETs were based in St. John's, Newfoundland, Canada. IIP's Operations Center uses an iceberg drift and deterioration model to produce twice-daily radio broadcasts to warn mariners of the limits of all known ice.

Vice Admiral Paul A. Welling was Commander, Atlantic Area and Commander Alan D. Summy was Commander, International Ice Patrol during the 1993 season. Appendix B presents a list of the Commanders of the International Ice Patrol since 1914.

Summary of Operations, 1993

The 1993 IIP year (October 1, 1992 - September 30, 1993) marked the 79th anniversary of the International Ice Patrol, which was established February 7, 1914. IIP's operating area is enclosed by lines along 40°N, 52°N, 39°W, and 57°W (Figure 1).

IIP's first preseason aerial ICERECDET of the year departed on January 11. The 1993 IIP season was opened on February 2 and from this date until July 27, 1993, an ICERECDET operated from Newfoundland every other week. The season officially closed on July 30, 1993. Coast Guard HC-130H aircraft equipped with the AN/APS-135 Side-Looking Airborne Radar (SLAR) and AN/APS-137 Forward Looking Radar (FLAR) flew 59 ice reconnaissance sorties, logging over 393 flight hours, and Coast Guard HU-25B aircraft equipped with the AN/APS-131 SLAR flew 16 reconnaissance sorties, logging over 42 flight hours.

Table 1
Sources of Sightings Entered into IIP's Drift Model

Sighting Source	Percent of Total
Coast Guard (IIP)	13.1
Other Air Recon	48.5
Canadian AES	12.8
BAPS	6.9
Ships	18.3
Other	0.4

IIP's Operations Center in Groton, Connecticut analyzed the iceberg sighting information from the ICERECDETs, ships, Atmospheric Environment Service (AES) of Canada sea ice/iceberg reconnaissance flights, and other sources. Air reconnaissance was the major source of iceberg sighting reports this season, accounting for 81% of the icebergs sighted in 1993 (Table 1). Ships provided about 18% of the iceberg sightings received by IIP in 1993. Their continued active participation indicates the value that they place on IIP's service. In 1993, 299 ships of 45 different nations provided ice information to IIP. This indicates that the number of nations using the services of and contributing to IIP far exceeds the 17 member nations underwriting IIP under SOLAS 1974. Appendix C lists the ships that provided iceberg sighting reports, including reports of radar targets. In Appendix C, several targets may have been included in a single report.

The largest contributor of air reconnaissance reports was Atlantic Airways. their reports account for nearly all of the category "Other Air Recon". Atlantic Airways is a private company that provides aerial reconnaissance services for the Canadian Department of Fisheries and Oceans (DFO) year round, and for AES June through December. Their DFO flights, which are designated to monitor the activities of fishing vessels, frequently carry them to areas with large iceberg concentrations. The next largest contribution to their air reconnaissance total is the IIP ICERECDETs. Due to the assigned mission of protecting North Atlantic shipping, IIP flights concentrate on the boundaries of the iceberg distribution, which are typically areas of low iceberg concentrations. BAPS sightings are icebergs detected north of 52°N primarily by AES reconnaissance. These are passed to IIP by AES as the icebergs cross into the Ice

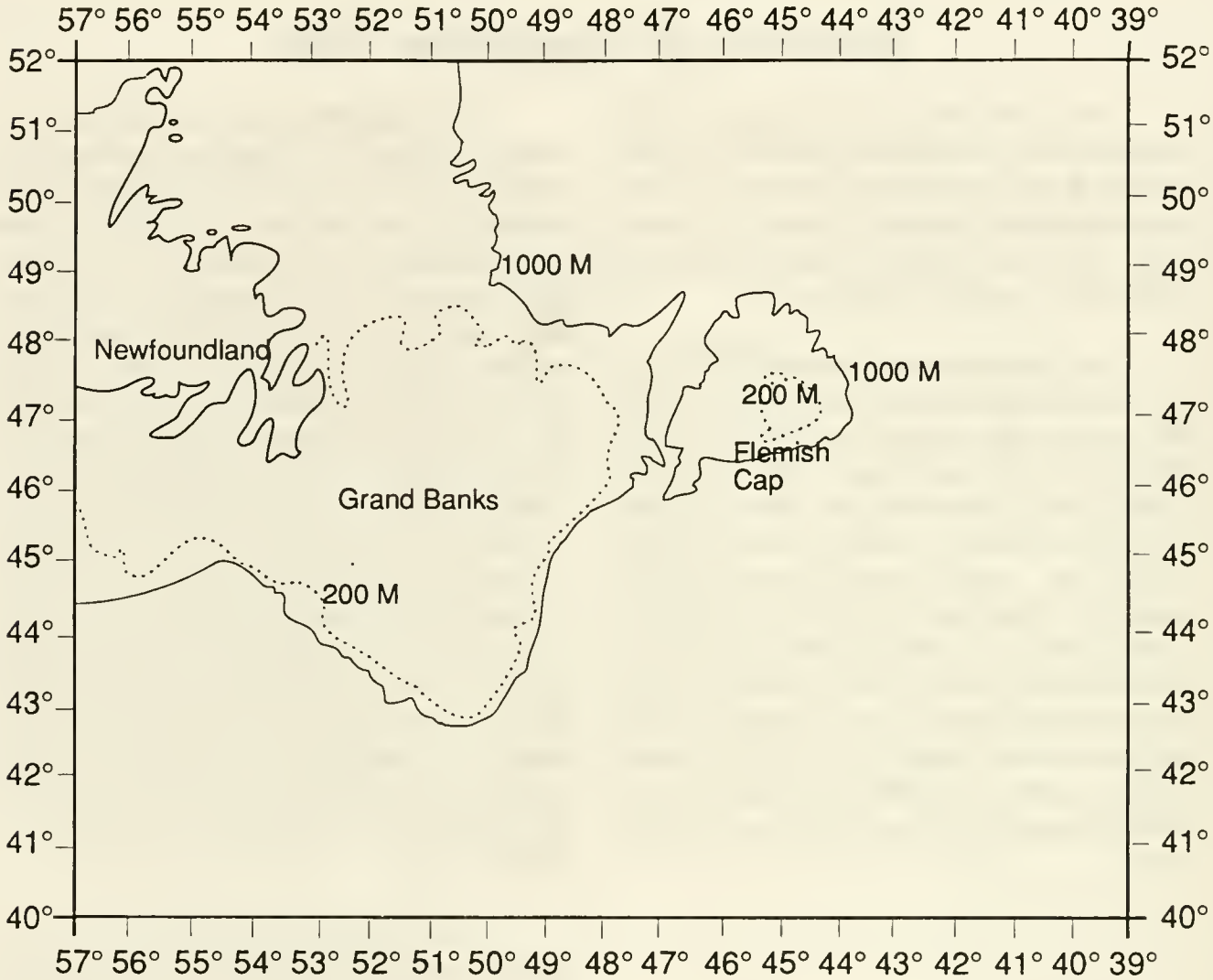

Figure 1
International Ice Patrol's Operation Area showing bathymetry of the Grand Banks of Newfoundland

Patrol operating area. As in 1992, AES flew few iceberg reconnaissance flights during 1993 because of a lack of funding. AES did acquire and relay to IIP some iceberg information obtained during sea ice reconnaissance flights and there were a few flights dedicated solely to iceberg reconnaissance.

During 1993, the IIP Operations Center received a total of 8058 target sightings within its operations area and away from the Newfoundland coast which were entered into IIP's drift model. This can be compared to 3170 target sightings during 1992. The 8058 targets entered into IIP's drift model do not represent all of the targets reported to IIP. Sightings of targets outside IIP's operations area were not entered into the model. Most of these were far to the north of IIP's area and were in areas not covered by IIP's model.

Table 2 compares the icebergs detected south of 48°N plus the number of icebergs which were predicted to drift across 48°N for each month of 1993 with the monthly mean total from 1983 - 1992, the period during which IIP has been patrolling with SLAR-equipped aircraft. During the 1993 ice year, an

estimated 1753 icebergs drifted south of 48°N; whereas, during 1992 876 icebergs drifted south of 48°N. Based on the historic iceberg counts of its entire 79 year history, IIP classifies the severity of the ice seasons. Ice years with fewer than 300 icebergs crossing 48°N are defined as light ice years; those with 300 to 600 crossing 48°N as average; those with 600 to 900 crossing 48°N as heavy; and those with more than 900 crossing 48°N as extreme (Alfultis, 1987). 1993 was an extreme year when compared to the entire history in addition, it is well above average for the recent years in which SLAR has been used. Appendix D presents a detailed description of IIP's reconnaissance techniques since 1960.

Table 2
Number of Icebergs South of 48°N

Number of icebergs South of 48°N during 1993 compared to the average for the period 1983-92, the SLAR reconnaissance period.

	Avg 1983-92	Ice Year 1993
OCT	1	0
NOV	1	0
DEC	1	16
JAN	1	112
FEB	36	336
MAR	86	276
APR	242	428
MAY	199	338
JUN	206	188
JUL	112	50
AUG	36	8
SEP	6	1
Era Average	927	1753

The 1993 season was the first year that IIP used its iceberg Data Management and Prediction System (DMPS). This system, which is nearly identical to the iceBerg Analysis and Prediction System (BAPS) used at the Canadian Ice Centre, Ottawa, combines an iceberg drift model with a deterioration model. The model uses wind, ocean current data, and iceberg size data to predict the movement and deterioration of all icebergs entered into DMPS. Appendix F presents an examination of the impact of the DMPS on IIP's correlation of most recent sighting data with the predicted movement of previously sighted icebergs. The drift prediction model uses a historical current data base which is modified weekly using satellite-tracked ocean drifting buoy data, thus taking into account local, short-term, current fluctuations. Murphy and Anderson (1985) described and evaluated the drift model.

The iceberg deterioration model uses daily sea surface temperature and wave height information from the U.S. Navy Fleet Numerical Oceanography Center (FNOC) to predict the melt of icebergs. Anderson (1983) and Hanson (1987) described the IIP deterioration model in detail.

Eight satellite-tracked ocean drifting buoys were deployed to provide current data for IIP's iceberg drift model during the 1993 season. All were World Ocean Circulation Experiment (WOCE) drifters. All buoys were equipped with temperature sensors. One of the buoys had a drogue at 15 meters and the remainder were drogued at 50 meters. Drift data from the buoys are discussed in the IIP 1993 Drifting Buoy Atlas, which is available upon request. Appendix E discusses in detail recent improvements in the drifting buoy program.

IIP conducted an oceanographic cruise aboard USCGC BITTERSWEET (WLB 389)

between 8 and 23 July 1993. The objective of the cruise was to provide surface truth for an evaluation of the iceberg detection and identification ability of the APS-137 Forward Looking Airborne Radar (FLAR).

During the 1993 season, IIP successfully deployed 37 Air-deployable eXpendable BathyThermographs (AXBTs). The AXBT measures temperature with depth and transmits the data back to the aircraft. Temperature data from the AXBTs were sent to the Canadian Meteorological and Oceanographic Center (METOC) in Halifax, Nova Scotia, Canada, the U.S. Naval Eastern Oceanography Center (NEOC) in Norfolk, Virginia, and FNOC for use as inputs into ocean temperature models. IIP directly benefits from AXBT deployments by having improved ocean temperature data provided to its iceberg deterioration model. IIP also provided weekly drifting buoy sea surface temperature (SST) and drift histories to METOC and NEOC for use in water mass and SST analyses. Canada's Maritime Command/ Meteorological and Oceanographic Centre provided the AXBT probes for IIP use, significantly increasing the temperature data IIP could obtain.

On April 15, 1993, IIP paused to remember the 81st anniversary of the sinking of the RMS TITANIC. During an ice reconnaissance patrol, two memorial wreaths were placed near the site of the sinking to commemorate the nearly 1500 lives lost.

Iceberg Reconnaissance and Communications

During the 1993 Ice Patrol year, 154 aircraft sorties were flown in support of IIP. Of these, 55 were transit flights to St. John's, Newfoundland, IIP's base of operations since 1989, and 75 were ice observation flights made to locate the southwestern, southern, and southeastern limits of icebergs. Seventeen logistics flights were required to support and maintain the patrol aircraft. Tables 3 and 4 show aircraft use during the 1993 ice year.

IIP's aerial ice reconnaissance was conducted with SLAR and FLAR-equipped U.S. Coast Guard HC-130H and a SLAR-equipped HU-25B aircraft. The HC-130H aircraft used on Ice Patrol are based at Coast Guard Air Station Elizabeth City, North Carolina, and HU-25B aircraft at Coast Guard Air Station Cape Cod, Massachusetts.

This was the first operational year for the FLAR, an Inverse Synthetic Aperture Radar (ISAR). IIP conducted a field test of the iceberg detection and identification ability of the FLAR in 1991 and as noted before, conducted an other test during 1993. The earlier test showed the FLAR to be a promising identification tool although the FLAR failed to detect some small icebergs and growlers (Ezman, Murphy, Fogt, Reed, 1991). The analysis of 1993's data has not been completed. However, the operational experience gained in 1993 show the SLAR/FLAR combination to be a vast improvement in iceberg identification over the SLAR only system.

The combined ability of the SLAR and FLAR to detect icebergs in all weather and IIP's computer models to estimate iceberg drift and deterioration enables IIP to schedule aerial iceberg surveys every other week rather than every week.

The HC-130H 'Hercules' aircraft has been the primary platform for Ice Patrol aerial reconnaissance since 1963, while the HU-25B has been used since 1988. The extended iceberg distribution throughout most of the

Table 3
Aircraft Used During The 1993 IIP Year

Sorties

Aircraft	Transit	Patrol	Research	Logistics	Total
HC-130H	49	59	3	17	128
HU-25B	6	16	0	4	26
Total	55	75	3	21	154

Flight Hours

Aircraft	Transit	Patrol	Research	Logistics	Total
HC-130H	149.0	393.1	16	45.3	603.4
HU-25B	11.5	42.2	0	9.9	63.6
Total	160.5	435.3	16	55.2	667.0

Table 4
Iceberg Reconnaissance Sorties

	HU-25B		HC-130		TOTAL	
MONTH	SORTIES	FLIGHT HOURS	SORTIES	FLIGHT HOURS	SORTIES	FLIGHT HOURS
JAN	0	0	7	44.8	7	44.8
FEB	0	0	6	39.9	6	39.9
MAR	0	0	9	61.2	9	61.2
APR	0	0	11	76.8	11	76.8
MAY	0	0	13	85.2	13	85.2
JUN	9	25.5	8	53.1	17	78.6
JUL	7	16.7	5	32.1	12	48.8
AUG	0	0	0	0	0	0
SEP	0	0	0	0	0	0
TOTAL	**16**	**42.2**	**59**	**393.1**	**75**	**435.3**

Table 5
Iceberg and SST Reports

Number of ships furnishing Sea Surface Temperature (SST) reports	52
Number of SST reports received	278
Number of ships furnishing ice reports	340
Number of ice reports received	837
First Ice Bulletin	021200Z FEB 93
Last Ice Bulletin	301200Z JUL 93
Number of facsimile charts transmitted	179

1993 season required the use of the HC-130 rather than the HU-25B. Thus, the HU-25B logged significantly fewer IIP flight hours than the HC-130. The total number of flight hours increased slightly from 623.6 hours in 1992 to 667.0 hours in 1993. The number of sorties decreased from 167 in 1992 to 154 in 1993.

Each day during the ice season, IIP prepared and distributed ice bulletins at 0000Z and 1200Z to warn mariners of the southwestern, southern, and southeastern limits of icebergs. U. S. Coast Guard Communications Station Boston, Massachusetts, NMF/NIK, and Canadian Coast Guard Radio Station St. John's Newfoundland/VON were the primary radio stations responsible for the dissemination of the ice bulletins. Other transmitting stations for the bulletins included METOC Halifax, Nova Scotia/CFH, Canadian Coast Guard Radio Station Halifax/VCS, Radio Station Bracknel, UK/GFE, and U.S. Navy LCMP Broadcast Stations Norfolk/NAM, Virginia, and Key West, Florida. On 25 Mar 1993, IIP began broadcasting the 0000Z and 1200Z ice bulletins (in addition to safety broadcasts) over the INMARSAT-C SafetyNet AOR-W satellite.

IIP also prepared a daily facsimile chart, graphically depicting the limits of all known ice, for broadcast at 1600Z daily. U. S. Coast Guard Communications Station Boston assisted with the transmission of these charts. Canadian Coast Guard Radio Station St. John's/VON and U.S. Coast Guard Communications Station Boston/NIK provided special broadcasts as required.

As in previous years, International Ice Patrol requested that all ships transiting the area of the Grand Banks report ice sightings, weather, and sea surface temperatures via Canadian Coast Guard Radio Station St. John's/VON or U. S. Coast Guard Communications Station Boston/NIK. Response to this request is shown in Table 5. Appendix C lists all contributors. IIP received relayed information from the following sources during the 1993 ice year: Canadian Coast Guard Marine Radio Station St. John's VON; Canadian Coast Guard Vessel Traffic Centre/Ice Operations St. John's; Ice Centre Ottawa; Canadian Coast Guard Marine Radio Halifax/VCS; ECAREG Halifax, Canada; U.S. Coast Guard Communications and Master Station Atlantic, Chesapeake, Virginia; and U.S. Coast Guard Automated Merchant Vessel Emergency Response/Operations Systems Center, Martinsburg, WV. Commander, International Ice Patrol extends a sincere thank you to all stations and ships which contributed reports. The vessel with the most reports was the M/V SYN PULKU, a Polish flag vessel.

Canadian Forces 727th Communications Squadron/St. John's Military Radio served as the primary facility for air ground communications, and the 726th Communications Squadron/Halifax Military Radio was the secondary facility.

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Discussion of Ice and Environmental Conditions

Background

The Labrador Current is the main mechanism transporting icebergs south to the Grand Banks. Its relatively cold water keeps the deterioration of icebergs in transit to a minimum.

The wind direction and intensity along the Labrador and Newfoundland coasts has a significant effect on iceberg drift. Icebergs can be accelerated along or driven out of the main flow of the Labrador Current (Figure 2). Departure from the Labrador Current normally slows their southerly drift and, in many cases, speeds up their rate of deterioration.

Sea ice protects the icebergs from wave action, the major agent of iceberg deterioration. If sea ice extends to the south and over the Grand Banks of Newfoundland, the icebergs will be protected longer as they drift south. When the sea ice retreats in the spring, large numbers of icebergs will be left behind on the Grand Banks. If this time of sea ice retreat is delayed by below normal air temperatures, the icebergs will be protected longer, and a longer than normal ice season can be expected. Less southerly sea ice extent or above normal air temperatures may result in a shorter season.

Sea ice can impede the transport of icebergs. The degree depends on the concentration of the sea ice and the size of the iceberg. The greater the sea ice concentration, the greater the affect on iceberg drift. The larger the iceberg, the less sea ice affects its drift.

The 1993 Season

Figures 3 to 14 compare the sea ice edge during the 1993 ice year to the mean sea ice edge. The mean sea ice edges were taken from Cote, 1989 and represent a 25 year average (1962-1987). The ice edge (sea ice concentration > = 1/10) is taken from the daily Ice Analysis from Ice Centre Ottawa.

Figures 15 to 29 show the Ice Patrol Limits of All Known Ice (LAKI) and the daily sea ice edge on the 15th and 30th day of each month during the ice season. The ice edge is taken from the Ice Centre Ottawa FICN2 daily product. The edge plotted is a coarse numeric representation of daily Ice Analysis. These figures show the distribution of all icebergs and radar contacts tracked by IIP's model at the given times. Numerals are given for clarity for those one-degree squares where six or more targets are located.

The following is a discussion of the environmental conditions (the meteorological and sea ice information is taken from the Ice Centre Ottawa Thirty Day Ice Forcast for Northern Canadian Waters):

December

The mean air temperatures were about 2-4°C below normal along the Labrador Coast and in East Newfoundland waters. This was due to a persisting northwesterly flow. The sea ice growth in the East Newfoundland waters was about four weeks ahead of normal (Figure 5). There were 16 icebergs crossing 48°N in December.

January and February

Sea ice growth along the Labrador Coast and in East Newfoundland waters was three months ahead of normal (By January, the southern limit of the sea ice was farther

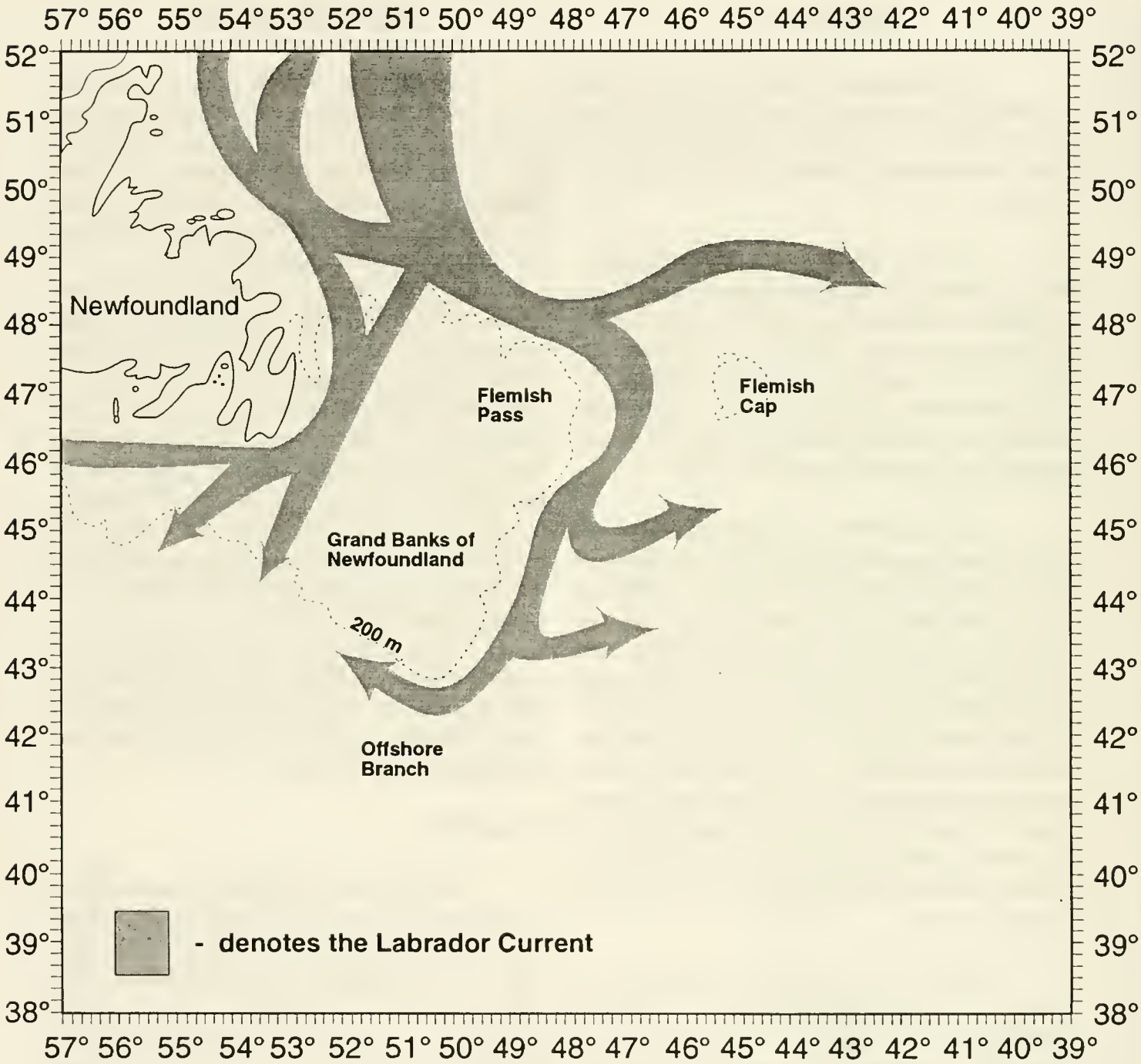

Figure 2
The Labrador Current, the main mechanism for transporting icebergs South to the Grand Banks.

south than at any time during an average year). The winds persisted from the northwest. During the month of January 92 icebergs drifted south of 48°N. The 1993 ice season opened on 2 February 1993, on which date the southern extent of the LAKI was at 43° 50'N (Figure 15). The southern extent of the LAKI at the end of February was 41° 30'N.

March and April

In late February through early March several storms crossed the East Newfoundland waters, causing sea ice destruction. As a result, the sea ice edge retreated to near normal conditions (Figure 8). However, during the rest of March and April the persistent northwesterly winds maintained below normal air temperatures and a greater than normal sea ice extent (Figure 9). The southern and eastern LAKI extended as far south as 41° 30'N and as far east as 37° 00'W respectively (Figures 18 - 21). There were 276 and 428 icebergs south of 48°N in March and April, respectively.

May and June

During the latter half of May, the prevailing winds were from the southeast. The air temperatures during May and June were slightly above normal. This combined with the seasonal rise in air temperature caused the sea ice to retreat rapidly (Figures 10 and 11). The southern LAKI remained about 41° 30'N throughout most of May and June. There were 338 and 188 icebergs crossing south of 48°N in May and June, respectively.

July

The sea ice retreated well north of 55°N (Figures 12 and 13). There were 50 icebergs crossing south of 48°N in July. The southern extent of the LAKI was north of 45°N (Figures 26 and 27). The 1993 ice season closed on 30 July 1993.

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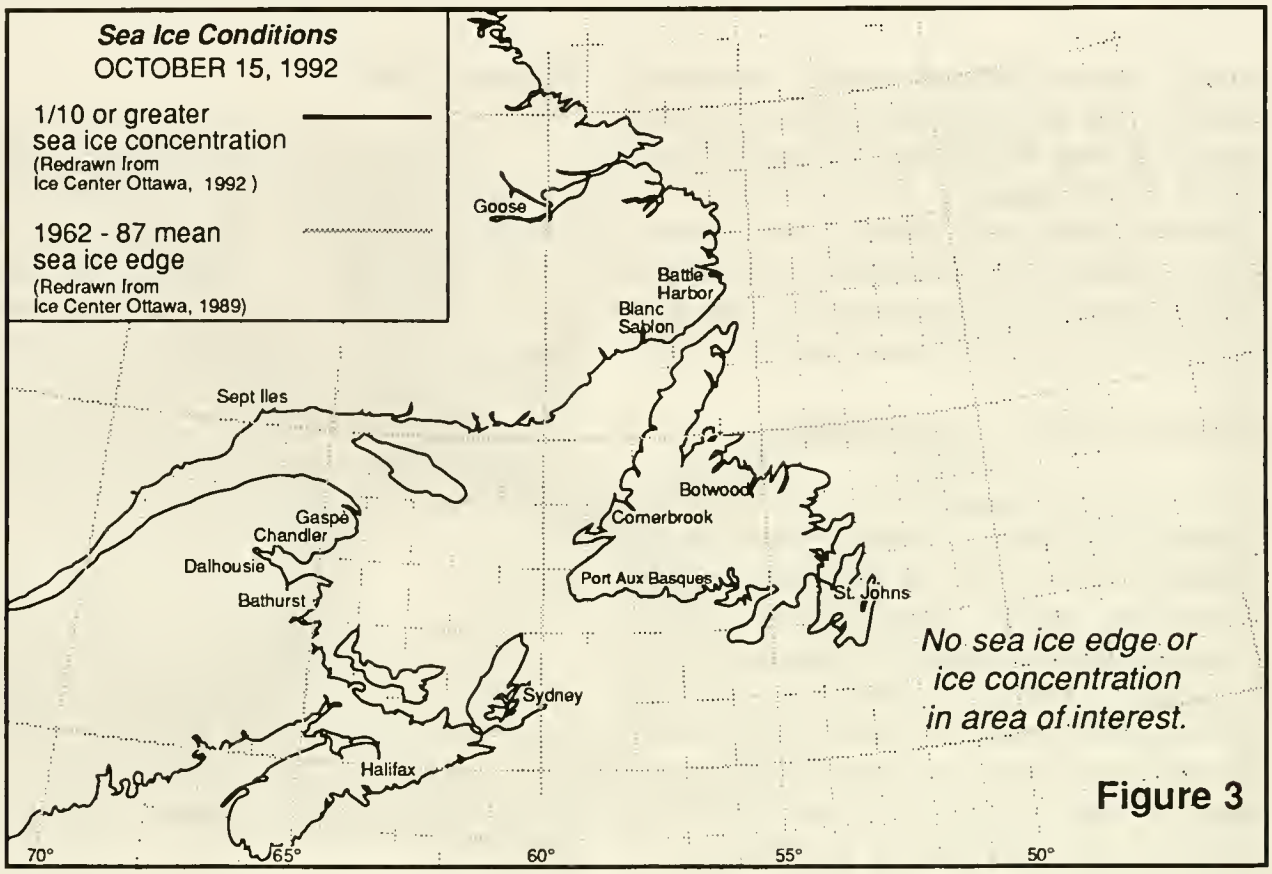


Figure 3

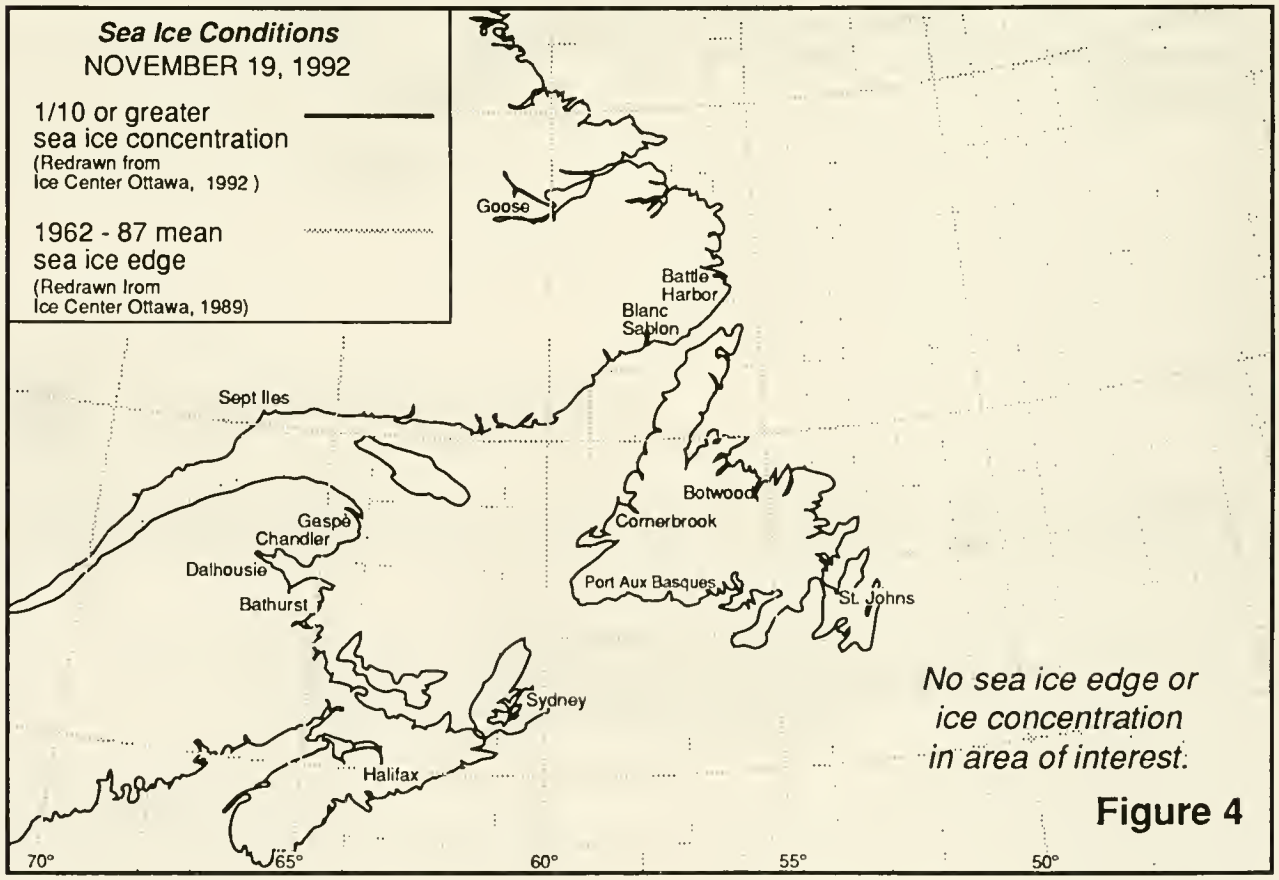


Figure 4

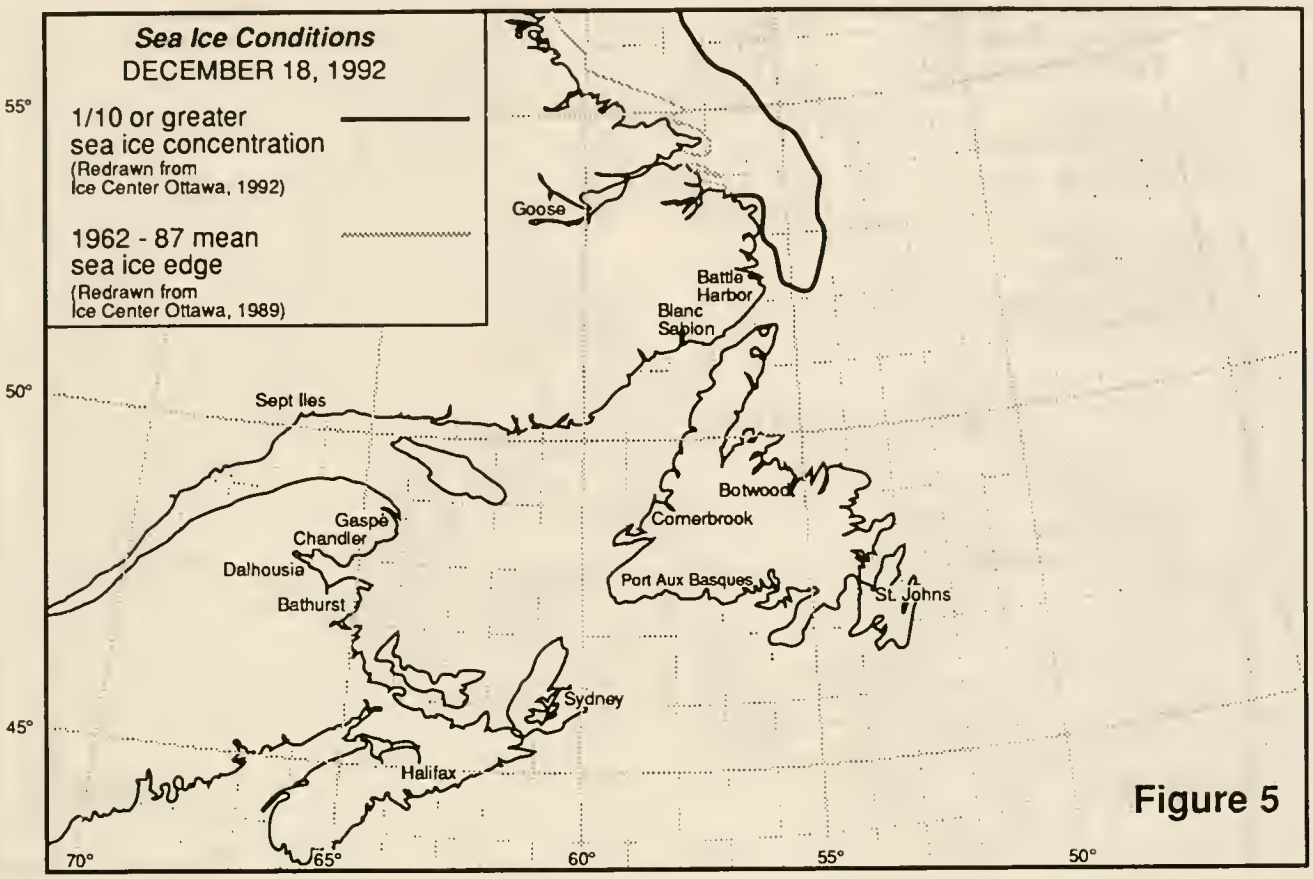
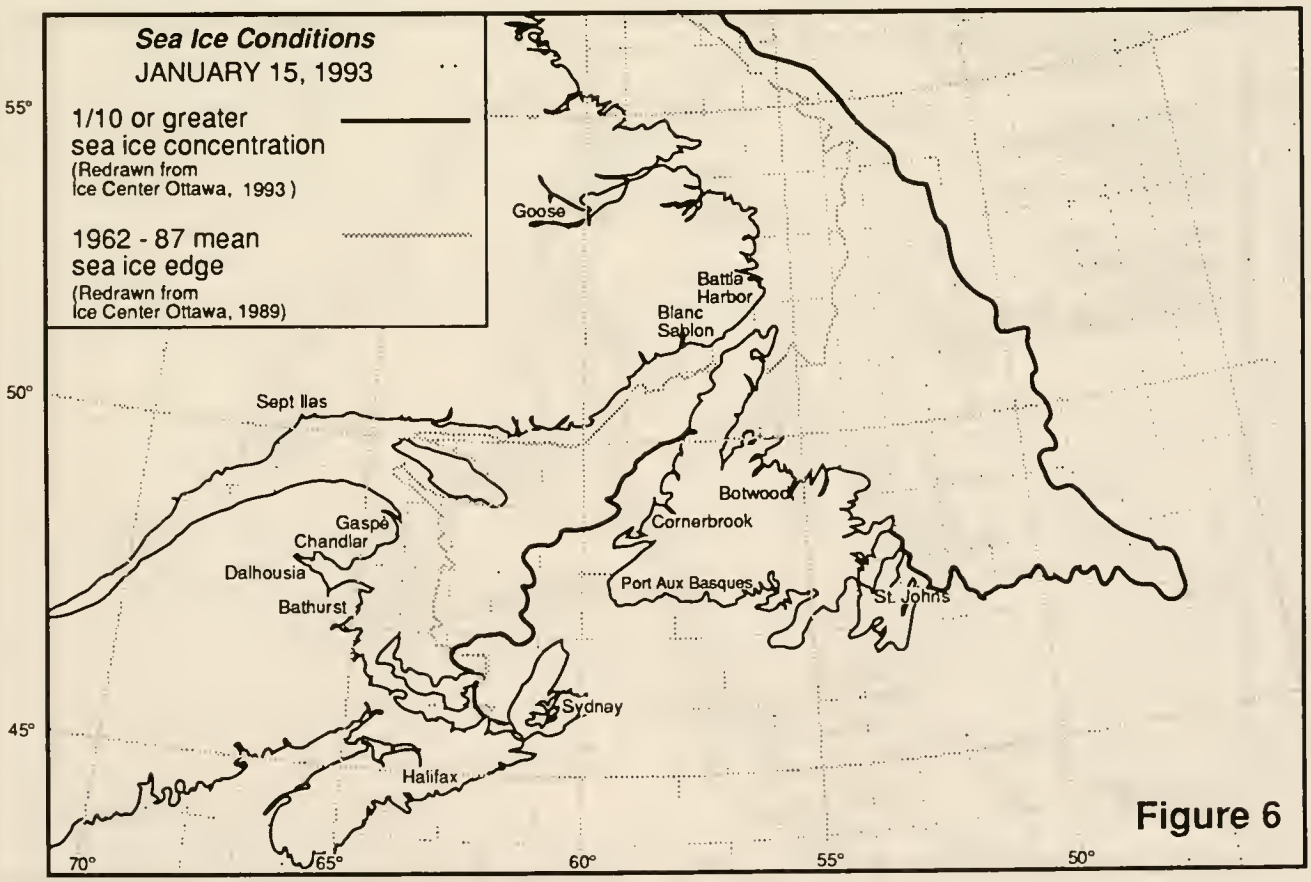


Figure 5



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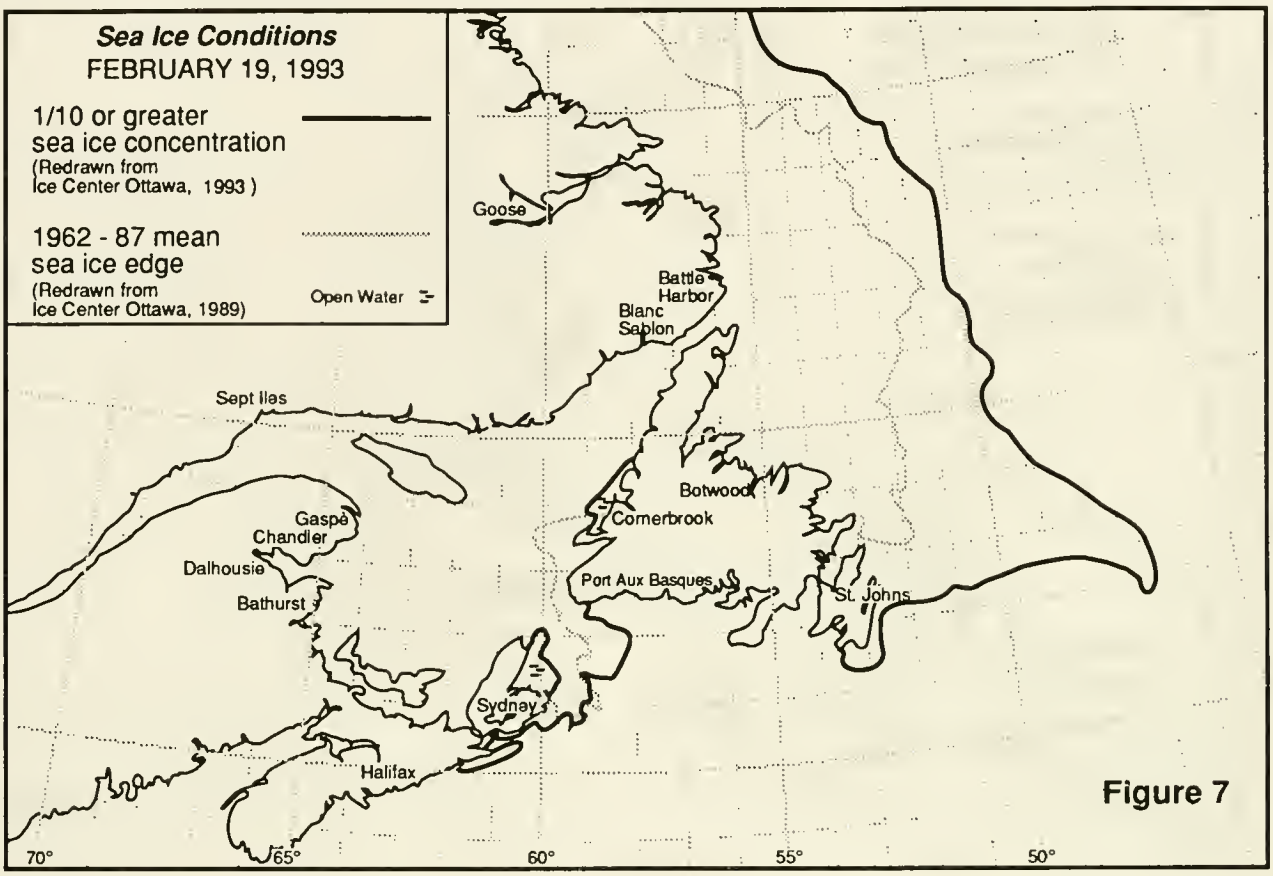

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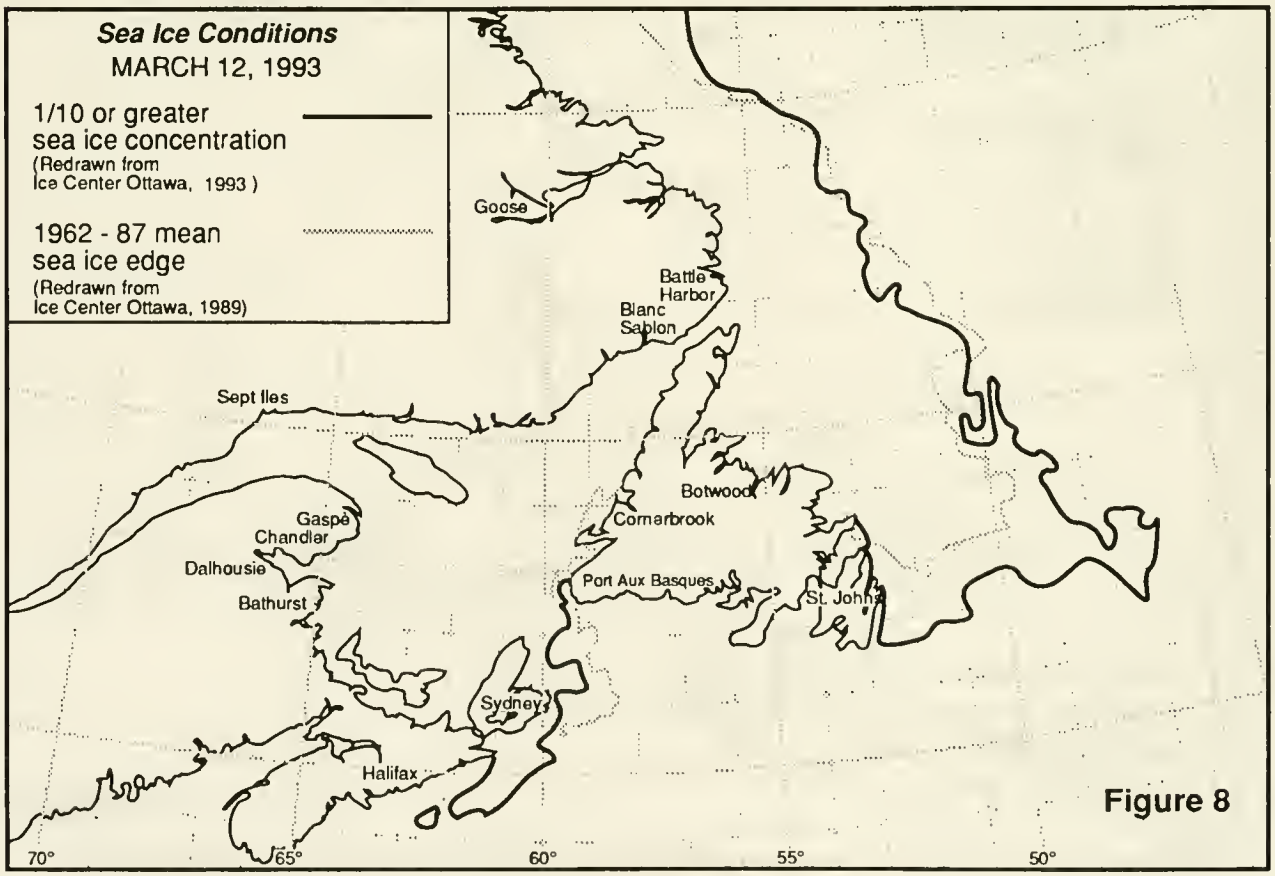


Figure 8

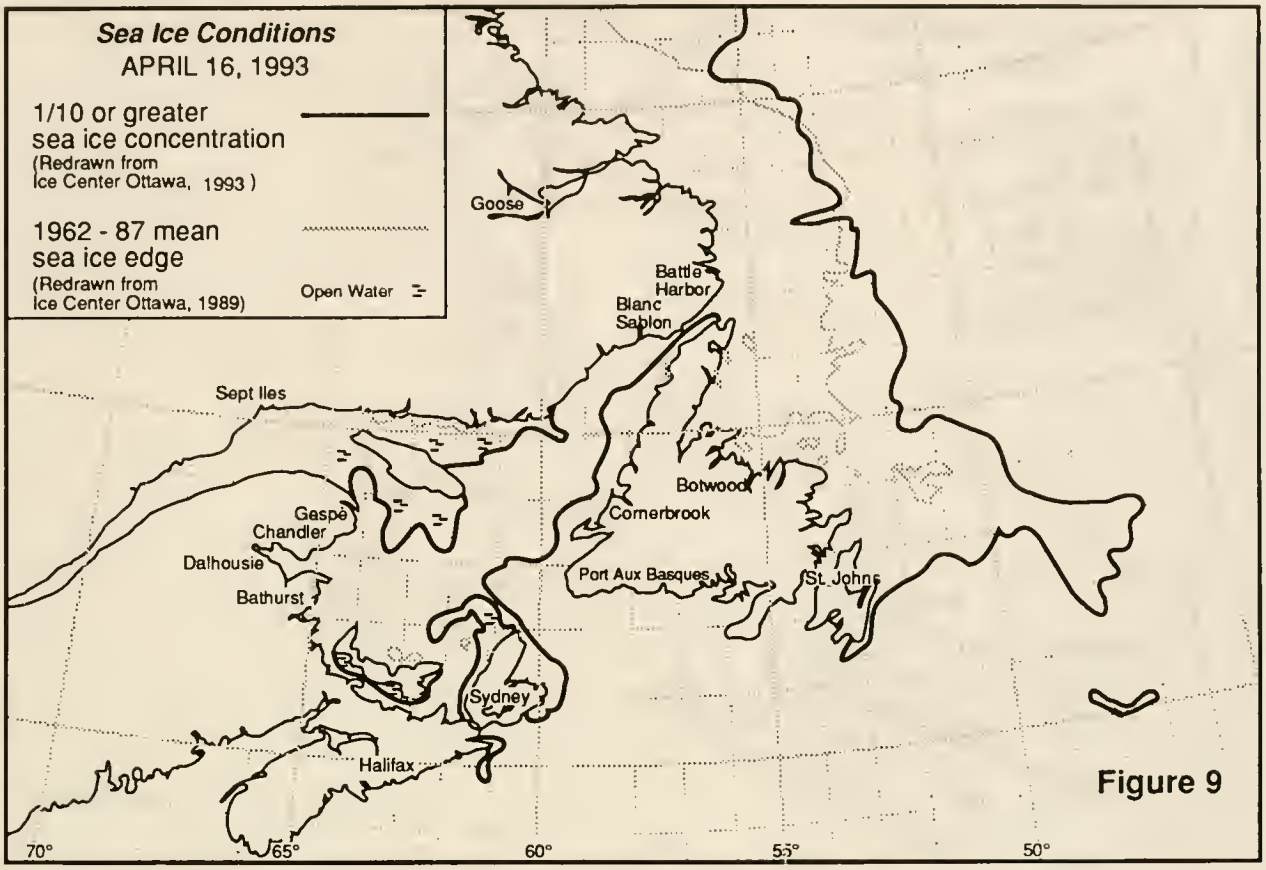


Figure 9

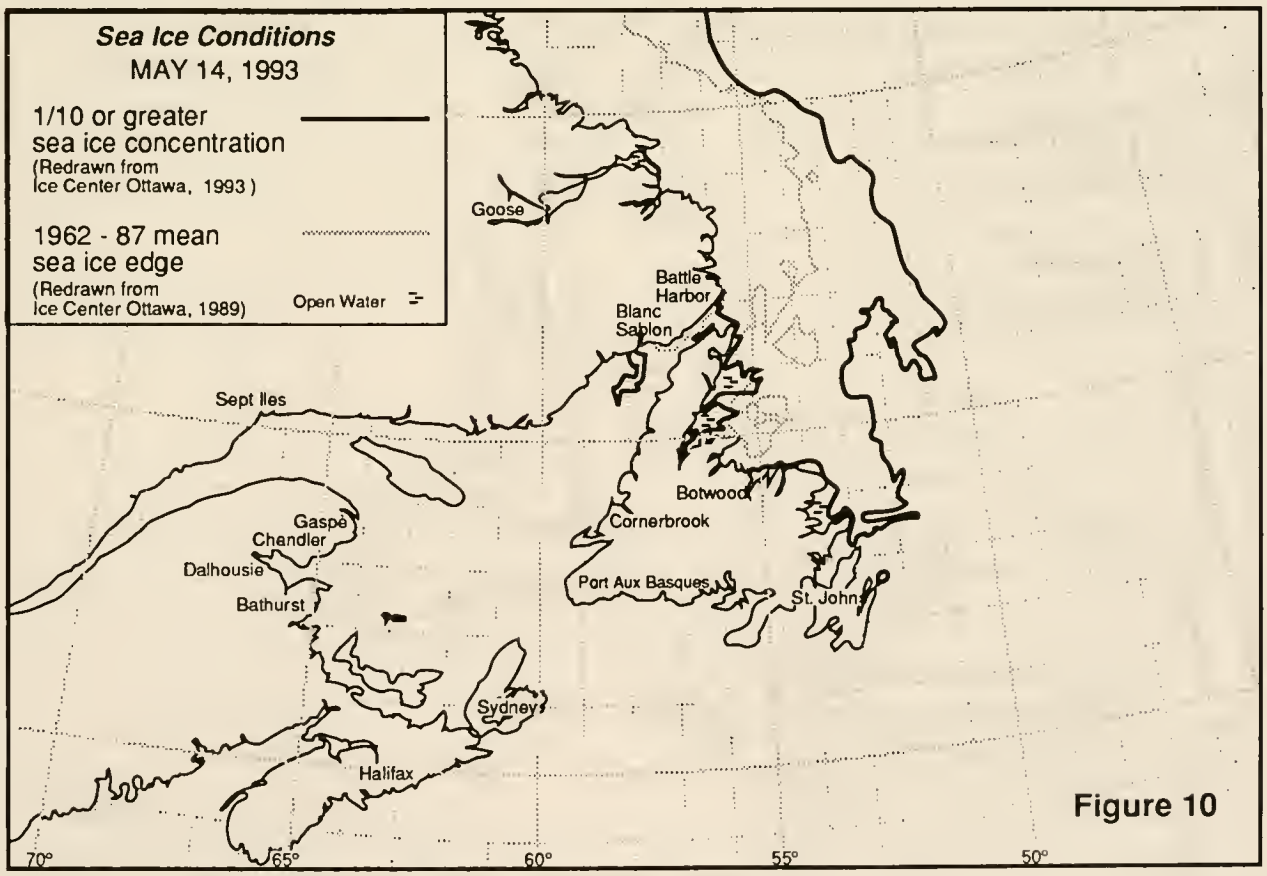


Figure 10

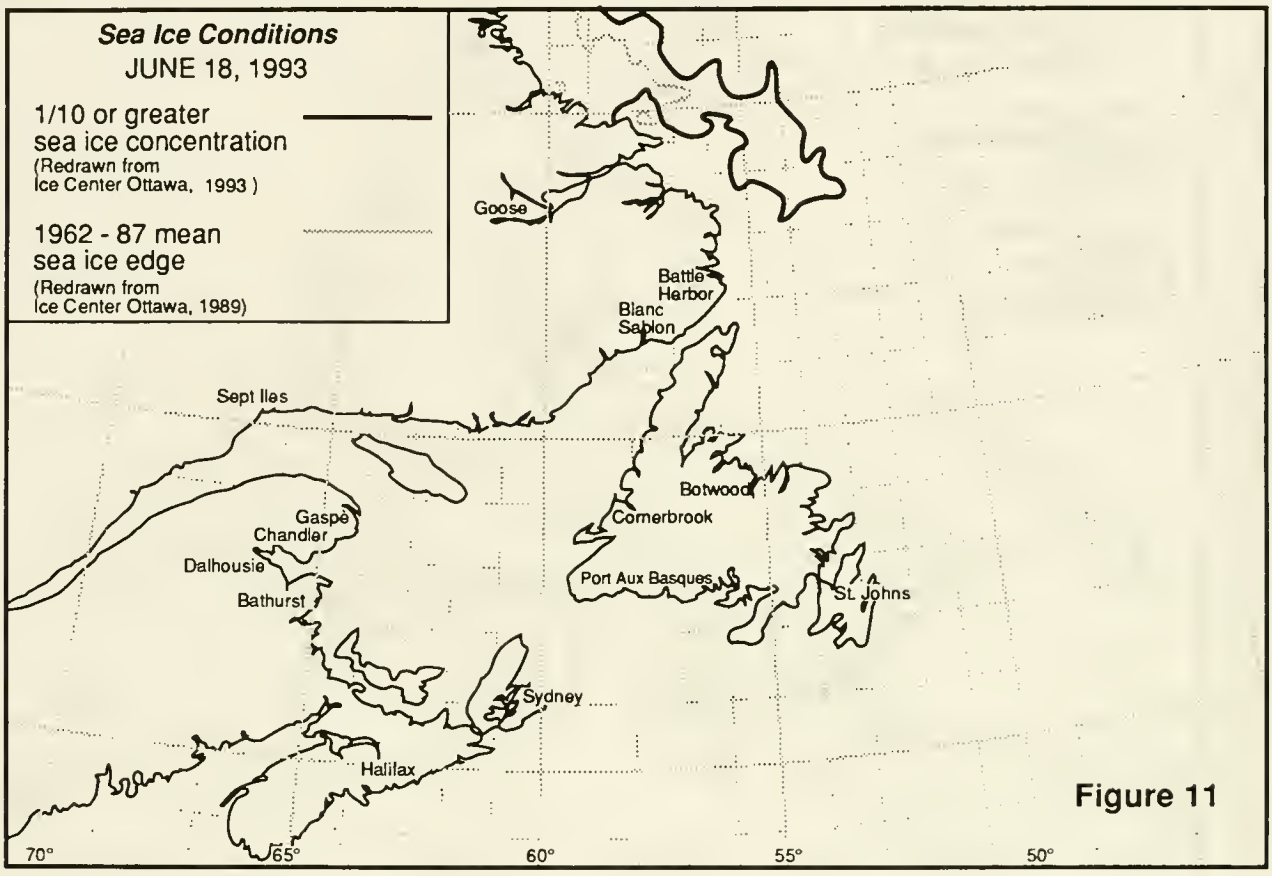


Figure 11

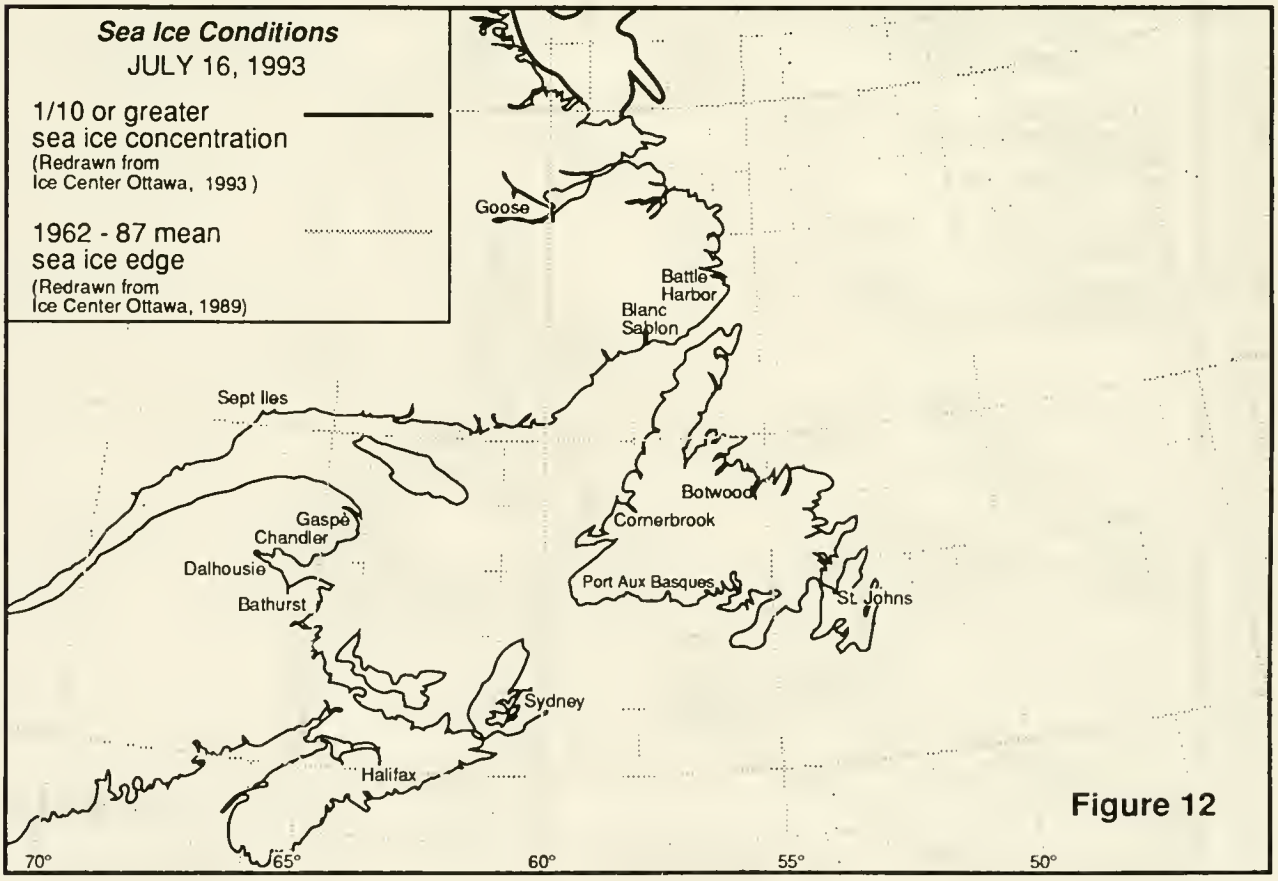


Figure 12

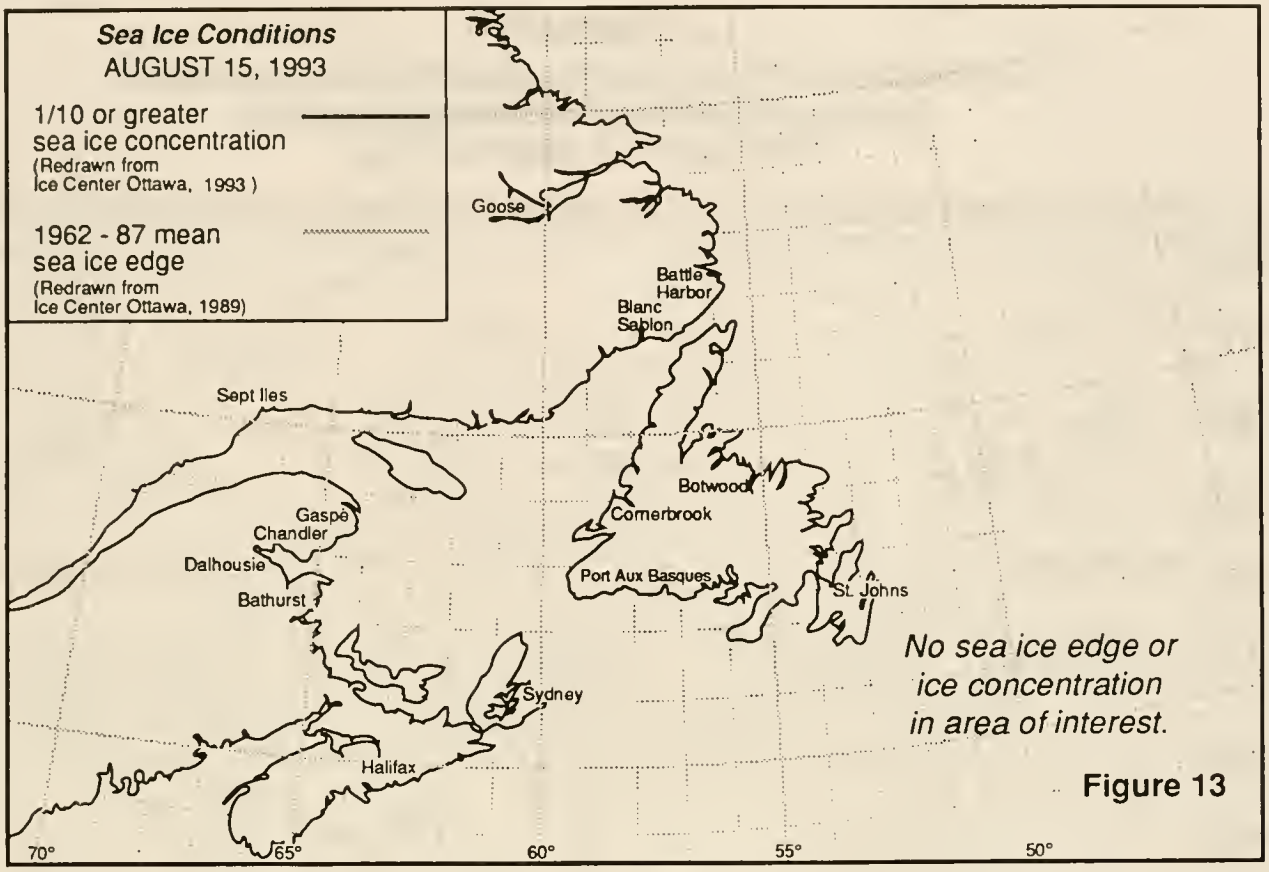


Figure 13

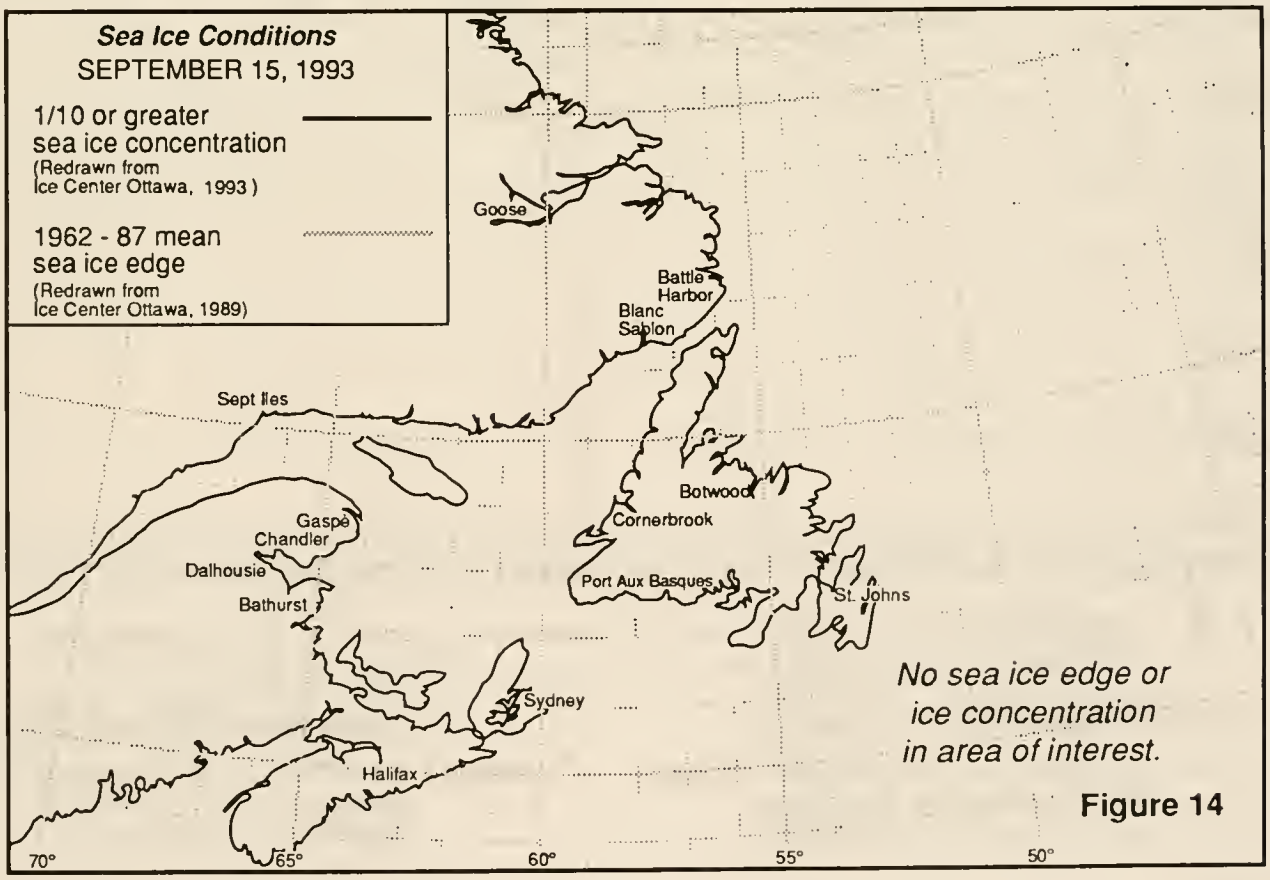
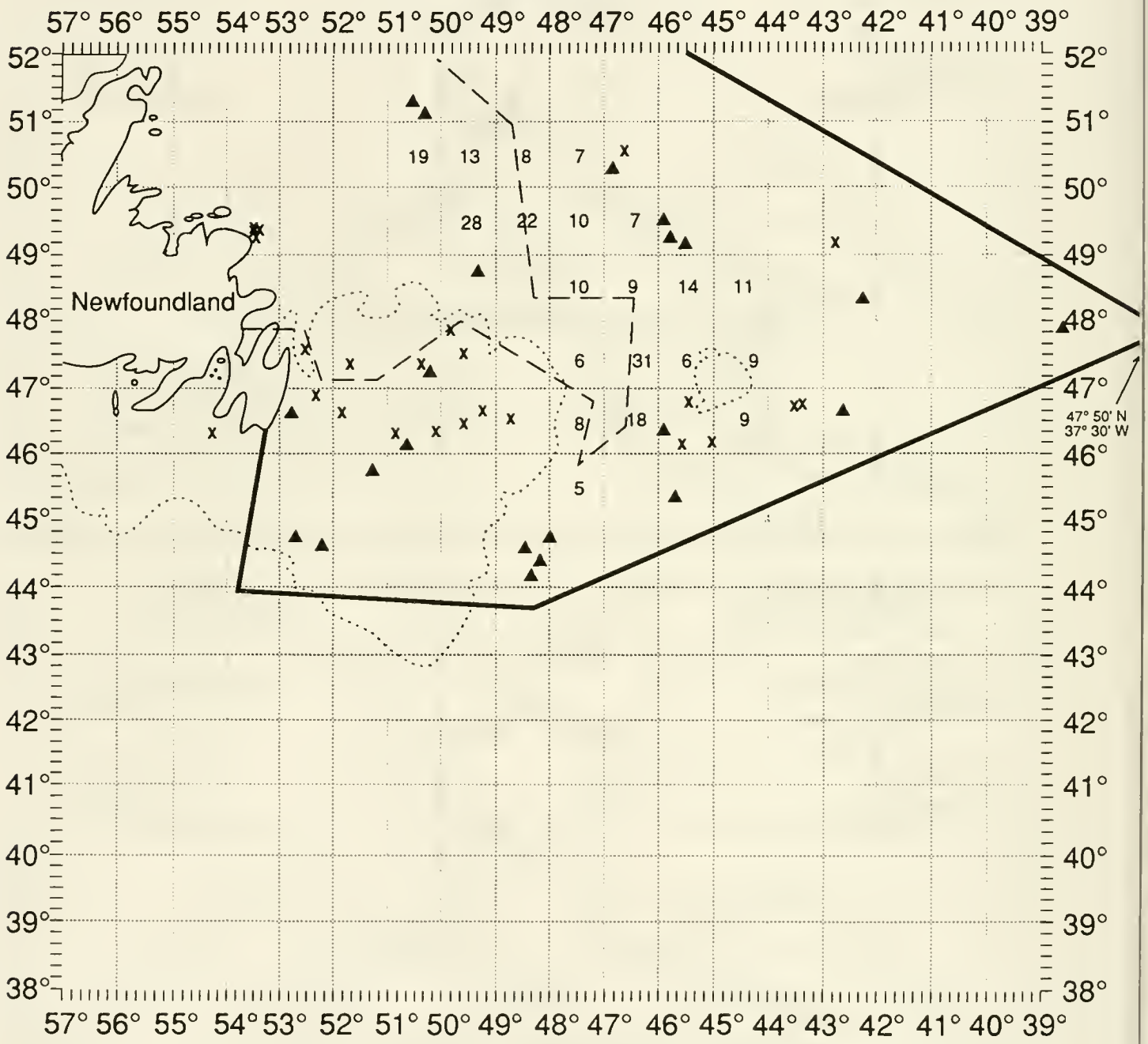


Figure 14

Figure 15

International Ice Patrol Ice Plot for **0000 GMT 02 Feb 93**
Showing Observed and Modeled Iceberg
Positions and Sea Ice Edge



▲ Iceberg
(for squares with fewer than 6 total icebergs)

X Radar Target
(for squares with fewer than 6 total targets)

N Number of Icebergs/Radar Targets
Per One Degree Rectangle
(for squares with 6 or more total targets)

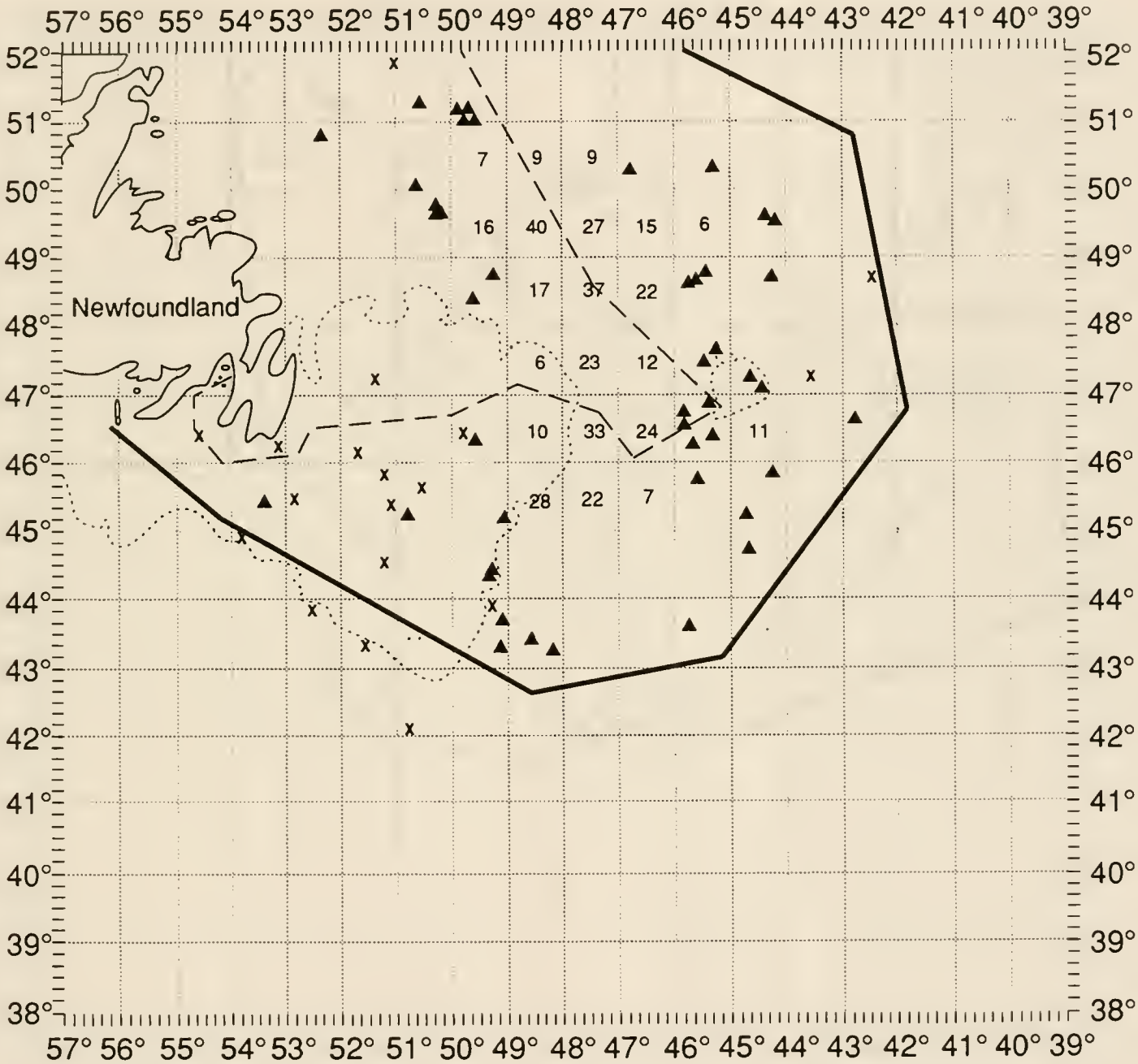
——— Limit of All Known Ice

– – – – Sea Ice Edge

····· 200 Meter Bathymetric Curve

Figure 16

International Ice Patrol Ice Plot for **0000 GMT 17 Feb 93**
Showing Observed and Modeled Iceberg
Positions and Sea Ice Edge



▲ Iceberg
(for squares with fewer than 6 total icebergs)

X Radar Target
(for squares with fewer than 6 total targets)

N Number of Icebergs/Radar Targets
Per One Degree Rectangle
(for squares with 6 or more total targets)

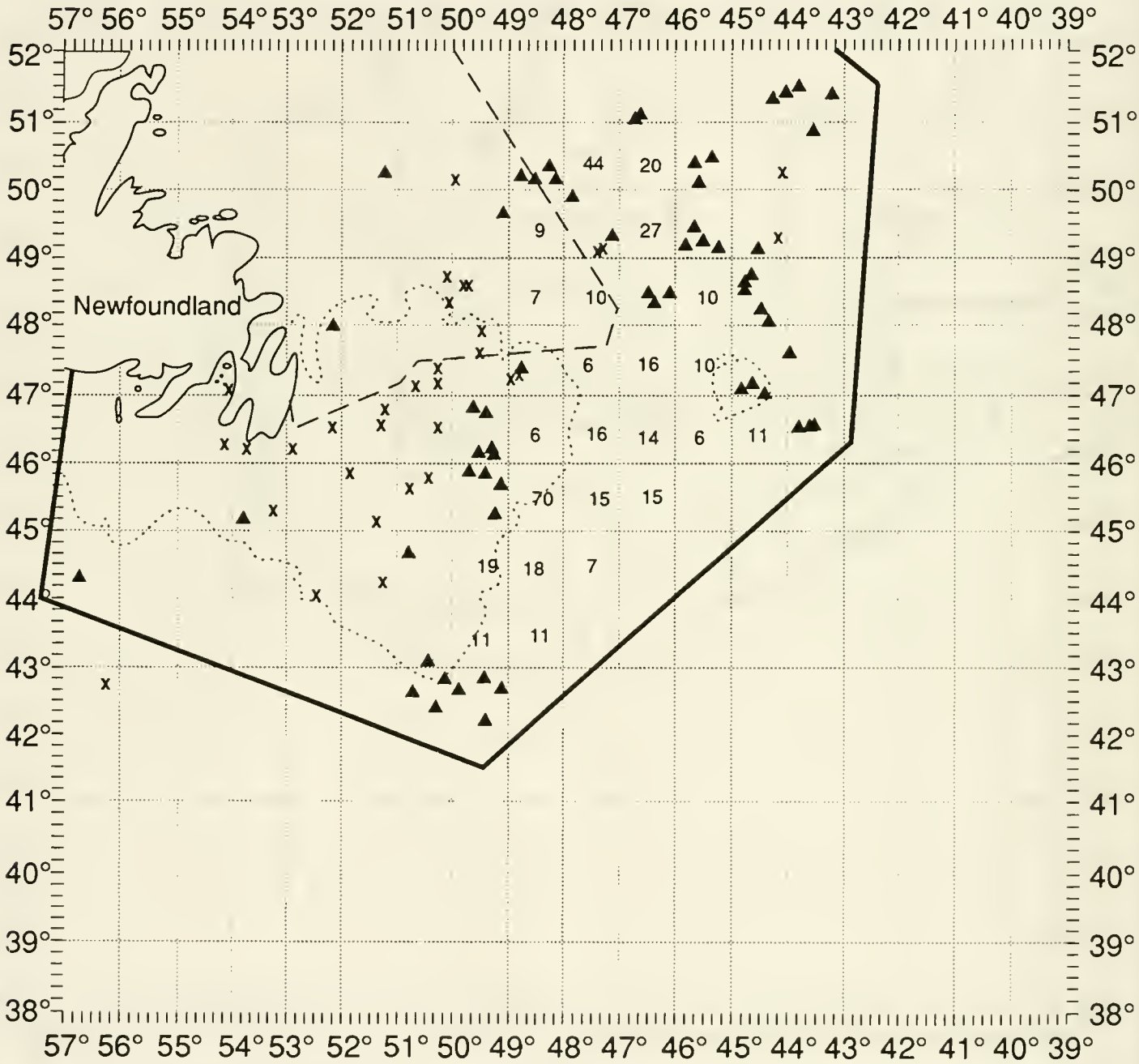
——— Limit of All Known Ice

– – – – Sea Ice Edge

····· 200 Meter Bathymetric Curve

Figure 17

International Ice Patrol Ice Plot for **0000 GMT 02 Mar 93**
Showing Observed and Modeled Iceberg
Positions and Sea Ice Edge



▲ Iceberg
(for squares with fewer than 6 total icebergs)

X Radar Target
(for squares with fewer than 6 total targets)

N Number of Icebergs/Radar Targets
Per One Degree Rectangle
(for squares with 6 or more total targets)

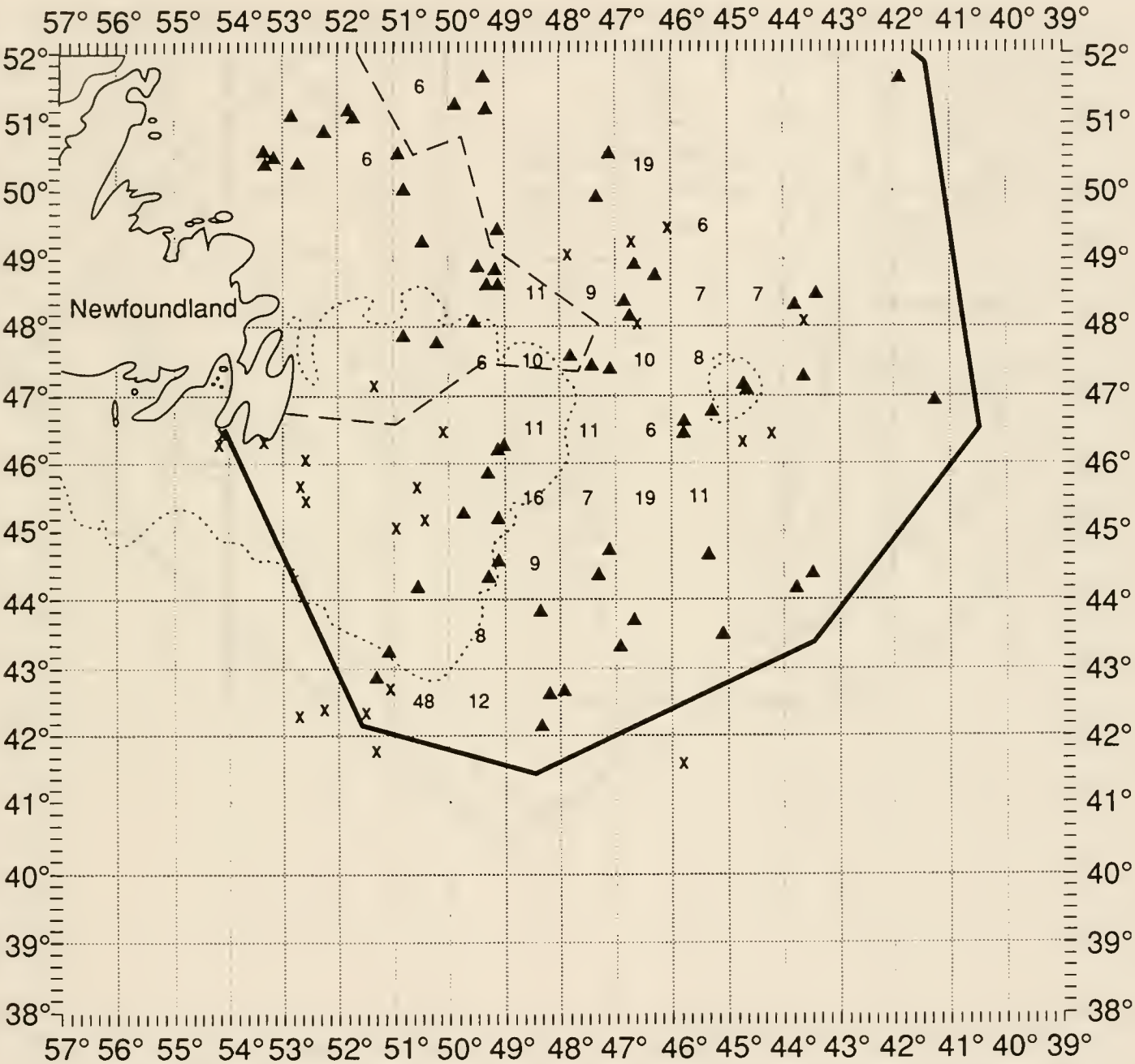
——— Limit of All Known Ice

– – – – Sea Ice Edge

····· 200 Meter Bathymetric Curve

Figure 18

International Ice Patrol Ice Plot for **0000 GMT 17 Mar 93**
Showing Observed and Modeled Iceberg
Positions and Sea Ice Edge



▲ Iceberg
(for squares with fewer than 6 total icebergs)

X Radar Target
(for squares with fewer than 6 total targets)

N Number of Icebergs/Radar Targets Per One Degree Rectangle
(for squares with 6 or more total targets)

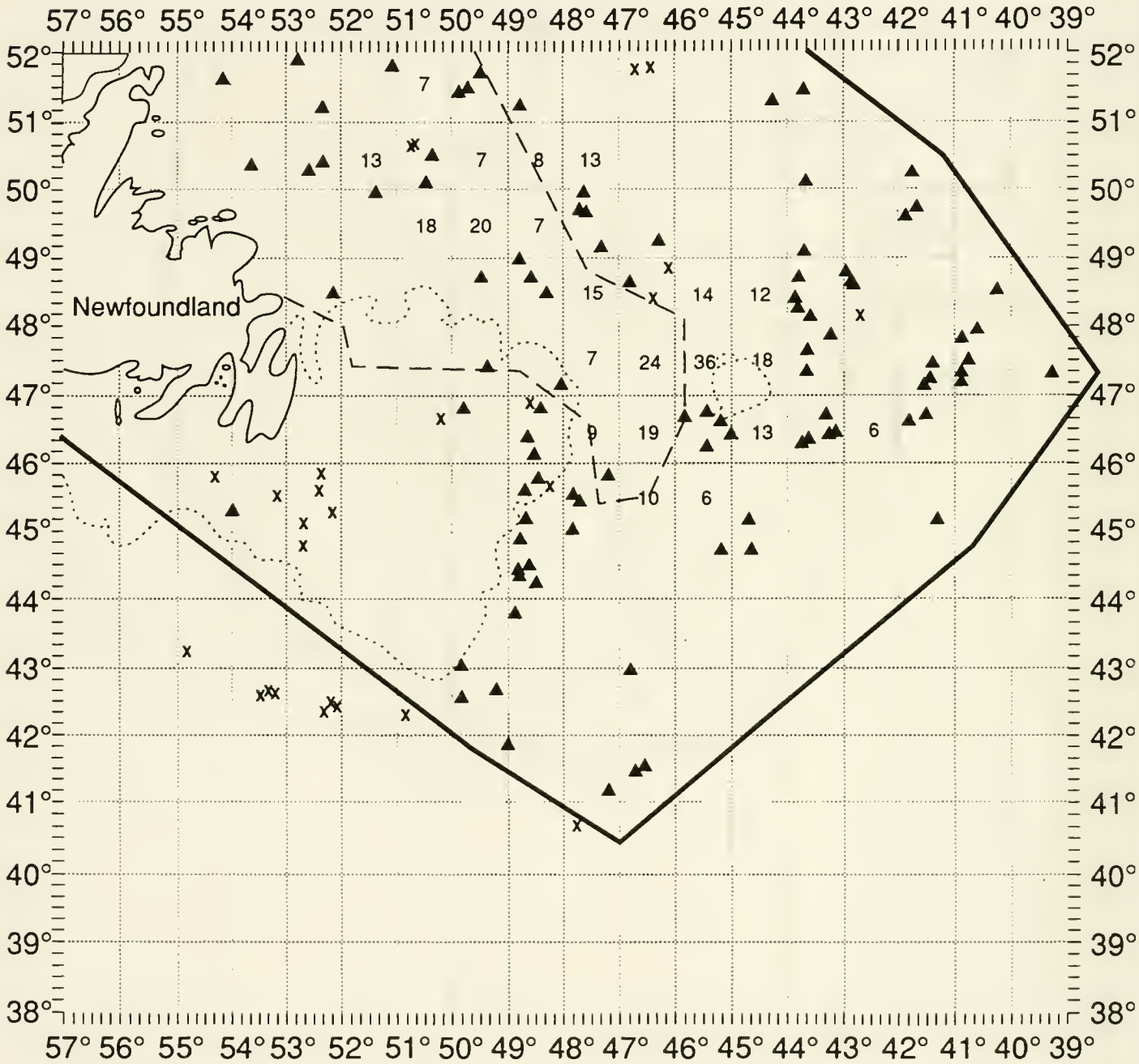
——— Limit of All Known Ice

– – – – Sea Ice Edge

····· 200 Meter Bathymetric Curve

Figure 19

International Ice Patrol Ice Plot for **0000 GMT 31 Mar 93**
Showing Observed and Modeled Iceberg
Positions and Sea Ice Edge



▲ Iceberg
(for squares with fewer than 6 total icebergs)

X Radar Target
(for squares with fewer than 6 total targets)

N Number of Icebergs/Radar Targets
Per One Degree Rectangle
(for squares with 6 or more total targets)

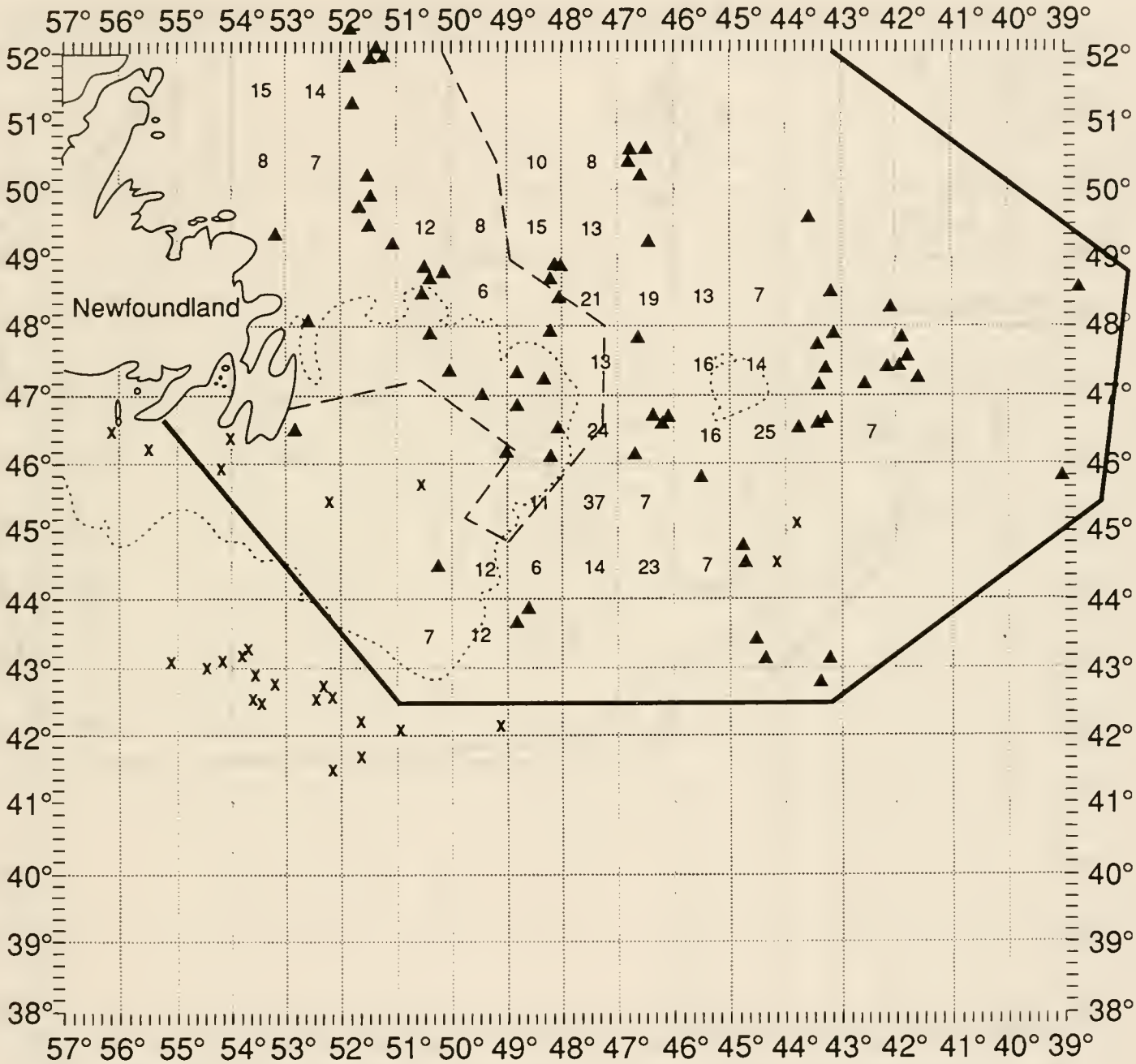
——— Limit of All Known Ice

– – – – Sea Ice Edge

····· 200 Meter Bathymetric Curve

Figure 20

International Ice Patrol Ice Plot for **0000 GMT 15 Apr 93**
Showing Observed and Modeled Iceberg
Positions and Sea Ice Edge



▲ Iceberg
(for squares with fewer than 6 total icebergs)

X Radar Target
(for squares with fewer than 6 total targets)

N Number of Icebergs/Radar Targets
Per One Degree Rectangle
(for squares with 6 or more total targets)

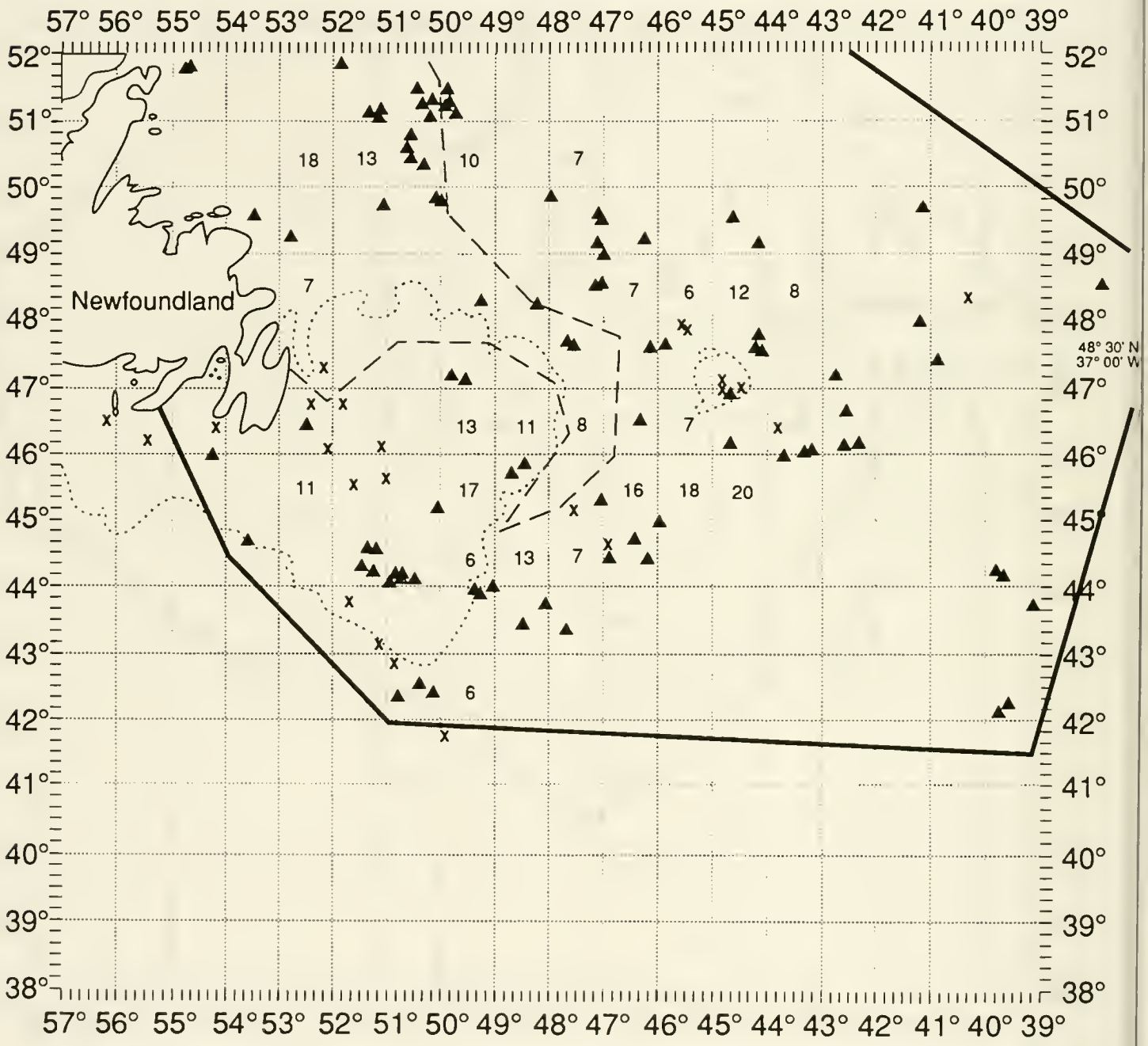
——— Limit of All Known Ice

– – – – Sea Ice Edge

····· 200 Meter Bathymetric Curve

Figure 21

International Ice Patrol Ice Plot for **0000 GMT 30 Apr 93**
Showing Observed and Modeled Iceberg
Positions and Sea Ice Edge



▲ Iceberg
(for squares with fewer than 6 total icebergs)

X Radar Target
(for squares with fewer than 6 total targets)

N Number of Icebergs/Radar Targets Per One Degree Rectangle
(for squares with 6 or more total targets)

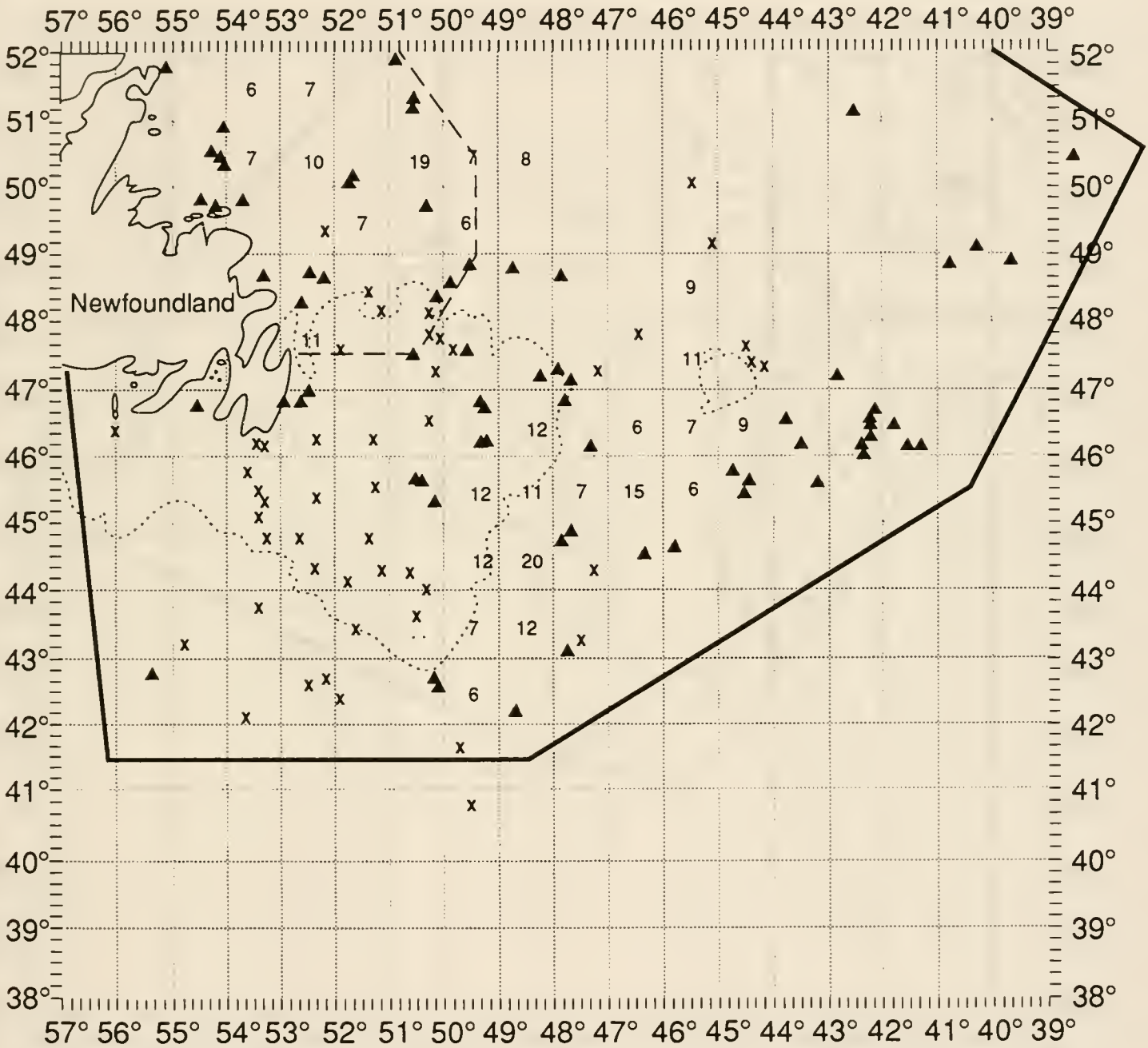
——— Limit of All Known Ice

– – – – Sea Ice Edge

····· 200 Meter Bathymetric Curve

Figure 22

International Ice Patrol Ice Plot for **0000 GMT 15 May 93**
Showing Observed and Modeled Iceberg
Positions and Sea Ice Edge



▲ Iceberg
(for squares with fewer than 6 total icebergs)

X Radar Target
(for squares with fewer than 6 total targets)

N Number of Icebergs/Radar Targets
Per One Degree Rectangle
(for squares with 6 or more total targets)

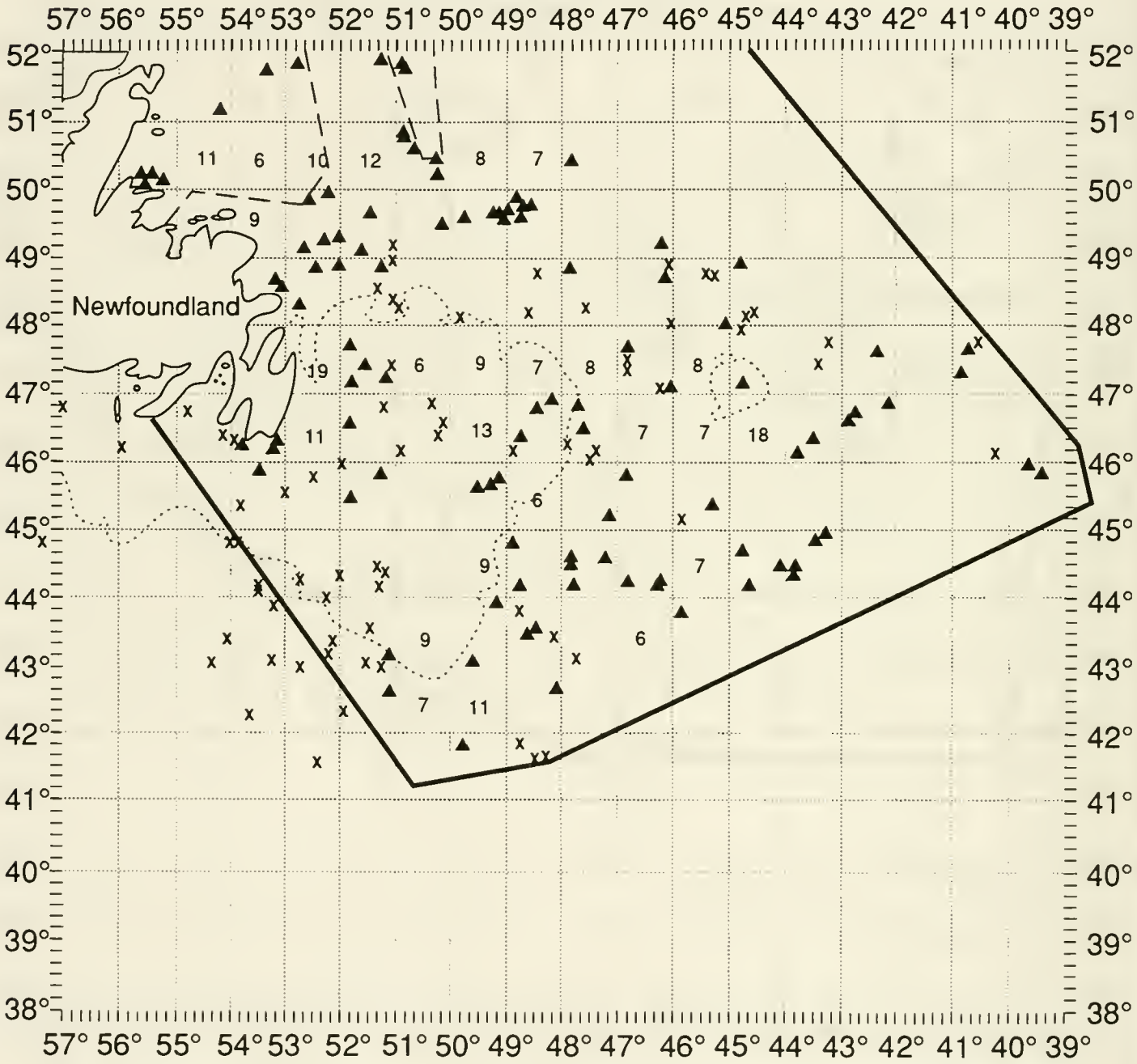
——— Limit of All Known Ice

– – – – Sea Ice Edge

····· 200 Meter Bathymetric Curve

Figure 23

International Ice Patrol Ice Plot for **0000 GMT 31 May 93**
Showing Observed and Modeled Iceberg
Positions and Sea Ice Edge



▲ Iceberg
(for squares with fewer than 6 total icebergs)

X Radar Target
(for squares with fewer than 6 total targets)

N Number of Icebergs/Radar Targets
Per One Degree Rectangle
(for squares with 6 or more total targets)

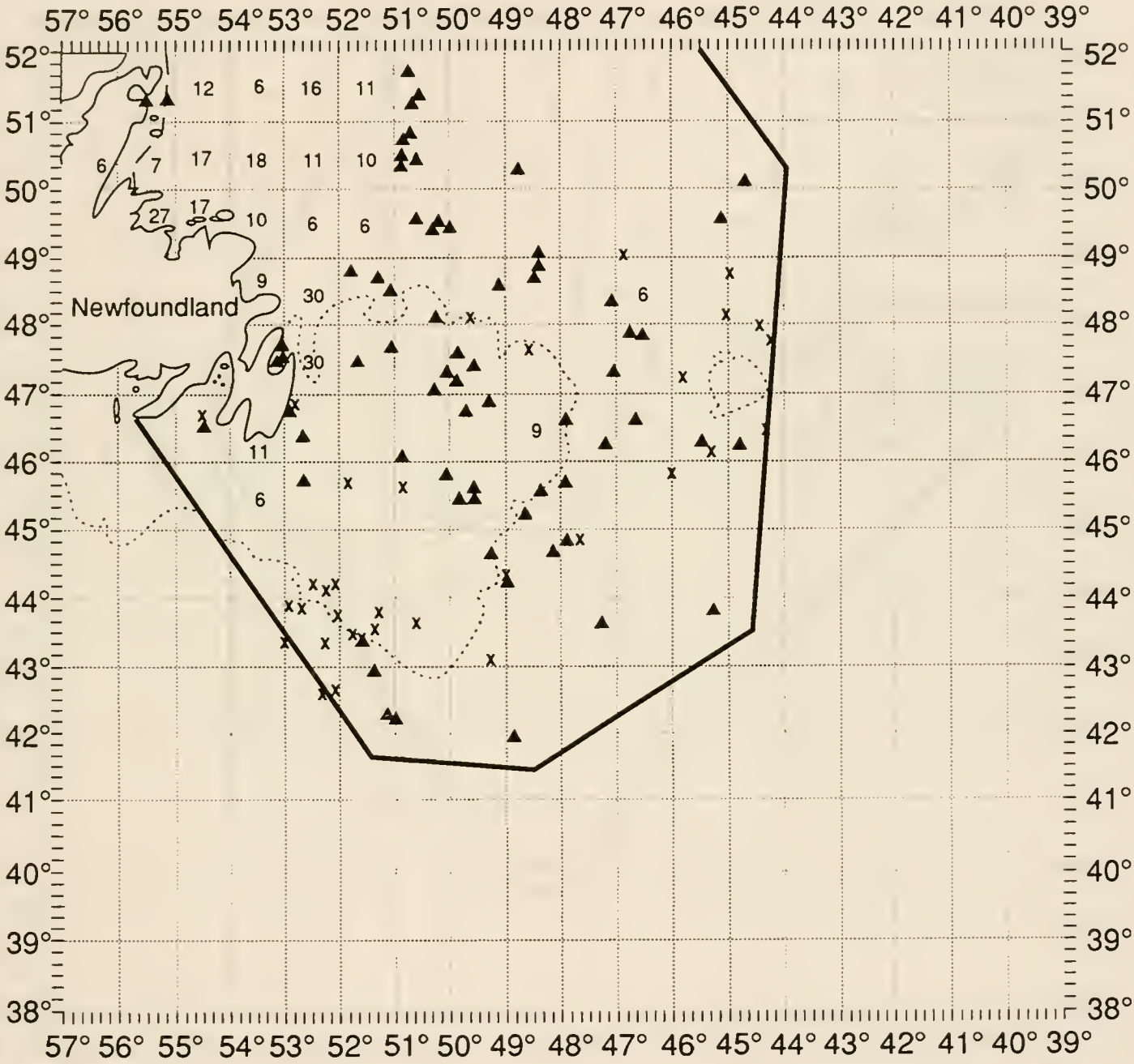
——— Limit of All Known Ice

– – – – Sea Ice Edge

····· 200 Meter Bathymetric Curve

Figure 24

International Ice Patrol Ice Plot for **0000 GMT 15 Jun 93**
Showing Observed and Modeled Iceberg
Positions and Sea Ice Edge



▲ Iceberg
(for squares with fewer than 6 total icebergs)

X Radar Target
(for squares with fewer than 6 total targets)

N Number of Icebergs/Radar Targets Per One Degree Rectangle
(for squares with 6 or more total targets)

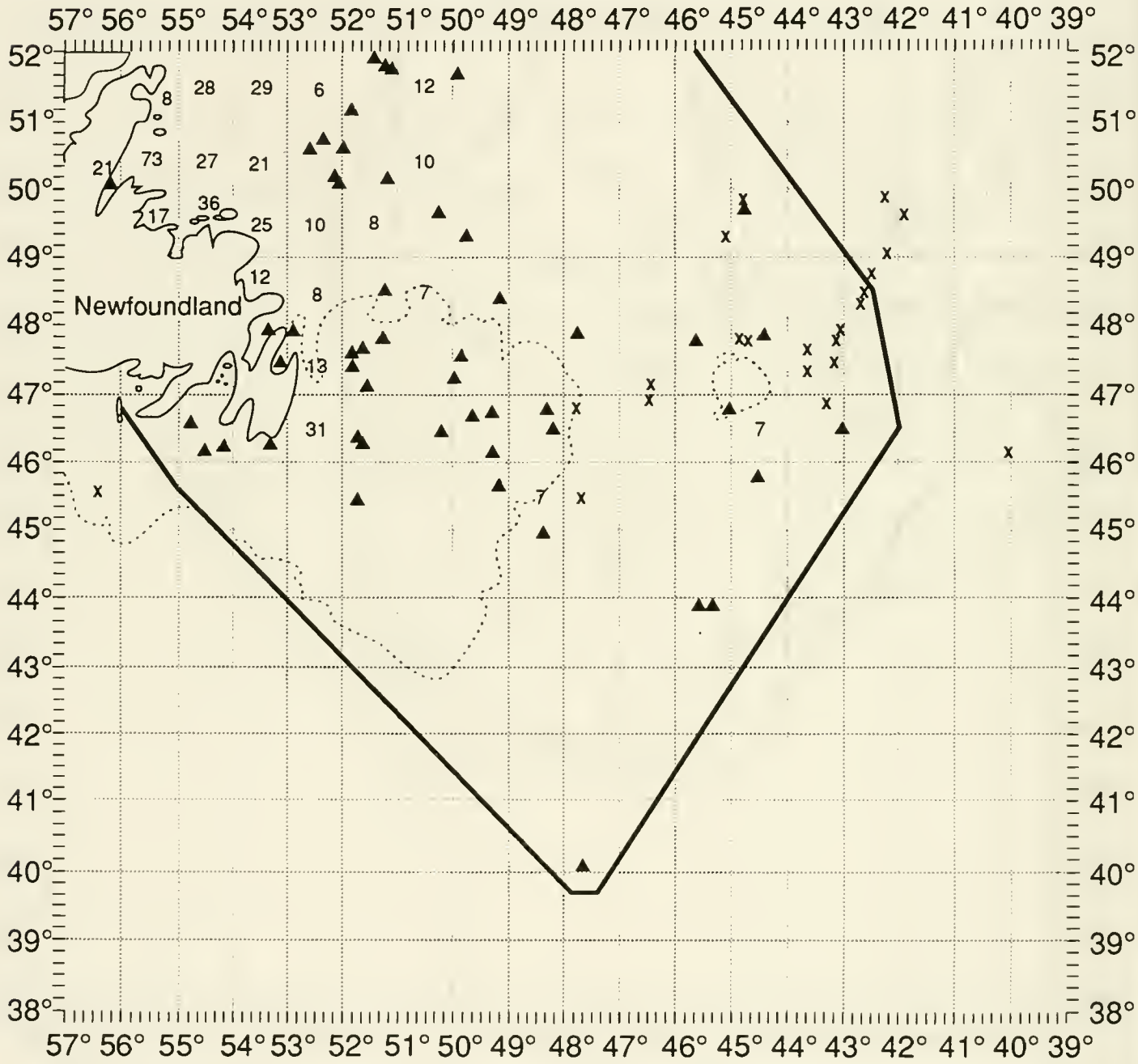
——— Limit of All Known Ice

– – – – Sea Ice Edge

····· 200 Meter Bathymetric Curve

Figure 25

International Ice Patrol Ice Plot for **0000 GMT 30 Jun 93**
Showing Observed and Modeled Iceberg
Positions and Sea Ice Edge



▲ Iceberg
(for squares with fewer than 6 total icebergs)

X Radar Target
(for squares with fewer than 6 total targets)

N Number of Icebergs/Radar Targets
Per One Degree Rectangle
(for squares with 6 or more total targets)

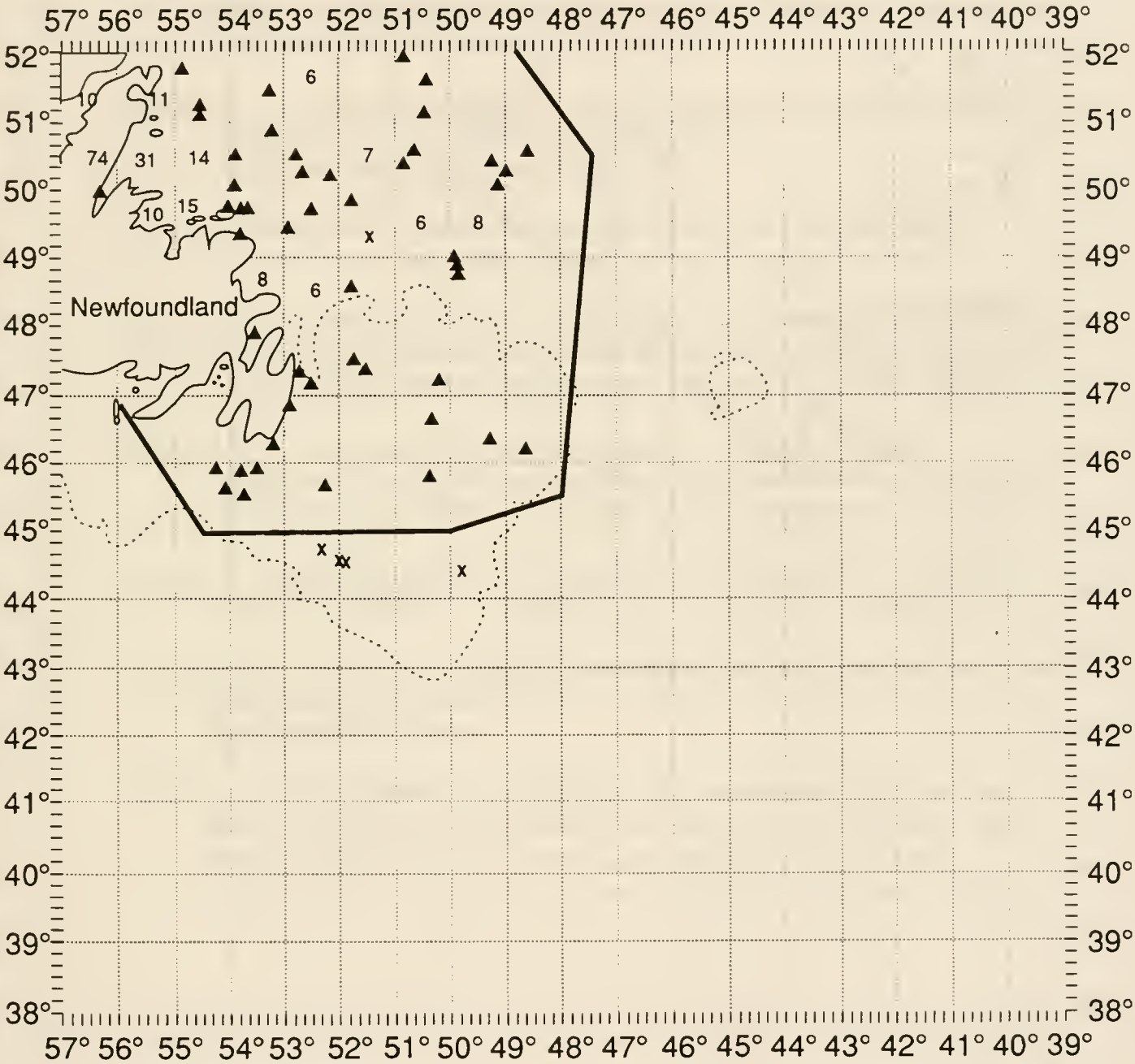
——— Limit of All Known Ice

– – – – Sea Ice Edge

····· 200 Meter Bathymetric Curve

Figure 26

International Ice Patrol Ice Plot for **0000 GMT 15 Jul 93**
Showing Observed and Modeled Iceberg
Positions and Sea Ice Edge



▲ Iceberg
(for squares with fewer than 6 total icebergs)

X Radar Target
(for squares with fewer than 6 total targets)

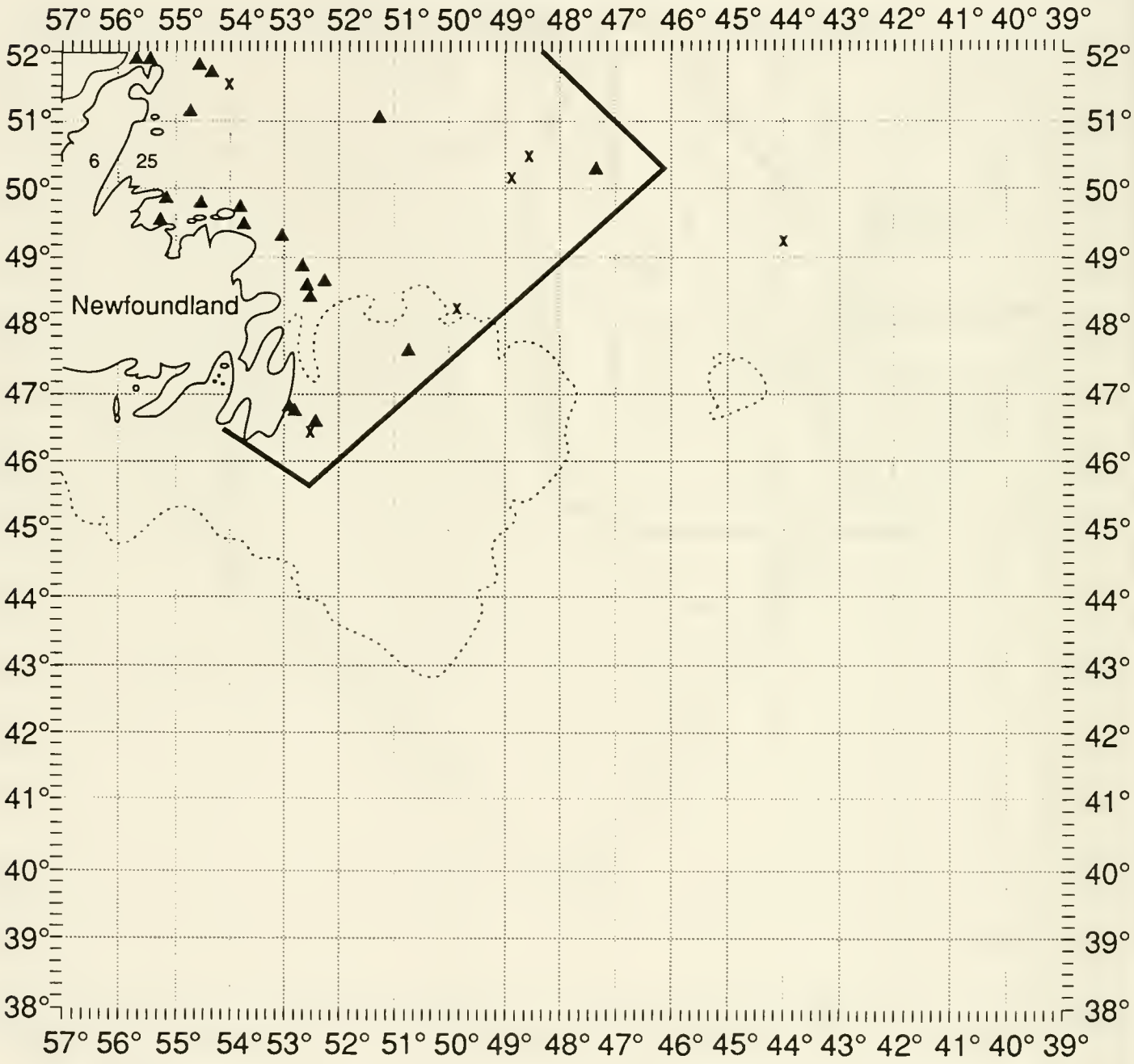
N Number of Icebergs/Radar Targets
Per One Degree Rectangle
(for squares with 6 or more total targets)

——— Limit of All Known Ice

– – – – Sea Ice Edge

····· 200 Meter Bathymetric Curve

Figure 27
International Ice Patrol Ice Plot for **0000 GMT 30 Jul 93**
Showing Observed and Modeled Iceberg
Positions and Sea Ice Edge



▲ Iceberg
(for squares with fewer than 6 total icebergs)

X Radar Target
(for squares with fewer than 6 total targets)

N Number of Icebergs/Radar Targets
Per One Degree Rectangle
(for squares with 6 or more total targets)

——— Limit of All Known Ice

– – – – Sea Ice Edge

····· 200 Meter Bathymetric Curve

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Atmospheric Environment Service of Environment Canada
Department of Fisheries and Oceans
Navy / NOAA Joint Ice Centre
U.S. Naval Fleet Numerical Oceanography Center
U.S. Naval Eastern Oceanography Center
U.S. Coast Guard Research and Development Center
Coast Guard Atlantic Area Staff
First Coast Guard District Communications Center
First Coast Guard District Operations Center

We extend our sincere appreciation to the staffs of these organizations for their excellent support during the 1992 International Ice Patrol season:

Canadian Coast Guard Radio Station St. John's, Newfoundland/VON
Ice Operation St John's, Newfoundland
Air Traffic Control Gander, Newfoundland
Canadian Forces Gander and St John's, Newfoundland
St. John's Weather Offices
U.S. Coast Guard Air Station Elizabeth City
U.S. Coast Guard Air Station Cape Cod
U.S. Coast Guard Communications Station Boston
National Meteorological Center, Maryland

It is also important to recognize the efforts of the personnel at the International Ice Patrol:

CDR A. D. Summy
LCDR I. Anderson
LCDR B. E. Viekman
Dr. D. L. Murphy
Mr. G. F. Wright
LT A. T. Ezman
LT G. A. Trivers
LT R. T. Haines
MSTCS D. R. Kennedy
YN2 C. B. Peters
MST1 P. S. Johnson
MST1 V. L. Fogt
MST1 R. V. Klarmann
MST1 M. W. Bauer
MST1 D. L. Alexander
MST2 C. L. Channel
MST2 W. S. Barton
MST3 J. A. Jordan
MST3 J. F. Cole
MST3 J. T. Sobiesczyk
MST3 B. B. Keating

Appendix A

Nations Currently Supporting International Ice Patrol

BELGIUM	NORWAY
CANADA	PANAMA
DENMARK	POLAND
FINLAND	SPAIN
FRANCE	SWEDEN
GREECE	UNITED KINGDOM
ITALY	UNITED STATES
JAPAN	GERMANY
NETHERLANDS	

Appendix B

Commanders of International Ice Patrol

Year of Command	Name of Commander
1914	CAPT J.H.Quinan
1915 -16	CAPT F.A.Levis
1919	CAPT H.G.Fisher
1920	LCDR O.F.A. DeOtte
1921	CDR A.L. Gambe
1922 - 23	CDR B.M. Chiswell
1924	LCDR W.J. Wheeler
1925 - 26	CDR H.G.Fisher
1927 - 28	CDR W.H. Munter
1929	CDR T.M. Molloy
1930	CAPT C. M. Gabbett
1931	LCDR N.G. Ricketts
1932	CAPT W.T. Stromberg
1933	LT R.M. Hoyle
1934	CDR W. J. Keester
1935	CDR E.D. Jones
1936	CDR R.L.Lucas
1937	CDR G.W. MacLane
1938	CDR C.H. Dench
1939 - 40	CDR E. H. Smith
1941	CDR P.K.Perry
1942 - 43	LCDR C.A. Barnes
1944 - 45	LT E.R. Challender
1946 - 47	Commodore L.W. Perkins
1948	CAPT D.G. Jacobs
1949	CAPT J.F. Jacot
1950	CAPT J.A. Glynn
1951 - 54	CAPT G. Van A. Graves
1955 - 58	CAPT K.S. Davis
1959	CAPT V.F. Tydlacka
1960 - 62	CAPT R.P. Bullard
1963	CAPT J. E. Richey
1964	CDR G. O. Thompson
1965-66	CAPT R. L. Fuller
1967-68	CDR J. E. Murray
1969-70	CDR J. R. Kelley
1971-73	CAPT E. A. Delaney
1974-77	CDR A. D. Super
1978	CAPT T. C. Volkle
1979-80	CDR J. C. Bacon
1981-83	CDR J. J. McClelland, Jr.
1983	LCDR A. D. Summy
*1983-86	CDR N. C. Edwards, Jr.
1987-89	CDR S. R. Osmer
1989-92	CDR J. J. Murray
1992 to present	CDR A.D. Summy

* International Ice Patrol first became a distinct command in October, 1983. Thus, CDR N. C. Edwards, Jr. was the first Commander, International Ice Patrol after it became an independent unit. Those prior to 1984 were senior International Ice Patrol officers serving on the staff of Commander, Atlantic Area.

Appendix C

Ship Reports

Ship Name	Ship Flag	Ice Report	SST* Report
AALSMEERGRACHT	NETHERLANDS	1	
ABBEY	HONG KONG	1	
ABITIBI CLAIBORNE	GERMANY	3	
ABITIBI MACADO	LIBERIA	1	
ABITIBI ORINOCO	UNKNOWN	1	
ADA GORTHON	BAHAMAS	3	
ADALYA	CENTRAL AFRICAN REP	1	
ADONIS	PANAMA	2	
ADRIATIC DYVI	NORWAY	1	
AFRICAN REEFER	DENMARK	1	
A. G. FARQUHARSON	CANADA	5	
AIVIK	CANADA	2	
ALANDIA BREEZE	BAHAMAS	2	2
ALANDIA PEARL	BAHAMAS	1	
ALEKSANDER ABERG	RUSSIA	3	
ALEXANDER GRACHT	NETHERLANDS	2	
ALMANAMA	LIBERIA	1	
AMBRA FIN	NORWAY	1	
AMELIA DESGAGNES	CANADA	3	
AMICA	NORWAY	2	2
AMORGOS	GREECE	1	
ANGLIA	ANTIGUA-BARBUDA	9	2
APJ SUSHMA	INDIA	2	1
APPLEBY	BAHAMAS	3	
ARABIAN SEA	PANAMA	1	
ARCTIC	CANADA	3	
ARINA ARCTICA	DENMARK	2	
ATLANTIC BREEZE	JAPAN	1	
ATLANTIC CARRIER	FRANCE	1	
ATLANTIC COMPASS	SWEDEN	2	
ATLANTIC CONVEYOR	UNITED KINGDOM	2	
ATLANTIC PURSUIT	CANADA	5	
BAKENGRACHT	NETHERLANDS	1	1
BALTIC SUN	NETHERLANDS	2	
BAMIA	PANAMA	5	
BCM ATLANTIC	CANADA	1	
BEURSGRACHT	NETHERLANDS	2	1
BAIA DE ARAMA	ROMANIA	9	9
BIJIN	VANUATU	1	
BILICE	MALTA	1	
BIOKOVO	UNKNOWN	2	

* Sea Surface Temperature

Ship Name	Ship Flag	Ice Report	SST* Report
BISCHOFSTOR	CYPRUS	1	
BITTERSWEET	UNITED STATES	7	3
BONA FREIGHTER	NORWAY	1	
BONN EXPRESS	GERMANY	2	
BOW LANCER	NORWAY	1	
BRUSSEL	LUXEMBOURG	1	
CABOT	CANADA	1	
CAMILLA	FINLAND	18	5
CANMAR AMBASSADOR	BERMUDA	7	
CANMAR EUROPE	UNITED KINGDOM	5	
CANMAR TRIUMPH	HONG KONG	4	
CANMAR VENTURE	HONG KONG	3	
CANMAR VICTORY	ISLE OF MAN	13	
CAPE DAWN	SWEDEN	1	
CAPE ROGER	CANADA	1	
CASPIAN TRADER	LIBERIA	1	3
CAST BEAVER	MALTA	6	2
CAST HUSKY	BAHAMAS	1	
CAST MUSKOX	BAHAMAS	41	39
CAST OTTER	BAHAMAS	1	
CAST POLAR BEAR	BAHAMAS	11	7
CASTILLO DE LORCA	SPAIN	1	
CASTILLO DE QUERMENSO	BAHAMAS	1	
CHFU	UNKNOWN	1	
CHIMO	NORWAY	1	
CLEMENT	BAHAMAS	1	
CMB PLANTIN	LUXEMBOURG	1	
COMPANION EXPRESS	SWEDEN	2	
CONCORD	LIBERIA	1	
CONNY	LIBERIA	1	
CORNELIAN	PANAMA	1	1
CORNER BROOK	LIBERIA	9	
CROJER	UNKNOWN	2	
CRYSTAL B	CYPRUS	1	
CYPRESS PASS	LIBERIA	1	
DAGHILD	BAHAMAS	10	
DAISHOWA	UNKNOWN	1	
DANILA	LIBERIA	1	12
DEGERO	FINLAND	3	3
DES GROSEILLIERS	CANADA	2	
DIANA	LIBERIA	3	
DIMITRIS	GREECE	10	
DOCETAURUS	BRAZIL	1	
DONAU	LIBERIA	4	
DONETSKIY KOMSOMOLETS	RUSSIA	1	

* Sea Surface Temperature

Ship Name	Ship Flag	Ice Report	SST* Report
EIRNI L	GREECE	2	
EL PIONERO	COLOMBIA	3	
ELLEN KNUTSEN	NORWAY	1	
ENDEAVOR	HONG KONG	1	
ENSOR	LUXEMBOURG	1	
ERATO II	CYPRUS	3	
ETERNITY	SINGAPORE	1	
EVERGRAND	PANAMA	1	
EVPO AGEOS	PANAMA	1	
FAUST	UNITED STATES	3	2
FEDERAL AGNO	PHILIPPINES	2	
FEDERAL DANUBE	CYPRUS	31	
FEDERAL FRASER	PHILIPPINES	4	
FEDERAL MACKENZIE	PHILIPPINES	2	
FEDERAL MAAS	CYPRUS	11	
FEDERAL MATANE	NORWAY	3	
FEDERAL OTTAWA	LUXEMBOURG	15	14
FEDERAL POLARIS	LIBERIA	2	
FEDERAL SAGUENAY	LIBERIA	1	2
FEDERAL THAMES	CYPRUS	4	
FINNFIGHTER	CANADA	2	
FJORD LAND	PANAMA	2	
FOSNA	NORWAY	1	
FRIO BREMEN	CYPRUS	2	
GADUS ATLANTICA	CANADA	1	
GALLANT TIGER	HONG KONG	1	
GALLATIN	UNITED STATES	19	
HMCS GATINEAU	UNKNOWN	1	1
GENERAL CABEL	PHILIPPINES	3	
GENERAL MADALINSKI	POLAND	5	
GERDT OLDENDORFF	LIBERIA	1	
GIOVANNI GRIMALDI	ITALY	2	2
GLETCHER	FINLAND	1	
GLOBE TRADER	LIBERIA	2	
GLUECKSBURG	GERMANY	2	
GUINOMAR TRADER	LIBERIA	4	
HARCOURT KENT	CANADA	2	
HARMONY STOVE	NORWAY	2	
CCGC HARP	CANADA	9	
HAVFALK	NORWAY	2	
HEIDELBERG EXPRESS	GERMANY	1	
HELENA OLDENDORFF	PANAMA	1	
HELICE	NORWAY	14	1
HIKU	FINLAND	1	
H. ISAKSSON SELNES	UNKNOWN	4	

* Sea Surface Temperature

Ship Name	Ship Flag	Ice Report	SST* Report
HITE SEA	UNKNOWN	1	
HOFSJOKULL	ICELAND	11	1
HOUTMANGRACHT	NETHERLANDS	2	2
HUBERT GAUCHER	CANADA	5	
HUDSON	CANADA	6	
HUMBER ARM	LIBERIA	3	
IBN AL-ROOMI	SAUDI ARABIA	1	
ICELAND REX	PANAMA	1	
ICE PEARL	DENMARK	1	
IMPERIAL ACADIA	CANADA	1	
IMPERIAL BEDFORD	CANADA	2	
INGRID GORTHON	BAHAMAS	3	
IRONBRIDGE	HONG KONG	3	
IRVING ARCTIC	CANADA	11	
IVIK	UNKNOWN	1	
IZURZA	PORTUGAL	2	
JIN TIANHIA	CHINA	1	
JOH GORTHON	BAHAMAS	1	
JOHN C. HELMSING	CYPRUS	4	
KAIROS	UNKNOWN	1	
KANDALAKSHAI	RUSSIA	1	
USNS KANE	UNITED STATES	2	
KAPITAN TKACHENKO	LIBERIA	1	
KAPITONAS GUDIN	RUSSIA	5	
KAPRELA	ARGENTINA	2	
KAVO MIKA	CYPRUS	1	
KHUDOZHNIK PAKHOMOV	RUSSIA	6	
KHUDOZHNIK REPIN	RUSSIA	19	
KIELGRACHT	NETHERLANDS	5	
KISTS ARTICA	UNKNOWN	1	
KLOSTER	CANADA	1	
KONTULA	FINLAND	1	
KRISTJAN PARLUSALU	RUSSIA	2	
L' ROCHETTE	CANADA	3	
LA FRENAIS	FRENCH ANTARCTIC TER	2	
LA RICHARDAIS	FRANCE	1	
LAKE CHAMPLAIN	UNKNOWN	1	
LAKE TAHOE	UNKNOWN	2	
LARINA	NORWAY	4	
LE CHENE 1	CANADA	5	
LIBERTY BELL VENTURE	LIBERIA	2	
LIPNO	CZECHOSLOVAKIA	1	
LISTEVEN	CANADA	1	
LITTLE JESSIE	UNKNOWN	1	
LOTILA	BAHAMAS	1	

* Sea Surface Temperature

Ship Name	Ship Flag	Ice Report	SST* Report
LOTILA	FINLAND	1	
LT ARGOSY	INDIA	1	
LULU	NORWAY	1	
MAC WARRIOR	CYPRUS	1	
MAKKA ARCTICA	DENMARK	1	
MALIK 2	NEW HEBRIDES	4	
MANDO V	GREECE	2	8
MANGAL DESAI	INDIA	1	
MARGIT GORTHON	BAHAMAS	1	1
MARIA ANGELICOUSSI	GREECE	1	
MARIA GORTHON	BAHAMAS	1	
MARIA LAURA	LIBERIA	1	
MARIANNA	UNKNOWN	1	
MARIA TOPIC	LIBERIA	2	2
MARY STOVE	NORWAY	1	
MAURICE EWING	MEXICO	2	
MC AMETHYST	BAHAMAS	3	1
MED SKY	NETHERLANDS ANTILLES	1	
MERIC	TURKEY	1	
METTE MAERSK	DENMARK	2	
MLJET	MALTA	2	
MONALINDA	PHILIPPINES	1	
MSC FEDERICA	PANAMA	2	
NADEZHDA OBUKHOVA	RUSSIA	3	
NARA	UNKNOWN	2	
NEPTUNE JADE	SINGAPORE	1	
NEPTUNE ORION	SINGAPORE	1	
NEWFOUNDLAND KESTREL	CANADA	1	
NEWFOUNDLAND TRADITION	CANADA	1	
HMCS NIPIGON	CANADA	11	
NOMADIC POLLUX	NORWAY	3	
NORTHERN PRINCESS	CANADA	1	
NS GOLOVANOV	RUSSIA	3	
OCEAN CASTLE	DENMARK	1	
OCEAN QUELL	CANADA	1	
OHYOH	PANAMA	1	
OLEMAR	CYPRUS	3	
OLYMPIC MIRACLE	GREECE	1	
OOCL ASSURANCE	HONG KONG	9	
OOCL BRAVERY	HONG KONG	3	
OOCL CHALLENGE	HONG KONG	2	
ORAGREEN	BAHAMAS	1	
ORIENT SEA	UNKNOWN	1	
OZERNITSA	RUSSIA	1	
PARIS	CYPRUS	6	

* Sea Surface Temperature

Ship Name	Ship Flag	Ice Report	SST* Report
PARIZEAU	CANADA	5	
PASSAT-2	RUSSIA	1	
PAUL BUCK	UNITED STATES	2	
PAVLOVSK	RUSSIA	1	
PETRAKI	CYPRUS	5	
POLAR SEA	UNITED STATES	1	
POLBALTIC	GREECE	3	
PORTLAND CARRIER	CANADA	1	
PRIMA VENTURE L	GREECE	1	
PRIME TRADER	MALTA	1	
PRODUCT SPLENDOR	HONG KONG	4	
PROFESSOR RYLKE	POLAND	1	
RED ROSE	CYPRUS	1	
REXTON KENT	CANADA	2	
RISNES	UNITED KINGDOM	1	
RIXTA OLDENDORFF	HONG KONG	2	
ROMO MAERSK	DENMARK	2	
ROYAL MARINER	CANADA	2	
ROYAL PRINCESS	UNITED KINGDOM	1	
RUS	RUSSIA	1	
SAGA OCEAN	NORWAY	1	
SAN LORENZO	UNITED KINGDOM	2	
SAQQARA	EGYPT	2	
SEA-LAND QUALITY	UNITED STATES	1	
SELNES	CYPRUS	1	
SIR HUMPHREY GILBERT	CANADA	3	
SIR JOHN FRANKLIN	CANADA	2	
SIR WILFRED GRENFELL	CANADA	1	
SKAUKAR	LIBERIA	3	
SKOGAFOSS	ANTIGUA-BARBUDA	3	
SKRIM	PANAMA	2	
SOLIN	YUGOSLAVIA	1	
SOLIN	MALTA	1	
ST. PETERSBERG SENATOR	UNITED STATES	1	
STANWICH	LIBERIA	1	
STAR	GERMANY	2	
STAR EVVIVA	NORWAY	1	
STAR LORRAINE	NETHERLANDS	1	
STAR OHIO	LIBERIA	1	1
STATE OF GUJARAT	INDIA	5	
STOLT ASPIRATION	PANAMA	1	
STORON	SWEDEN	4	
STRONG ICELANDER	UNITED STATES	8	
SYBIL W.	CANADA	1	
SYN PULKU	POLAND	43	72

* Sea Surface Temperature

Ship Name	Ship Flag	Ice Report	SST* Report
TAIKO	UNKNOWN	1	
TANGLAP	PANAMA	2	1
TEMPERA	FINLAND	1	
TEXAS	NORWAY	1	
THIRD WING	MEXICO	2	
THIS PEACOCK	PANAMA	1	
TIMOFY GORNOV	RUSSIA	2	
TIMONEER	GREAT BRITIAN	2	
TINGANES	BAHAMAS	1	7
TOBA	ARGENTINA	1	
TOL TRADER	NORWAY	1	1
TRANS SCANDIC	NORWAY	2	
TROMSO CHALLENGER	LIBERIA	1	
TURID KNUSTEN	NORWAY	2	
URSULA LEONHARDT	SINGAPORE	1	
VANRI	PHILIPPINES	1	
VARDEN	NORWAY	1	1
VARJAKKA	BAHAMAS	1	
VIGOSTONE	BAHAMAS	1	
VILJANDI	ESTONIA	1	
VINGA POLARIS	SWEDEN	1	
VITIN	FAEROES	2	
VULCAN	CYPRUS	1	
WAH SHAN	CHINA	9	
WILFRED TEMPLEMAN	CANADA	3	
WLADYSLAW SIKORSKI	POLAND	1	
YANKCANUCK	CANADA	1	
YEOMAN BURN	LIBERIA	1	
YEYSKIV LIMAN	RUSSIA	2	
ZAFIRO	MALTA	3	3
ZIEMIA CIESZYNSKA	POLAND	2	
ZIEMIA SUWALSKA	POLAND	1	
ZIEMIA ZAMOJSKA	POLAND	2	1

TOTAL ICE REPORTS 837

TOTAL SST REPORTS 278

* Sea Surface Temperature

Appendix D

International Ice Patrol's Iceberg Sighting DataBase 1960-1991

Iain Anderson

Introduction

International Ice Patrol has been actively collecting iceberg data in the vicinity of the Grand Banks of Newfoundland and off the coasts of Labrador and Greenland since 1913. This paper concentrates on the period from 1960 to present. The objectives of this paper are to describe the iceberg sighting data for the period 1960 to the present, describe how the data was collected, the limitations of the data set, and what the data set represents.

In 1984, Ice Patrol placed all available historical iceberg sighting information from the original paper records into a computerized format. The data covered the period from 1960 to 1982. The original sighting information from the period prior to 1960 was no longer available. Summaries of the sighting information prior to 1960 is contained in the International Ice Patrol bulletins (Älfultis, 1987).

For example, recently the scientific community has shown a renewed interest in the International Ice Patrol's iceberg sighting data base. This interest has been spurred by the growing research into global warming and a renewed interest in hydrocarbon production off the Grand Banks of Newfoundland. Marko et al. (1991) and Davidson, et al. (1986) have used the Ice Patrol data base as part of their research. There have also been numerous efforts to predict the severity of the seasonal variations of icebergs off Newfoundland (Examples: Schell (1961), Ebbesmeyer, et al. (1980), Davidson, et al. (1986), and Walsh (1986)). The cautious reader might consider a review of Kinsman (1957) before applying the Ice Patrol database to another geophysical problem.

The above studies have all used the Ice Patrol data as the basis of their studies, but there is a weak recognition of the subjectivity of the Ice Patrol data set. Few authors have considered the importance of the subjectivity, the implications of changing technology, or most importantly, the nature of the Ice Patrol mission itself. Although Davidson, et al. (1986) have more appreciation than most of the complexity of the data set, even they do not consider the significance of the nature of the IIP mission itself.

The International Ice Patrol Mission

The U.S. Coast Guard conducts the International Ice Patrol Service in the North Atlantic under the provisions of U.S. Code, Title 46, Sections 738, 738a through 738d, and the International Convention for the Safety of Life at Sea (SOLAS), 1974, regulations 5 through 8. The above stipulate that the International Ice Patrol Service be maintained "during the whole ice season in guarding the southeastern, southern, and southwestern limits of the region of icebergs in the vicinity of the Grand Banks of Newfoundland, and the patrol shall inform trans-Atlantic and other passing vessels by radio and such other means as are available of the ice conditions and the extent of the dangerous region."

The philosophy of Ice Patrol aerial reconnaissance to accomplish the mandated mission was described in the 1960 Ice Patrol Bulletin. The philosophy as stated then and repeated below holds true for the entire period covered by this paper. " Search areas are determined by the degree and reliability of available ice information over the Grand Banks, prevailing weather conditions of wind, sea, and visibility, and the activity of the Labrador Current. The primary objective (of Ice Patrol's aerial reconnaissance) is to maintain accurate information concerning the southwest, southern, and southeastern limits of the ice. A secondary objective is to fix the location of as much of the ice within the limits as is consistent with the accomplishment of the primary objective."

Using the above philosophy as the basis of accomplishing its mission, Ice Patrol does not and has never attempted to conduct a complete census of the icebergs or survey the whole of the Grand Banks for icebergs. The presence or absence of icebergs in areas removed from the extreme limits of the region of iceberg danger does not affect the performance of the Ice Patrol mission. Generally, areas of the Grand Banks removed from the limits of iceberg danger can have significant concentrations of icebergs and because of the nature of the mission, the icebergs located there may not be included in the data set.

Iceberg Data Collection

The traditional measure of an iceberg season's severity is the estimate of the number of icebergs drifting south of latitude 48 North. The methods used to collect and analyze the data has changed over the years. In addition to changes in methods, a variety of factors affect the accuracy of the estimate published each year. These include the use of numerical models, the severity of the season itself, reconnaissance techniques and technological advancements, subjectivity caused by change in personnel, and navigation accuracy. A summary of the technological changes is included in Attachment 1. These factors will be discussed in more detail below.

The reason for selecting 48 North as the boundary at which to begin counting icebergs is tied to the great circle shipping routes from Europe to America. The great circle route from the English Channel to New York would pass through the island of Newfoundland so the routes used had a turn point off Cape Race, the southern point of Newfoundland. Cape Race is located at about 46 degrees 35 minutes North. Early reports of the International Ice Patrol Service (prior to 1926) refer to icebergs south of Newfoundland. Mecking (1907) collected data from U.S. Signal Service, U.S. Hydrographic Office and the Deutsche Seewarte (the German Hydrographic Office) and published the first estimate of icebergs for the period 1880 to 1897. Smith (1926) continued the analysis and published the estimate of icebergs for the period 1898 to 1926 and used the 48th parallel as the northern point of his analysis. IIP has published the yearly estimate of icebergs drifting south of 48 North in the annual Reports of International Ice Patrol Service ever since (Figure 1).

Presently, International Ice Patrol does not include sighting reports of growlers or radar targets in the estimate of the number of icebergs drifting south of 48 North. Radar target reports (targets which cannot be identified) come from a variety of sources including ships and aircraft. Therefore, this paper does not include radar targets or growlers as part of the discussion.

General

The present Ice Patrol operations area is bounded by the area 40 to 52 North and 57 to 39 West (Figure 2). Ice Patrol's statutory mandate requires Ice Patrol to define the limits of the dangerous region, not survey the entire area where icebergs might exist. Ketchen (1977) provides a synopsis of icebergs sighted well outside of the Ice Patrol operations area. Although these are dramatic sightings because of their extraordinary location, they represent only a small fraction of the icebergs seen in most years.

The area encompassed by the limit of the iceberg danger fluctuates on a season to season basis and also within a season. Traditionally, the portion of the Ice Patrol operations area enclosed by the limit of iceberg danger is largest during the months of April through June within each season. There have been seasons where the area of iceberg danger has extended south of 40 North, the southern border of Ice Patrol's normal operations area. When this occurs, Ice Patrol's reconnaissance efforts are concentrated in the southern area because Ice Patrol is not able to use the available model to predict the movement of icebergs in this area. This last occurred in 1989.

The available reconnaissance flights are first used to fly the edge of the area of iceberg danger (where the iceberg concentration is low) to accurately define the limits of iceberg danger. The more available flight time spent in transit to reach extended limits, means proportionally less of the limit of iceberg danger that can be covered per flight. Therefore,

Figure 1
Annual Counts of Icebergs Crossing 48° North Latitude (1912-93)

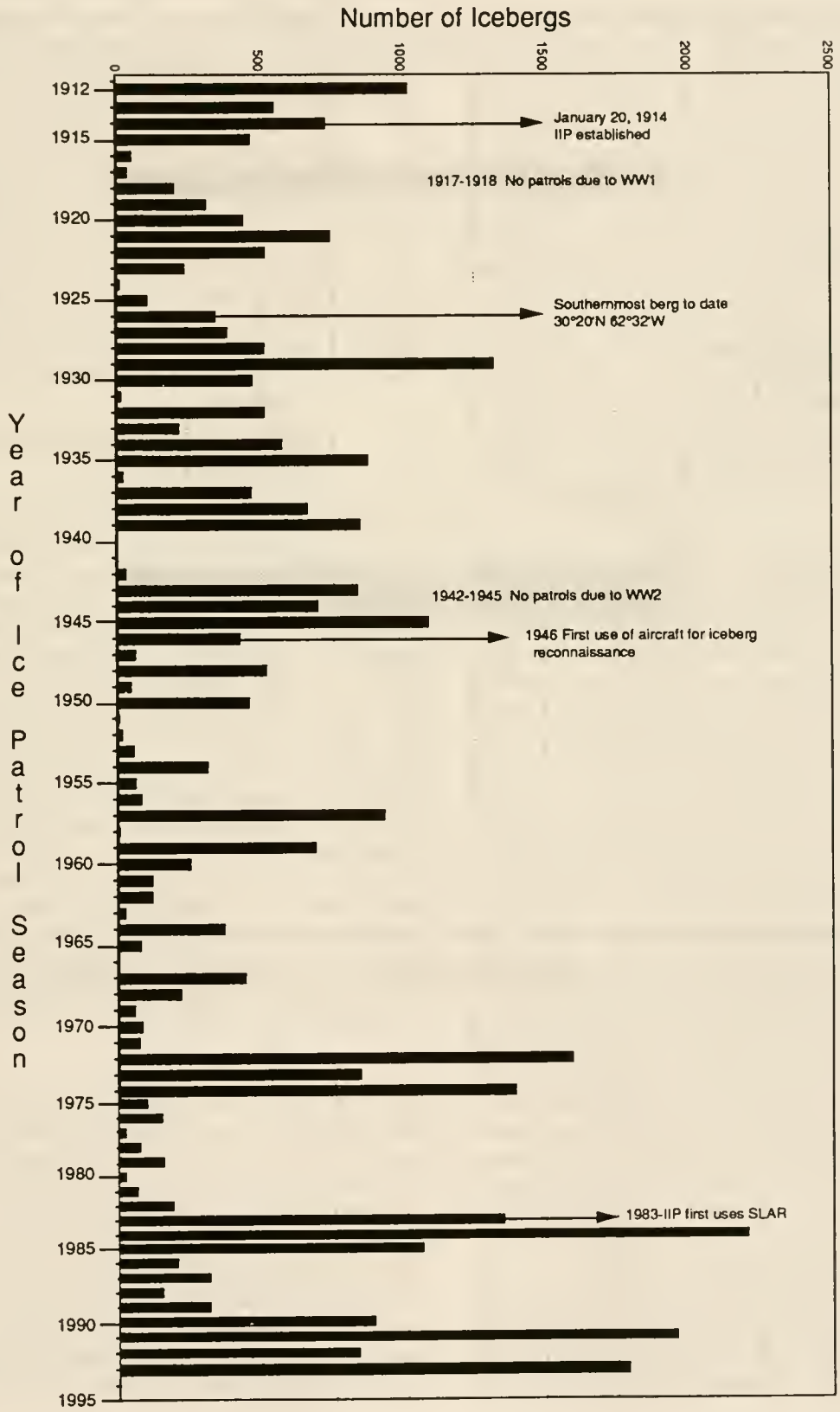
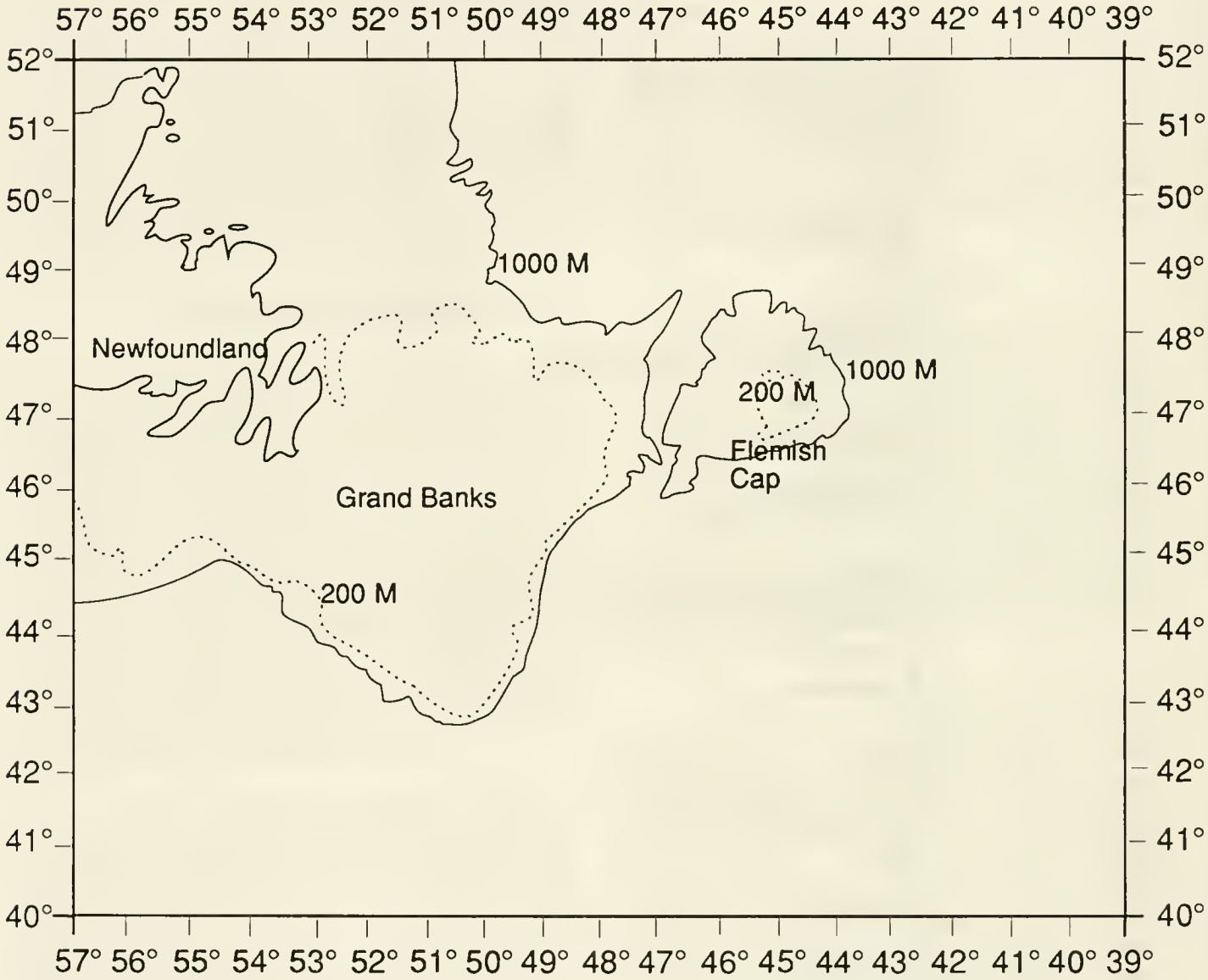


Figure 2

International Ice Patrol's Operation Area showing bathymetry of the Grand Banks of Newfoundland



more flights are required to cover the whole of the limits leaving less time to cover interior areas. When the area encompassed by the limits of iceberg danger is large, the potential for Ice Patrol reconnaissance to sight icebergs is reduced. The further north in the Labrador Current reconnaissance is conducted, the higher the density of icebergs. When all reconnaissance flights are dedicated to flying along the limits to define the area, the potential coverage of the interior is greatly reduced and thepotential for icebergs to drift south of 48 North in the Labrador Current and never be sighted increases. The lack of interior coverage does not effect Ice Patrol's ability to fulfill its mission but it does affect Ice Patrol's annual report of the estimate of icebergs that drift south of 48 North.

Ice Patrol Reconnaissance (1960-1982)

Ice Patrol conducted visual aerial reconnaissance during this period. On an as needed basis, surface patrol craft, supplemented aerial reconnaissance. The surface patrol craft's duty was to stand by the southern most iceberg and report its position to shipping and Ice Patrol headquarters. When it melted, the patrol craft would locate and remain with the next most southern iceberg. Surface patrol craft were used only during the 1972 and 1973 seasons. Vessels capable of conducting oceanographic work were deployed to the Ice Patrol operation area to conduct oceanographic research for many of the years covered by this report. These vessels were not considered surface patrol craft but did report the positions of observed icebergs. Neither the surface patrol vessels nor the research vessels contributed substantially to the number of iceberg sightings.

During the period from 1963 to 1982, Ice Patrol made iceberg survey flights north along the Labrador coast up into Baffin Bay. The iceberg sighting data from some of these flights are included in the digital database. The information entered into the data base does not represent the complete set of sightings received by Ice Patrol from these flights. Only the data contained in the retained Ice Patrol paper records was entered into the data base. These flights were used to get an early indication of the upcoming season's severity and therefore did not effect the estimate of icebergs crossing 48 North.

Coast Guard aircraft were deployed and available at a Canadian base of operations throughout the season. In 1962, the HC-130 (B model) was introduced as the aircraft for Ice Patrol's mission replacing the R5D (average patrol length 1200 miles). The HC-130 was a longer range aircraft allowing more area to be covered in a single flight. The B model ice reconnaissance flights averaged about 1500 miles in length, including transits to and from the search area. In 1981, the HC-130 H model was introduced into service with Ice Patrol. This model had about 20 percent more range (average flight track length of 1800 miles) than the B model. With each increase in range, the aircraft covered more area increasing the possibility of detecting more icebergs during a single flight.

From 1960 to 1970, Ice Patrol reconnaissance aircraft were based out of Argentia, Newfoundland. A permanent Coast Guard aviation detachment was stationed in Argentia with several aircraft at their disposal. This allowed for more than one aircraft to fly ice patrol reconnaissance flights to different areas on the same day when the weather was good. In 1970 with the closing of the U.S. Naval Air Station at Argentia, Ice Patrol moved its base of operations to the Canadian Forces Base at Summerside, Prince Edward Island. The one aircraft used by Ice Patrol was deployed from Coast Guard Air Station Elizabeth City, NC and not permanently stationed in Canada. The move from Argentia to Summerside greatly increased the time required to make the transit from the operating base to the iceberg search area. The increase in transit corresponded to a decrease in search time (and area) for icebergs. During periods when good weather was forecast, the aircraft would remain overnight in St. Johns, Newfoundland reducing the transit time to the search area.

In 1974, the Ice Patrol base of operations for aerial reconnaissance was moved from Summerside to St. Johns. The base of operations remained in St. Johns through the end of the 1982 season. This change in

operating locations reduced the transit time to reach the selected search areas. Occasional poor terminal weather conditions (fog) at St. Johns reduced the number of potential available reconnaissance days. A high percent of the poor terminal conditions days also directly reflected poor weather in the search areas.

During the visual reconnaissance period, weather, both at the search area and the terminal, was a primary factor in iceberg reconnaissance flight planning. Fog is prevalent on the Grand Banks during the period of about mid-April through early July. The aircraft generally flew their patrols at an altitude of about 1000 feet with a track spacing of 25 nautical miles. If the terminal weather conditions were acceptable for takeoff and return, a flight was planned for an area of the boundary of all known ice where the weather was good. Good weather on scene was defined as having visibility forecast for over at least 50 percent of the planned search area. From 1960 to 1982, an average of about one flight was conducted every 4.5 days during the season. Non-flying days were due to bad weather and aircraft mechanical problems. Occasional flights to the interior of the limits were also conducted. Occasionally fights to the same area on consecutive days would be flown to evaluate radar targets detected on the previous day's flight.

During the years 1960 to 1968, the percent of the area flown that was able to be effectively searched visually (where cloud cover was less than five tenths) was published in the annual Ice Patrol Bulletins. On an average, only 70 percent of the area flown was able to be searched visually. This means icebergs possibly existed undetected within the search area.

During the early and mid-1970s, Ice Patrol mostly used preset flight plans to cover specific sections of the operations area. Information about these preset flight plans can be determined by reviewing the flight plans published in the Ice Patrol Bulletins for that period. If needed, a nonstandard flight would be flown.

In 1960, the only electronic method of navigation available to the Ice Patrol aircraft was LORAN-A. In 1964, Doppler navigation equipment was installed on the aircraft. The LORAN-A coverage of the Ice Patrol operations area was limited and Doppler improved the navigation accuracy. In 1973, an Inertial Navigation System (INS) was installed on the Ice Patrol aircraft. INS is presently the primary navigation system on the aircraft used by Ice Patrol. This system did not require the receipt of an external signal and greatly improved the navigational capabilities of the aircraft. The cumulative error for the INS over an Ice Patrol patrol is on the order of 10 nautical miles. Each improvement in the navigation capability of the patrol aircraft meant the aircraft could fly the planned patrol area more accurately with less gaps in the area coverage caused by navigational errors. The improvements also meant the iceberg position reports were more accurate.

Ice Patrol Reconnaissance (1983-Present)

1983 saw the introduction of the APS-135 Side Looking Airborne Radar (SLAR) aboard the assigned HC-130 H model aircraft as the primary iceberg detection tool, supplementing the human eye. This instrument had a profound effect on Ice Patrol's reconnaissance operations. The SLAR provided a near all weather target detection capability. It also changed our reconnaissance strategy, including aircraft deployment scheduling.

Beginning as early as 1957, the International Ice Patrol had began evaluating a variety of SLARs. Although a variety of testing and evaluation was conducted, no SLAR was used on a continuous, operational basis prior to 1983. Ice Patrol used the results of the limited SLAR research flights as input into the drift prediction model, however these targets were not differentiated from visual sightings. These research flights did not contribute significantly to the number of sightings.

In 1983, SLAR became an integral part of Ice Patrol's routine reconnaissance operations. The SLAR equipped aircraft conduct patrols at 6000-8000 feet. The flights are flown with a 25 nautical mile track spacing. The SLAR range used is 27 nautical miles (50 kilometers). This SLAR range combined with the track spacing allows for about 200 percent

coverage of the interior portion of a standard parallel leg type search (Figure 3). Moderate or greater turbulence and moderate or greater precipitation reduces the SLAR's ability to detect targets. Flights are planned to avoid both of these factors. Flight cancellations due to poor on-scene weather conditions were greatly reduced with the introduction of SLAR.

Also in 1983, Ice Patrol moved its base of operations from St. Johns to Gander, Newfoundland. In 1988, Ice Patrol returned its base of operations to St. Johns. Both of these moves had little effect on Ice Patrol operations. Although St. Johns is a little closer to the southern portion of the area of iceberg danger, the small increase in flight transit time and corresponding decrease in search area had a minimal effect on Ice Patrol reconnaissance efforts.

The use of SLAR drastically altered the Ice Patrol aircraft deployment schedule. Instead of having an aircraft deployed to Canada on a continuous basis during the ice season, a SLAR equipped aircraft was deployed for a one week period every other week. With SLAR, Ice Patrol was able to conduct a similar number of flights and increase the coverage of the operations area. Transit legs to and from the search area could be searched with SLAR, increasing area coverage per flight. During the visual flight era, the transit legs were flown at altitude, generally above the clouds and very few iceberg sightings were recorded. The change in aircraft deployment schedule placed a larger reliance on Ice Patrol's iceberg drift and deterioration prediction models. Research efforts during the period 1986-1988 focused on evaluating the model performance. The results indicted, with good environmental input, the models performed within acceptable error tolerances (Murphy and Anderson, 1985, and Hanson, 1987).

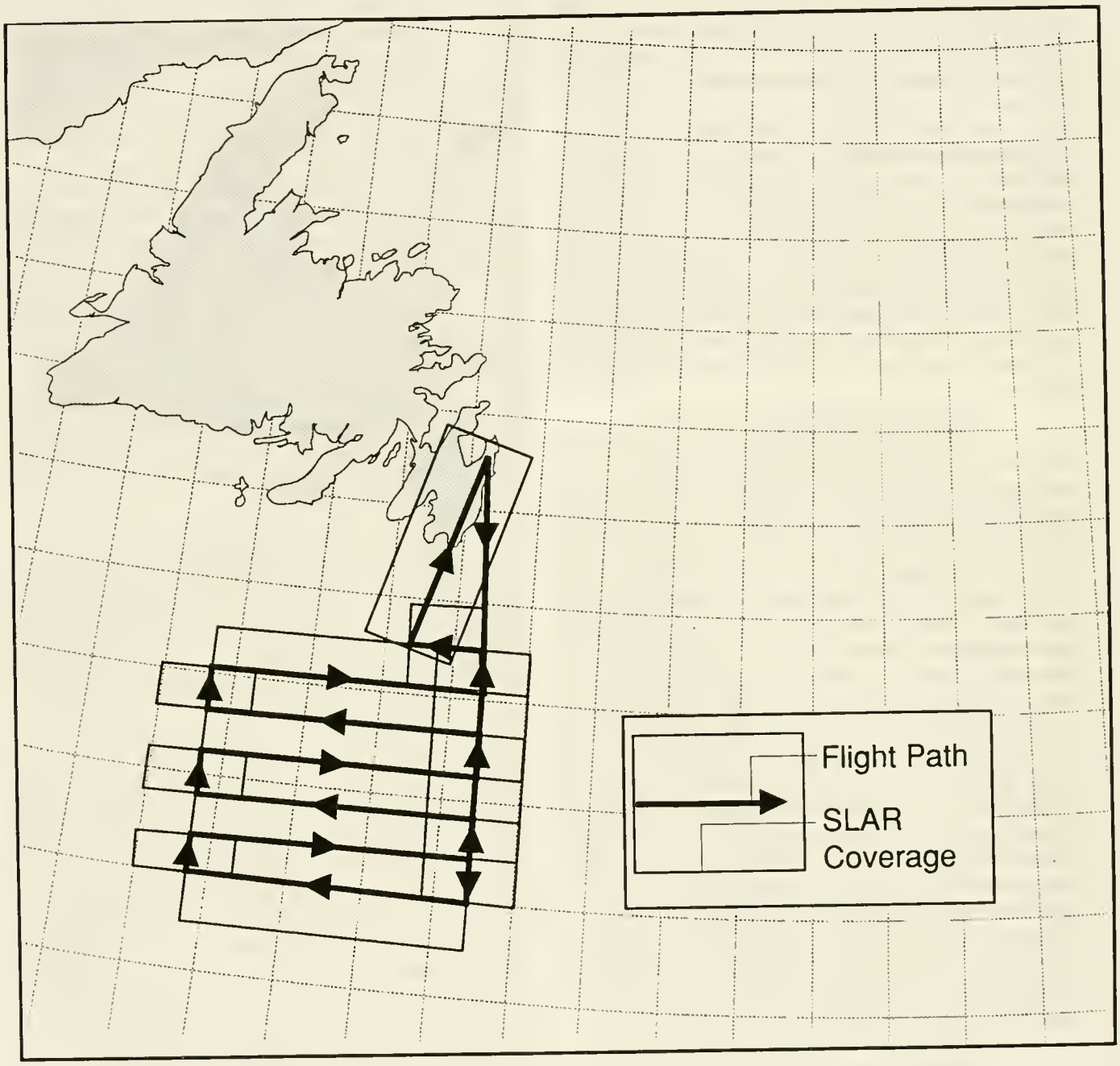
Research was conducted in 1984 and 1985 to evaluate the APS-135 SLAR performance. The results indicated the SLAR was a very capable iceberg detection tool (Rositter, et al., 1985 and Robe et al., 1985).

In 1989, the HU-25B Falcon jet equipped with an APS-131 SLAR was first used as a Ice Patrol aerial reconnaissance platform. The APS-131 SLAR also provides a near all-weather target detection capability. There is only one central antenna pod on the Falcon with the antenna being half as long as the antenna on the HC-130. The HU-25B is a much smaller airframe and is more susceptible to being rocked by air turbulence. On a turbulence free flight, the detection capability of the APS-131 SLAR is similar to that of the APS-135 SLAR (Alfultis and Osmer, 1988). The Falcon's range of 700 nautical miles is considerably less than the HC-130 and thus it is not capable of reaching and then searching the limits of iceberg danger during the peak of the season. The HU-25B is generally only used near the beginning and end of the season and is deployed in place of an HC-130 as part of the same every other week schedule. The HU-25B flies two three hour sorties per day compared to one seven hour sortie for an HC-130. The total area covered per day by the HU-25 is considerably less than the HC-130. Due to its limited range, the HU-25B has not been used extensively.

Along with SLAR's operational benefits came an important problem, target discrimination. When unable to see the surface, the operator must decide whether the target detected is an iceberg or not. Farmer (1972) provides a general overview of why SLAR is a good iceberg detection tool and a description of the visual cues used to classify SLAR targets. On the basis of this study, Ice Patrol decided to make identifications without seeing icebergs using the available cues. The cues on the film aid the experienced operator in determining the identification of some targets. When two looks at the same target from different legs of the search pattern are available, movement or lack of movement of the target is a particularly useful tool in deciding if a target was an iceberg or not. For targets without any cues, the operator's ability to discriminate between an iceberg and a vessel correctly is only just above chance (Thayer, 1985).

During the first several years use of the SLAR, the operators were learning how to use the available cues to discriminate between vessel and iceberg targets. This target discrimination problem effects Ice Patrol's estimate of the number of icebergs drifting south of 48 North. During the first several years of

Figure 3
A Typical Ice Patrol Parallel Leg Ice Reconnaisance Flight with 200 Percent SLAR Coverage



SLAR use, it is probable that some of the targets identified as icebergs from the SLAR were not icebergs but fishing boats. Although the estimate of the number of icebergs drifting south of 48 North may have been effected, the 1983-1985 seasons would still remain classified as extreme. As Ice Patrol's experience with the SLAR increased, the probability of the operator wrongly identifying a target has been reduced but not eliminated.

In light of the target discrimination problem, visual confirmation is still sought for icebergs that set the limits of the area of iceberg danger. Flights are planned during the deployment period to make the best use of available visibility.

Other Sighting Sources

The estimate of the icebergs south of 48 North is made from all data collected and analyzed by Ice Patrol throughout the year. Ice Patrol actively solicits other reporting sources to supplement Ice Patrol's own data gathering efforts. Ice Patrol relies on reports from commercial shipping to help improve the quality and accuracy of the products delivered to the maritime community. As an example, in 1991 reports from shipping accounted for over 50 percent of the icebergs entered into the drift prediction model.

Throughout the period covered by this paper, other sources of iceberg sighting reports have been added. With the addition of each new source, the potential for increasing the annual estimate of the icebergs drifting south of 48 North increases, particularly when the new source's efforts are concentrated in areas not otherwise fully covered.

The sighting source for icebergs was recorded as one of three types from 1960 to 1981. The three source categories used were USCG aircraft, USCG ship report, and other. USCG vessels transiting to and from ocean stations in the North Atlantic and vessels performing oceanographic research on the Grand Banks for Ice Patrol provided the sighting reports recorded under this category. Examples of reports received within the "other" category includes commercial shipping reports, reports from commercial, U.S., and Canadian military aviation, and reports from lighthouses. Between 1981 and 1983, the sources of sighting reports entered into the drift model were not recorded and are now no longer available. In 1984, a ten category sighting source code was added to the drift model as part of the data entry procedure.

In the early 1980s, the Canadian Atmospheric Environment Service (AES) began flying dedicated iceberg reconnaissance flights. Funding for this program has varied and the number of reports received is directly proportional to funding. The AES iceberg reconnaissance efforts to date peaked during the 1987 and 1988 seasons. AES used an APS-94E SLAR as the primary iceberg sensor on their Electra patrol aircraft through 1990. The APS-94E was evaluated in 1984 and its detection capability was less than the APS-135 (Rossiter, et al., 1985). In 1988, a DASH-7 with a CAL SLAR was introduced into service by AES. The AES iceberg flight efforts within the Ice Patrol model area are concentrated near the sea ice edge within the Canadian exclusive economic zone. The sea ice edge is within the area of higher iceberg density. AES iceberg dedicated flights emphasize visual searches. AES reports SLAR targets which are not visually confirmed icebergs as radar targets.

In about 1984, Ice Patrol began to receive iceberg reports through the NOAA/U.S. Navy Joint Ice Center. The information comes from a variety of Department of Defense sources and is passed to Ice Patrol for entry into the drift prediction model. The sighting reports are spread throughout the model area. In 1986, this source accounted for an all-time high of 11 percent of the icebergs entered into the model.

In the 1980s, exploratory efforts to develop the hydrocarbon resources on the Grand Banks began. The Hibernia oil field area lies between about 46 to 49 North on the eastern portion of the Grand Banks. The Canadian government regulations concerning drilling requires the operators to conduct surveillance for icebergs in their exploration area. Beginning in about 1985, the sightings made by the hydrocarbon industry were voluntarily supplied to Ice Patrol. This period of activity only lasted about 4 years and led to an increase in

the number of sighting reports in the area of the Hibernia oil field and effected the value of the estimate of icebergs crossing 48 North for those years.

In 1989, the sighting source code used for the hydrocarbon industry was renamed "Other aerial reconnaissance." This category now includes iceberg sightings received from the Canadian Department of Fisheries and Oceans (DFO). DFO contracts flights to conduct reconnaissance of foreign fishing vessels activity on the Grand Banks. The contractor supplies reports of the icebergs and unidentified radar targets seen on each flight to Ice Patrol. The fishing activity is concentrated along the shelf break of the Grand Banks and Flemish Cap, areas of potential high iceberg density. The number of flights conducted by the contractor increased in about 1991 with a commensurate increase in the number of iceberg reports.

The sighting code used by the model was changed in 1989 to accommodate a new source of icebergs. The AES iceBerg Analysis And Prediction System (BAPS) models iceberg drift in an area to the north of Ice Patrol's model area. AES supplied the predicted positions of those icebergs which were predicted to have drifted across 52 North and Ice Patrol entered them into its model. This particular source did not affect the estimate of icebergs drifting south of 48 north because none of these icebergs reached 48 North prior to either melting or being resighted by another source closer to 48 North.

Modeling Of Iceberg Drift

The Ice Patrol models described below were operated only during the portion of the year of iceberg danger. Generally, this would be about one month on both sides of the period when Ice Patrol daily bulletins were issued. This means that reports of icebergs received outside of this period may not have been included in the annual estimate of the number of icebergs crossing 48 North.

1960 to 1971

From 1960 to 1971, Ice Patrol maintained a hand plot of the iceberg's predicted motion. Ice Patrol used vector addition of the effects of the wind and sea current on icebergs to predict their motion. The exact origin and basis of this technique was not recorded but was based upon research conducted by Ice Patrol since its inception.

The wind component vector was computed as the downwind direction plus 50 degrees to the right (to include the effects of coriolis) with a magnitude of drift (in miles/12 hour period) of $.003684 \times W \times W + .282 \times W$ (where W = wind speed in knots) (Morgan, 1970). This portion of the drift component was to take into account leeway and the Ekman current component. The coefficients of the equation were adjusted over the years. The above coefficients are from the late 1960s.

The wind data for the vector addition routine was obtained from the U.S. Navy Meteorological office at Argentia until the closure of Air Station Argentia in 1970. After 1970, the wind data was supplied by the U.S. Navy Fleet Numerical Weather Center (FNWC) in Monterey, the predecessor of the Fleet Numerical Oceanographic Center (FNOC).

The ocean current information was derived from two sources. Ice Patrol conducted hydrographic surveys in the vicinity of the Grand Banks beginning shortly after the inception of Ice Patrol and developed geostrophic current data using the methods described in Sverdrup et al., 1942. Monthly mean dynamic heights for the area of the Grand Banks were developed (Soule, 1964). The U.S. Navy Oceanographic Office monthly mean charts of sea current were used to provide information for the area outside of that covered by the Ice Patrol mean dynamic height charts. The sea current was vectorially added to the wind component to predict iceberg drift.

With a manual plot method, there was a practical limit to the time available to predict the drift of icebergs upstream of the icebergs closest to the area defining the limit of all known ice. During light iceberg years, it was possible to predict the drift of all of the icebergs reported to Ice Patrol. During a heavy iceberg year, it may have been impractical to predict the drift of all the reported icebergs. The manual plot was updated twice daily. The plot

was used by the Ice Patrol personnel to help determine if an iceberg report was a new sighting or a resight of an iceberg already being monitored.

Lenczyk (1964) published a method of predicting the deterioration of icebergs that was used by Ice Patrol up until 1983. The method used sea surface temperature and iceberg size as its inputs to predict, in an average sea state, the number of days for an iceberg to melt. The deterioration was done twice weekly and records for each iceberg were kept by hand. The sea surface temperature was obtained from charts prepared by the U.S. Navy and updates provided by ships reporting sea surface temperature directly to Ice Patrol. This deterioration method was used as input by the Ice Patrol officer to decide to remove an iceberg from the active plot.

1971 to 1979

In 1971, Ice Patrol began using a computerized version of the manual vector addition routine. The program is described in Morgan (1971). The model area for the computerized vector addition routine was selected to cover the area from 40 to 52 degrees North and from 39 to 57 degrees West. At the time of the model creation, it was felt this area would allow modeling of nearly every iceberg that would create a threat to navigation within the area of Ice Patrol's statutory responsibility.

A computerized version of the monthly currents field was created from the same data Ice patrol had been using as the input to the manual vector addition method. The current fields were updated by Scobie and Schultz (1976) by incorporating recent survey information into the monthly means.

FNWC provided a computer-readable wind input for the computer model on a one degree latitude by two degree longitude grid covering the model area. Analysis winds along with predicted winds 12 hours, 24 hours, and 36 hours into the future were provided. This allowed Ice Patrol to be able to predict iceberg movement for periods up to 36 hours into the future.

The computerization of the manual vector addition routine helped eliminate cumulative errors associated with hand plotting. The computer also allowed all iceberg reports received within the model region to have their drift predicted without adding much work load to the Ice Patrol staff. The introduction of the model provided a better tool to determine whether an iceberg sighting report was either a new iceberg or a report of an iceberg already being monitored. This improved ability to model all icebergs and determine if the report was for a new iceberg or not helped improve the accuracy of the estimate made by Ice Patrol of the number of icebergs crossing south of 48 North. Icebergs which were drifted south of 48 North by the model without actually being seen were included in the estimate of icebergs crossing 48 North.

1979 to Present

In 1979, the vector addition computer program was replaced by a dynamical balance of forces model (Mountain, 1979). The input procedures, the appearance of the model output, and the model area did not change with the model replacement. The winds used as the new model input were supplied by FNOC. The monthly sea current files were combined into a single mean historical current field and used as the current input into the new model (Murray, 1979). In 1981, an addition was made to the model to allow the mean current field to be modified by real time satellite tracked drifter data (Summy and Anderson, 1983). The addition of real time current data allowed the drift prediction model to produce better results. In 1982, a computerized deterioration prediction model was implemented (Anderson, 1983). The deterioration model allowed the melting of all the icebergs being tracked by IIP to be predicted, not just the icebergs done by hand close to the limits of all known ice.

During the active season, sighting reports received in the area where no model ocean current data exists (along the coast and in the bays of the Newfoundland coast) are not entered into the model. Only a small percentage of the icebergs reported in the Avalon Channel (the area just off the east coast of Newfoundland) are entered into the model. Icebergs in this area, although south of 48

North, do not effect the limits of the area of iceberg danger. The total number of iceberg sighting reports received and not entered into the model for this area (and therefore the data base) is unknown.

Analysis Techniques Of Sighting/Drift Data

All iceberg sighting data received by Ice Patrol is treated the same regardless of sighting source. After a sighting report is received, Ice Patrol personnel must determine whether the report is for a new iceberg or a resight of an iceberg already reported. The reported position is compared to the predicted positions of previously reported icebergs.

The criteria for determining whether a sighting report is a resight or not have changed over the years and also vary by geographic position within the Ice Patrol area and with proximity to the limits of all known ice. The criteria described below are the general principles used from 1960 to 1991.

If the report is in an area known to have variable currents (particularly near the Tail of the Banks), a sighting report within about 30-40 miles (depending upon when the iceberg was last reported) of the predicted position of a previous report could be considered a resight. Icebergs further from the limits of all known ice are more likely to be resighted, particularly those on the northern portion of the Grand Banks.

As the "Limits of all known ice" are approached, a more conservative approach to resights is taken. Unless the sighting report closely approximates the predicted position and size of a previous report, the iceberg is added rather than resighted. This philosophy ensures all of the icebergs near the limits of all known ice are reported in Ice Patrol's products.

There are four ways icebergs are removed from the list of active icebergs being monitored by Ice Patrol. If an Ice Patrol flight overflies the location of an iceberg and the iceberg is not located, the iceberg will be deleted from the active iceberg list. If the iceberg is predicted to have melted, it will be removed from the active list. A more conservative approach to removing icebergs because of melt is applied when the iceberg is close to the limits of all known ice. If an iceberg has been on the active list for thirty days without been resighted, it will be removed. If an iceberg is predicted to drift to the east or west of the Ice Patrol area, it will be removed from the list of active icebergs and a note about the last predicted position will be put in the iceberg bulletin sent to shipping.

Icebergs are not removed from the active list when a ship report of no ice in an area is received because the errors associated with the drift prediction could easily have placed the iceberg outside the detection capability of the ship.

"Counting" The Icebergs South Of 48 North

From 1960 to 1988, the estimate of icebergs crossing south of 48 North was determined by hand counting from the paper records and/or model outputs. The Ice Patrol officer was responsible for determining the estimate of the number of icebergs crossing 48 North, a task that was easier in light ice years than during heavy years.

1960-1970

A technician was assigned to keep track of the number of iceberg sightings that were reported south of 48 North. Icebergs that were predicted to drift south of 48 North were also included. In heavy ice years, not all of the icebergs reported may have had the manual drift done. The numbers produced by the technician were reviewed by the Ice Patrol officer prior to release.

1970-1988

For the computer model years, the technician would review the daily model printouts each month and determine which icebergs had either been sighted or drifted south of 48 North. No differentiation was made between icebergs sighted and those drifted south of 48 North (without actually being seen south of 48 North). For each iceberg south of 48 North, the technician would have to determine how

many icebergs that model entry represented. (When IIP received reports with multiple icebergs in the same location, only one entry would be made into the model and the number of icebergs that entry represented would be noted in the model input log.) The technician would also ensure that the target number was not included in last month's count. The number of chances for errors within the manual counting scheme increased with the number of icebergs entered into the model.

Beginning in 1982, the computer model used by International Ice Patrol created a file containing the sighting and final drift position for each sighting entered into the model. Only sighting reports received by Ice Patrol with positions within the bounds of the model (40 to 52 North and 39 to 57 West) were entered into the model. This means all sighting reports after 1982 outside the bounds of the model are NOT included in the data base. The number of reports received outside of the model area is estimated to be less than 100 per year with the majority of the reports being north of 52 North. After 1982, sighting reports received when the model was not being run are not included in the data base.

1989-1991

Development of a computerized technique to "count" the number of icebergs crossing 48 North began in 1989. This method was used to generate the numbers published in the 1989 to 1991 bulletins. Development was completed in 1991. The new technique takes into account the number of icebergs each entry represents and provides a break down by sighted versus drifted but never sighted south of 48 North. The new computerized technique uses the model iceberg sighting history file. This file contains the sighting date and position, and final drift position for each target entered into the model, including resights. The counting program examines all of the entries for each target number that was an iceberg (not a radar or growler) to see if: (1) an iceberg entry was sighted south of 48 North or (2) if an entry was drifted south of 48 North without being sighted south of 48 North.

A "Count" Review

A summary of the iceberg sightings from the database for the period 1960 to 1981 is shown in Table 1. Also included in Table 1 is the estimate of the icebergs to have crossed south of 48 North for each year. In comparing the database summary to the published estimate of icebergs drifting south of 48 North, some observations can be made.

In 1966, Ice Patrol published an estimate of zero icebergs drifting south of 48 North yet the database includes 12 iceberg reports representing 14 icebergs sighted south of 48 North. No explanation for this observation is offered.

In 1969, 1979, 1980, and 1981, the number of icebergs represented by the database iceberg sighting reports sighted south of 48 North is less than the published estimate of the number of icebergs drifting south of 48 North. A possible explanation for this observation would be the inclusion in the published estimate of icebergs predicted to have drifted south of 48 North by the prediction scheme used during those years. In 1960 through 1964, the number of icebergs represented by the database sighted south of 48 North is larger than the published estimate of the number of icebergs drifting south of 48 North. This could be accounted for by the resighting of icebergs already reported and regular reconnaissance flights of the same area.

The new computerized counting technique was applied to the model iceberg sighting history files from 1982 to 1991. A summary of this application is in Table 2. A more detailed break down by year is included in Attachment 2. For the period 1982 to 1984, the sighting source was not entered into the model. For the period 1982 to 1985, the number of icebergs each entry represented was not entered into the model. The new computerized counting technique was applied consistently to all of the data. The results show differences with the previous methods used. The computerized technique is believed to be a more accurate reflection of the icebergs WHICH IIP INCLUDED IN ITS MODEL that were either sighted south of 48 North or drifted south of 48 North.

Table 1

Ice Patrol Iceberg Sighting Database Summary 1960-1981

Year	Iceberg* Sighting Reports	Icebergs* Represented by Reports	Iceberg Reports South of 48N	Icebergs Represented by Reports South of 48N	Published Estimate of Icebergs Drifting South of 48N
1960	1837	2484	1157	1384	253
1961	2268	2811	1239	1489	117
1962	2378	3557	906	1060	120
1963	585	1107	137	180	25
1964	4274	5935	2735	3373	369
1965	1195	2256	234	310	76
1966	1108	1710	12	14	0
1967	2832	3780	1156	1704	441
1968	2920	3653	480	41	219
1969	1815	3394	36	175	57
1970	1398	2807	136	117	85
1971	735	867	86	3192	73
1972	4961	5596	2957	2326	1587
1973	3309	3752	2114	2835	847
1974	4393	4685	2747	319	1386
1975	476	519	319	202	101
1976	803	843	196	28	151
1977	582	583	28	247	22
1978	1030	1035	245	129	75
1979	371	372	129	3	152
1980	101	102	3	19	20
1981	127	128	19		63

Note:* These entries also include icebergs sighted during some but not all of the survey flights north of the Ice Patrol Operations Area, including preseason survey flights into Baffin Bay conducted from 1963 to the late 1970's.

Summary

The IIP iceberg sighting database is not a complete set of all icebergs actually drifting south of 48 North each year. A detailed description of the database contents is contained in Attachment 3. Although not complete, the Ice Patrol database does represent the most complete and continuous iceberg data set available.

Over the past 30 years, numerous changes have occurred that effected Ice Patrol's ability to estimate the number of icebergs crossing 48 North. As the people at Ice Patrol changed, the methods used to accomplish manual tasks changed (Examples: determining if a report is a resight of an iceberg already being drifted and performing the annual counts). Technological advances affected, and continue to affect, Ice Patrol's operations and thus the gathering and processing of data. Bursts of activity in the Ice Patrol area by outside concerns (oil industry, fishing industry, and government agencies) provide increases in the volume of data to be processed. All of these factors have significantly affected the annual estimate of icebergs crossing 48 North and make difficult direct year to year comparisons.

Several efforts have been made by a variety of authors to use different methods to classify/rank the severity of a year with regards to icebergs. Although these methods are all based on the estimates of icebergs crossing 48 North, the methods do not use definitive numbers as a measure. In 1987, Ice Patrol began classifying season severity (Alfultis, 1987). Ice seasons are classified as either light (less than 300 icebergs estimated south of 48 North), intermediate (between 300 and 600 icebergs estimated south of 48 North), heavy (between 600 and 900 icebergs estimated south of 48 North), or extreme (more than 900 icebergs estimated south of 48 North). Prior to 1987, the ice seasons were classified by Ice Patrol as light, normal, or heavy by comparing the annual estimate of the number of icebergs crossing 48 North to the long term average. Davidson et al. (1986) describe a severity ranking system they used in their work with the data set. This system relies on relative comparison of seasons.

Hopefully, this paper has provided enough insight into the Ice Patrol iceberg database to allow it to be used within its collection constraints by others.

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Table 2

Summary of Model Entry Data Estimated South of 48 North From 1982 to 1991

Characteristic	1982	1983	1984	1985	1986	1988	1989	1990	1991
Number of Targets Entered into Model (Note 2)	817	2080	2560	2175	513	1102	1157	1129	1599
Total Model Entries (Notes 1 and 2)	993	2627	3693	4405	1022	2186	2987	2701	2970
Model Entries Representing Icebergs (Note 1)	716	2203	2926	3683	611	1958	2634	2292	2626
Total Icebergs Entered into Model (Note 1)	*	*	*	*	712	2451	2775	2497	3680
Iceberg Model Entries Sighted South of 48 N	58	928	1133	831	140	161	342	636	1068
Iceberg Model Entries Drifted South of 48 N	49	151	143	147	35	58	75	47	81
Total Iceberg Model Entries South of 48 N	107	1079	1276	978	175	219	417	683	1149
Icebergs Represented By Model Entries Sighted South of 48 N	*	*	*	*	147	180	362	737	1861
Icebergs Represented By Model Entries Drifted South of 48 N	*	*	*	*	44	83	75	56	113
Total Icebergs Represented by Model Entries South of 48 N	*	*	*	*	191	263	437	*** 793	1974
Published Estimate of Icebergs South of 48 N	18	1352	2202	1063	204	187	301	856	1974
Percent of Total Model Icebergs South of 48 N Reported by IIP SLAR	**	**	37 %	13 %	26 %	23 %	21 %	19 %	23 %
Percent of Total Model Icebergs South of 48 N Reported by Ships	**	**	38 %	45 %	30 %	19 %	29 %	44 %	51 %

Note 1: Includes Resights. All other entries do not include resight information for the same iceberg.
Note 2: Includes Growler and Radar Target information entered into model.
* Number of Icebergs each entry represented not entered into model.
** Source of sighting not entered into model.
*** In addition to model icebergs, 5 icebergs were sighted south of 40 North.

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Attachment 1

Major Changes in IIP Technology

Milestone	Potential Effect
1960: Use of hand vector addition routine to predict iceberg drift.	Procedure allowed for more accurate limit production and allowed for better resighting of icebergs.
1962: Introduction of HC-130B as IIP recon aircraft. Last year for use of R5D.	Provided for a longer range aircraft to cover more area per flight.
1964: Introduction of a manual iceberg deterioration method based on size and sea surface temperature/	Method provided a means of removing icebergs from plot after they were predicted to have melted.
1970-73: IIP base of operations moved from Argentia to Summerside, PEI. Would RON in St. Johns if forecast good.	Longer transit flights reduced available flight time to be dedicated to reconnaissance.
1971: Eliminated request for SST/Wx in ice bulletins.	Reduced available data as input to FNOC. Removed a measurement of traffic in IIP operations area.
1971: Began use of computerized vector addition model. Apparently already using a manual deterioration routine.	Allowed more icebergs than just limit setters to be drifted. Removed errors associated with hand methods. Better capability to resight icebergs.
1973: Operational use of Inertial Navigation System (INS) on the IIP Aircraft	Greatly improved position accuracy of patrols and sighting reports.
1974: IIP base of operations moved to St. Johns.	Weather at airport (fog) kept aircraft on ground even if on scene weather good. Greatly reduced transit times to on scene.
1976: First satellite tracked drifting buoy deployment.	Provided first real time current data vs dynamic height sections as data for input to drift model.
1979: Introduction of IBERG model.	Introduction was transparent to watchstander. Still had computer cards to deal with, model ran on CDC 3300. New model improved drift prediction and therefore resighting capability.
1981: Introduction of HC-130H models.	Provided for longer flights (1800 vs 1500 mile). Increased area covered in single flight.

1981: Introduction of TOD data current update scheme.	Allowed near real time current data as drift model input. Improved drift prediction. Better resight capability.
1983: Introduction of APS-135 SLAR.	The biggest effect on data collection since the introduction of aerial reconnaissance in 1945. Provides an all weather detection capability but target discrimination (iceberg from small vessel) is not perfect. Early years (83-85) probably had many fishing vessels reported as icebergs. First two years of use legitimate extreme seasons which further helped add to the target discrimination problem.
1983: IIP base of operations moved to Gander. Aircraft now deployed once every two weeks versus a continuous presence in Newfoundland.	Move to Gander little effect. Since able to use SLAR in all weather, approx. same number of flights completed during one week deployment as during a two week deployment awaiting good visual on-scene weather.
1983: Last use of HC-130B as visual recon aircraft.	SLAR now the primary reconnaissance tool.
1983: Began using computerized iceberg deterioration model.	Provided ability to model melt of all icebergs not just limit setters.
1987: Introduction of HU-25B and APS-131 SLAR.	Provided another platform. 131 SLAR not as good as 135 due to antenna length. Reduced range of HU-25 will not allow use of aircraft during times limits expanded.
1988: IIP base of operations moved back to St. Johns.	Effect minimal on data collection. Hanger available for aircraft maintenance.

Attachment 2

Detailed Model Entries
1982-1991

1982
MODEL ENTRIES ESTIMATED SOUTH OF 48 N BY MONTH

Month	Sighted	Drifted	Total
January	0	2	2
February	0	0	0
March	5	1	6
April	30	4	34
May	8	1	9
June	14	32	46
July	1	8	9
August	0	1	1
September	0	0	0
October	0	0	0
Totals	58	49	107

Highest Model Target Number Used: 817
Total Model Entries: 993
Model Entries Representing Icebergs: 716

1983
MODEL ENTRIES ESTIMATED SOUTH OF 48 N BY MONTH

Month	Sighted	Drifted	Total
January	6	2	8
February	86	11	97
March	86	14	100
April	261	16	277
May	338	57	395
June	126	30	156
July	25	20	45
August	0	1	1
September	0	0	0
October	0	0	0
Totals	928	151	1079

Highest Model Target Number Used: 2080
Total Model Entries: 2627
Model Entries Representing Icebergs: 2203

1984

MODEL ENTRIES ESTIMATED SOUTH OF 48 N
BY MONTH

Month	Sighted	Drifted	Total
January	0	0	0
February	0	0	0
March	83	0	83
April	473	45	518
May	304	16	320
June	126	25	151
July	109	46	155
August	33	10	43
September	5	1	6
October	0	0	0
Totals	1133	143	1276

Highest Model Target Number Used: 2560
Total Model Entries: 3693
Model Entries Representing Icebergs: 2926

ICEBERG MODEL ENTRIES BY SIGHTING SOURCE

	Estimated South of 48 N			Iceberg
Sighting Source	Sighted	Drifted	Total	Entries
IIP-SLAR	483	89	572	1070
IIP-Visual	210	33	243	455
AES-SLAR	3	0	3	8
AES-Visual	3	3	6	46
Other Air Recon	90	5	95	162
Ship Reports	304	8	312	1111
Lighthouse/Shore	0	0	0	0
DOD Sources	26	0	26	29
Other	14	5	19	45
BAPS	*	*	*	*
Totals	1133	143	1276	2926

1985

MODEL ENTRIES ESTIMATED SOUTH OF 48 N BY MONTH

Month	Sighted	Drifted	Total
January	2	0	2
February	61	2	63
March	116	3	119
April	205	14	219
May	153	21	174
June	166	11	177
July	100	55	155
August	18	26	44
September	10	15	25
October	0	0	0
Totals	831	147	978

Highest Model Target Number Used: 2175
Total Model Entries: 4405
Model Entries Representing Icebergs: 3683

ICEBERG MODEL ENTRIES BY SIGHTING SOURCE

	Estimated South of 48 N			Iceberg
Sighting Source	Sighted	Drifted	Total	Entries
IIP-SLAR	247	46	293	493
IIP-Visual	87	41	128	477
AES-SLAR	48	3	51	192
AES-Visual	69	21	90	496
Other Air Recon	51	3	54	197
Ship Reports	299	21	320	1668
Lighthouse/Shore	3	6	9	24
DOD Sources	23	5	28	117
Other	4	1	5	19
BAPS	*	*	*	*
Totals	831	147	978	3683

1986

MODEL ENTRIES / ICEBERGS REPRESENTED
ESTIMATED SOUTH OF 48 N BY MONTH

Month	Sighted	Drifted	Total
January	0/0	0/0	0/0
February	3/3	0/0	3/3
March	33/37	0/0	33/37
April	54/54	2/2	56/56
May	43/46	4/9	47/55
June	5/5	13/14	18/19
July	2/2	14/14	16/16
August	0/0	2/2	2/2
September	0/0	0/0	0/0
October	0/0	0/0	0/0
Totals	140/147	35/44	175/191

Highest Model Target Number Used: 513
Total Model Entries: 1022
Model Entries Representing Icebergs: 611/712

ICEBERG MODEL ENTRIES BY SIGHTING SOURCE

	Estimated South of 48 N Model Entries/Icebergs Represented			
Sighting Source	Sighted	Drifted	Total	Iceberg Repres.
IIP-SLAR	77/83	2/2	79/85	183
IIP-Visual	8/9	11/14	19/23	140
AES-SLAR	3/3	2/2	5/5	41
AES-Visual	7/7	2/2	9/9	44
Other Air Recon	4/4	0/0	4/4	5
Ship Reports	23/23	7/7	30/30	217
Lighthouse/Shore	0/0	0/0	0/0	0
DOD Sources	18/18	11/17	29/35	81
Other	0/0	0/0	0/0	1
BAPS	*	*	*	*
Totals	140/147	35/44	175/191	712

1987
MODEL ENTRIES / ICEBERGS REPRESENTED ESTIMATED SOUTH OF 48 N BY MONTH

Month	Sighted	Drifted	Total
January	1/1	0/0	1/1
February	17/17	1/1	18/18
March	46/51	3/3	49/54
April	55/63	21/25	76/88
May	50/61	33/42	83/103
June	64/75	51/66	115/141
July	17/17	6/6	23/23
August	0/0	2/2	2/2
September	0/0	0/0	0/0
October	0/0	0/0	0/0
Totals	250/285	117/145	367/430

Highest Model Target Number Used: 954
Total Model Entries: 993
Model Entries Representing Icebergs: 1457/1785

ICEBERG MODEL ENTRIES BY SIGHTING SOURCE

	Estimated South of 48 N Model Entries/Icebergs Represented			
Sighting Source	Sighted	Drifted	Total	Iceberg Repres.
IIP-SLAR	46/52	16/27	62/79	244
IIP-Visual	30/34	13/18	43/52	243
AES-SLAR	13/15	3/6	16/21	78
AES-Visual	18/23	38/42	56/65	615
Other Air Recon	28/28	2/2	30/30	67
Ship Reports	106/121	23/23	129/144	416
Lighthouse/Shore	1/1	0/0	1/1	1
DOD Sources	8/11	21/24	29/35	116
Other	0/0	1/1	1/1	5
BAPS	*	*	*	*
Totals	250/285	117/145	367/430	1785

1988

MODEL ENTRIES / ICEBERGS REPRESENTED
ESTIMATED SOUTH OF 48 N BY MONTH

Month	Sighted	Drifted	Total
January	0/0	0/0	0/0
February	0/0	0/0	0/0
March	9/9	1/1	10/10
April	91/99	8/10	99/109
May	33/41	8/16	41/57
June	22/25	29/43	51/68
July	5/5	7/7	12/12
August	1/1	5/6	6/7
September	0/0	0/0	0/0
October	0/0	0/0	0/0
Totals	161/180	58/83	219/263

Highest Model Target Number Used: 1102
Total Model Entries: 2186
Model Entries Representing Icebergs: 1958/2451

ICEBERG MODEL ENTRIES BY SIGHTING SOURCE

	Estimated South of 48 N Model Entries/Icebergs Represented			
Sighting Source	Sighted	Drifted	Total	Iceberg Repres.
IIP-SLAR	51/55	15/17	66/72	575
IIP-Visual	14/15	7/7	21/22	466
AES-SLAR	0/0	0/0	0/0	43
AES-Visual	5/5	21/30	26/35	701
Other Air Recon	24/24	5/19	29/43	133
Ship Reports	51/69	9/9	60/78	466
Lighthouse/Shore	5/5	0/0	5/5	23
DOD Sources	4/6	0/0	4/6	17
Other	1/1	1/1	2/1	17
BAPS	*	*	*	*
Totals	161/180	58/83	219/263	2451

1989
MODEL ENTRIES / ICEBERGS REPRESENTED
ESTIMATED SOUTH OF 48 N BY MONTH

Month	Sighted	Drifted	Total
January	0/0	0/0	0/0
February	18/18	2/2	20/20
March	157/166	6/6	163/172
April	64/69	4/4	68/73
May	58/60	30/30	88/90
June	44/48	22/22	66/70
July	1/1	11/11	12/12
August	0/0	0/0	0/0
September	0/0	0/0	0/0
October	0/0	0/0	0/0
Totals	342/362	75/75	417/437

Highest Model Target Number Used: 1157
Total Model Entries: 2987
Model Entries Representing Icebergs: 2634/2775

ICEBERG MODEL ENTRIES BY SIGHTING SOURCE

	Estimated South of 48 N Model Entries/Icebergs Represented			
Sighting Source	Sighted	Drifted	Total	Iceberg Repres.
IIP-SLAR	68/77	17/17	85/94	590
IIP-Visual	59/65	13/13	72/78	376
AES-SLAR	0/0	3/3	3/3	52
AES-Visual	5/5	8/8	13/13	182
Other Air Recon	89/89	3/3	92/92	225
Ship Reports	105/110	19/19	124/129	800
Lighthouse/Shore	0/0	0/0	0/0	27
DOD Sources	11/11	9/9	20/20	251
Other	4/4	3/3	7/7	55
BAPS	1/1	0/0	1/1	217
Totals	342/362	75/75	417/437	2775

1990
MODEL ENTRIES / ICEBERGS REPRESENTED ESTIMATED SOUTH OF 48 N BY MONTH

Month	Sighted	Drifted	Total
January	0/0	0/0	0/0
February	8/8	1/1	9/9
March	101/104	8/8	109/112
April	298/375	1/1	299/376
May	148/168	19/19	167/187
June	61/62	5/14	66/76
July	17/17	9/9	26/26
August	3/3	4/4	7/7
September	0/0	0/0	0/0
October	0/0	0/0	0/0
Totals	636/737	47/56	683/793

Highest Model Target Number Used: 1129
Total Model Entries: 2701
Model Entries Representing Icebergs: 2292/2497

ICEBERG MODEL ENTRIES BY SIGHTING SOURCE

	Estimated South of 48 N Model Entries/Icebergs Represented			
Sighting Source	Sighted	Drifted	Total	Iceberg Repres.
IIP-SLAR	127/162	11/11	138/173	472
IIP-Visual	116/126	2/2	118/128	330
AES-SLAR	0/0	0/0	0/0	11
AES-Visual	32/40	0/0	32/40	78
Other Air Recon	86/100	13/13	99/113	342
Ship Reports	218/252	19/28	237/280	1087
Lighthouse/Shore	0/0	0/0	0/0	7
DOD Sources	56/56	2/2	58/58	165
Other	1/1	0/0	1/1	1
BAPS	0/0	0/0	0/0	4
Totals	636/737	47/56	683/793	2497

1991
MODEL ENTRIES / ICEBERGS REPRESENTED
ESTIMATED SOUTH OF 48 N BY MONTH

Month	Sighted	Drifted	Total
January	0/0	0/0	0/0
February	19/20	0/0	19/20
March	106/112	3/3	109/115
April	119/138	6/6	125/144
May	203/259	6/10	209/269
June	343/985	31/45	374/1030
July	247/315	10/10	257/325
August	31/32	25/39	56/71
September	0/0	0/0	0/0
October	0/0	0/0	0/0
Totals	1068/1861	81/113	1149/1974

Highest Model Target Number Used: 1599
Total Model Entries: 2970
Model Entries Representing Icebergs: 2626/3680

ICEBERG MODEL ENTRIES BY SIGHTING SOURCE

	Estimated South of 48 N Model Entries/Icebergs Represented			
Sighting Source	Sighted	Drifted	Total	Iceberg Repres.
IIP-SLAR	267/582	14/35	281/617	853
IIP-Visual	146/307	0/0	146/307	412
AES-SLAR	19/19	7/10	26/29	51
AES-Visual	28/30	14/15	42/45	82
Other Air Recon	85/233	12/12	97/245	380
Ship Reports	501/668	30/36	531/704	1862
Lighthouse/Shore	0/0	1/2	1/2	7
DOD Sources	21/21	3/3	24/24	32
Other	1/1	0/0	1/1	1
BAPS	0/0	0/0	0/0	0
Totals	1068/1861	81/113	1149/1974	3680

Attachment 3

The Iceberg Sighting DataBase Contents

Data Base Contents

The objective in creating an iceberg sighting data base was to take the variety of formats in which the data existed and place it in one single format without any loss of data definition. The set of sighting records with the largest number of fields was used as the basis for creating the iceberg sighting data base. The following fields are included for each record:

- Iceberg number. This field contains a sequential number for each iceberg sighted within each iceberg season (1 October to 30 September).

- Sighting Index. This is a symbol used by the model to indicate whether the iceberg is a resight of a previous sighting. A "+" is used to indicate the iceberg is an earlier sighting of a resighted iceberg. A "D" is used to indicate the last sighting of an iceberg. In some cases, the first and last sighting of an iceberg are the same.

- Resight. A "Y" (for yes) or "N" (for No) is entered in this field to indicate whether or not the sighting was considered a resight of a previously sighted iceberg.

- Sighting Source. This column is used to describe the source that reported the iceberg to Ice Patrol. This column was first recorded digitally in 1984 and the code was modified in 1989. The following code is used to describe the sighting source:

Number	1984-1988	1989 to Present
1	Ice Patrol Aircraft Radar/SLAR	Ice Patrol Aircraft Radar/SLAR
2	Ice Patrol Aircraft Visual	Ice Patrol Aircraft Visual
3	AES Aircraft Radar/SLAR	AES Aircraft Radar/SLAR
4	AES Aircraft Visual	AES Aircraft Visual
5	Ship Report - Radar	Other Air Reconnaissance *
6	Ship Report - Visual	Ship Reports
7	Oil Industry Sources	Lighthouse/Shore
8	Lighthouse/Shore	Defense Department Sources
9	Defense Department Sources	Other
0	Other	BAPS Iceberg **
X	Unknown	Unknown

* - This category includes iceberg sighting reports received from aircraft flying support for the hydrocarbon industry operating on the Grand Banks.

** - The Canadian Atmospheric Environmental Service (AES) operates an iceberg drift prediction model called BAPS. When icebergs drift south of 52 North they will report the predicted positions to Ice Patrol and Ice Patrol will enter the sighting in our iceberg drift model.

- Sighting Position. The latitude and longitude of the sighted position of the iceberg.

- Sighting Date. The date the iceberg was sighted.

- Sighting Time. The time (in Universal Coordinated Time) of the iceberg sighting.

- Iceberg Description. Ice Patrol uses a simplified code to describe the sighted icebergs. The code is tied to generalized sizes and shapes used by the iceberg drift model. The following code is used:

1 - Growler (less than 15 meters in length)
3 - Small Non-Tabular (between 15 and 60 meters in length)
4 - Small Tabular (between 15 and 60 meters in length)
5 - Medium Non-Tabular (between 60 and 122 meters in length)
6 - Medium Tabular (between 60 and 122 meters in length)
7 - Large Non-Tabular (greater than 122 meters in length)
8 - Large Tabular (greater than 122 meters in length)
9 - Radar Target

If Ice Patrol receives a visual iceberg sighting report without a size, medium is used. If Ice Patrol receives a visual iceberg sighting report without a description, non tabular is used. Non-tabular includes all iceberg shapes (examples; pinnacle, dry-dock, domed) except tabular.

- Last Model Analysis Position. The last model predicted position for the iceberg produced using analysis winds before the iceberg was removed from the active list. (An iceberg report can be removed from the active model list by being resighted or deleted by the operator.)

- Number of Icebergs represented by sighting record. In areas of heavy concentrations, groups of icebergs may be reported together. The number of icebergs in each sighting report is represented in this field.

- Days on Plot. This field indicates the number of days the iceberg sighting was drifted by the model before being removed from the list of active icebergs.

- Date of Last Model Position. The date of the position of the last model analysis position.

The Pre-Model Season File Years Portion of the Data Base

This portion of the data base covers the years 1960 to 1981. The below comments for each data field apply to this portion of the database:

- Iceberg Number. Although this number is intended to be unique for each ice season, some numbers were duplicated within the same season. All of the duplicate numbers which represent sightings of different icebergs were retained in the data base.

- Sighting Index. This field was left blank.

- Resight. Prior to about the late 1970s, Ice Patrol made few to no distinction between resights and new iceberg sightings.

- Sighting Source. When this portion of the data base was originally placed in computer-

ized format, three source choices were used; USCG Aircraft, USCG Ship, or other. In merging this portion of the data set, USCG ship reports were encoded as a "6" (ship reports). If the iceberg description was recorded as a radar target and the sighting source was an USCG aircraft, the sighting source was set to 1 (USCG Aircraft Radar/SLAR). If the iceberg description was a non-radar and the sighting source was an USCG aircraft, the sighting source was encoded as a 2 (USCG Aircraft Visual). The "other" category could include lighthouse reports, shipping reports, and reports from commercial aviation.

- Sighting Time. No sighting times were originally recorded for this portion of the data base and the sighting time field was set to 0000.

- Last Model Analysis Position. The iceberg drift model was not in use and this position was set to 0 North 0 West.

- Number of Icebergs. Original sightings during this period were classified in different manners with respect to the number of icebergs each sighting represented. The following code was used when the data for this period was computerized: 1 - Unknown, 2 - Numerous, and 3 - Many. If the actual number of icebergs the record represented was actually known, that number was entered. This number could be 1, 2, or 3. After about the mid-1970s, one record generally represented a single iceberg. When this portion of the data base was being entered, the original entry for the number of icebergs represented by the record was carried forward unless the number was greater than 20. In that case, the number of icebergs for the record was questionable and the number was set to one.

- Days on Plot. Set to zero.

- Date of Last Model Position.
Set to xxxxxx.

Model Season File Years Portion of the Data Base

During the early years of the model, not all of the data fields were used. The below comments for the data field refer to the years in parenthesis following the data field:

- Iceberg Index (1982-1984). During this period, a problem in the computer program logic occasionally allowed a "D" to placed where a "+" belonged. The error was carried forward into the data base and is not considered critical because of the proper use of the resight data field.

- Sighting Source (1982-1983). This field was not used by the model during this period. In creating the data base, the sighting source was set to "X - Unknown" for these records.

- Number of Icebergs (1982-1985). This field was not used in the model during this period. In creating the data base, this field was set to 1 for these records.

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Appendix E

Improvements in Ice Patrol's Drifter Program

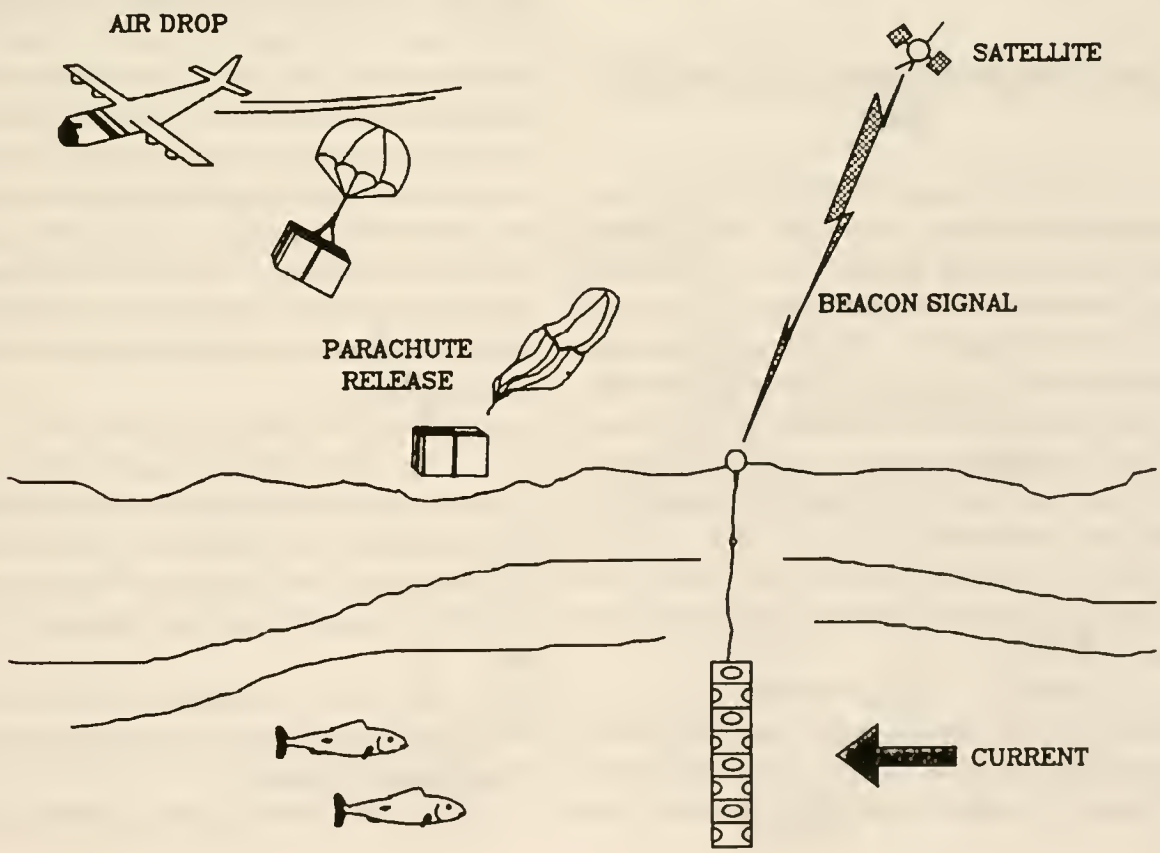
Geoffrey A. Trivers and Donald L. Murphy

Introduction

Since 1976, International Ice Patrol (IIP) has deployed satellite-tracked drifting buoys near the Grand Banks off Newfoundland, Canada. The buoys provide ocean current and sea surface temperature data for Ice Patrol's iceberg drift and deterioration models. From the program's inception through 1991, most of the buoys were 2 m spar hulls with window-shade drogues suspended 50 m below the surface. In the early years, the buoys were deployed from Ice Patrol research vessels, but starting in 1979, they were launched from U. S. Coast Guard HC-130s during regularly scheduled iceberg reconnaissance flights (See Fig. 1). An airborne delivery system allows Ice Patrol to monitor the currents throughout the ice season, and permits great flexibility in determining the buoy deployment locations and times.

The spar buoys, together with their air-deployment packages, are large, heavy and expensive. By 1990, a buoy rigged for air-deployment cost about $12,000-$14,000. In the same year, oceanographers completed development of a small, inexpensive buoy that had superior drift characteristics to the 2 m spar buoy (Sybrandy and Niiler, 1991). It consists of a 35 cm diameter spherical surface

Figure 1. Scheme for Airborne Deployment of WOCE Buoy



float that contains the electronics, a small subsurface float, and a holey-sock drogue. It is known as the World Ocean Circulation Experiment/Tropical Ocean and Global Atmosphere (WOCE/TOGA) Lagrangian drifter. It costs approximately $2500.

In 1990, Ice Patrol began to evaluate the WOCE buoys, and, in 1993, started using them in its operations. The only difference between the buoy described in Sybrandy and Niiler (1991) and Ice Patrol's is that the drogues on IIP's buoys are centered at 50 m. The original WOCE drifter, which is intended to be a mixed-layer drifter, has its drogue centered at 15 m.

The most important step in making the WOCE buoys usable by Ice Patrol was to develop a reliable air-deployment system. This appendix summarizes the development of IIP's WOCE drifter air-deployment package. It also provides a brief summary of IIP's WOCE drifter experience with the new drifters during late 1992 and 1993, the first season of operational use.

Airborne Delivery System For The WOCE Buoy

In most cases, WOCE drifters are launched from ships. They are usually packaged in cardboard boxes held together by water soluble tape. Inside the box, the buoy, tether and drogue are arranged so that the buoy self-deploys (without being fouled) after the cardboard box comes apart. The buoy and its box are designed to be dropped from a maximum height of 10 meters. This arrangement was used to deploy many of the drifters launched by ships of opportunity during the WOCE/TOGA study of the circulation of the Pacific Ocean.

Clearwater Instrumentation, Inc. of Massachusetts developed a WOCE/TOGA buoy air-deployment package in 1990. It was designed to be launched from relatively slow aircraft (< 100 knots). It simply consisted of an arrangement of nylon straps around the cardboard box and a small parachute, whose riser was cut free using a parachute cutter with a timer. This air-deployment package was used successfully several times.

In 1991, the US Navy developed a WOCE/TOGA buoy air-deployment package designed to be launched from an HC-130 at a speed of approximately 130 knots. In this package, the buoy was placed inside a tri-walled cardboard shipping container, which was attached to a wooden pallet using steel bands. The bottom of the pallet was covered with plywood to facilitate moving along the rollers on the cargo ramp of HC-130s. The entire package was then secured with a nylon parachute harness assembly. A detailed description of this air-deployment package is contained in Annex 3 of the Report of the Fifth Meeting of the WOCE/TOGA Surface Velocity Programme Planning Committee.

Although both of the previously described packages were used several times, there were no reported cases in which the escape of the buoy from the air-deployment package was observed from a surface vessel. This is an important issue, because IIP's experience in air-deploying larger buoys has shown that, even with relatively simple arrangements of straps, there is always a risk that a strap will tangle with and foul the tether. Therefore, IIP decided to develop and test its own air-deployment package.

The basic design criteria were:

(1) The package must be simple and robust enough to allow for a safe and effective air-deployment at speeds of 130-140 knots. (For example, the container must be heavy enough to depart the aircraft without hitting the tail.)

(2) The container must be sturdy enough to protect the buoy during the rigors of shipping and airdrop.

(3) The package must easily and reli-

ably self-deploy, i.e., come apart. This means that the number of bands and straps must be kept to a minimum.

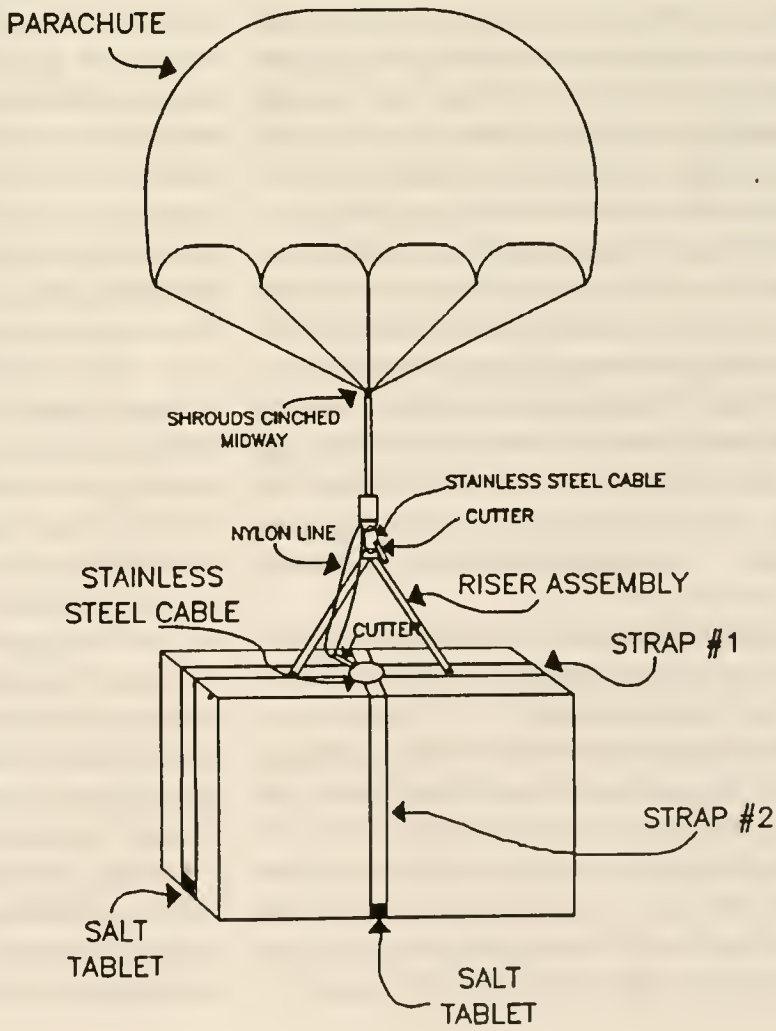
(4) The package must, to the maximum extent possible, use standard, off-the-shelf components.

IIP recognized that the main problem with air-deploying a WOCE drifter from an HC-130 would be the danger of striking the aircraft's tail with this large but light package. There are two ways to minimize this danger. First, the USCG HC-130 Standardization Unit (STAN Team) which is based in Elizabeth City, NC chose the deployment speed of 140 knots to minimize the nose-up attitude of the aircraft during the launch. The intent was to give a clear path to the package as it departs the cargo ramp. Second, weight was added to the package. This was simply a matter of placing the double-walled cardboard box (the WOCE/TOGA shipboard deployment box) inside a half inch plywood shipping/deployment box. This made the package about 200 pounds. Before launch, the screws that hold the plywood box together (they are marked with orange paint) are removed, allowing the sides to fall away after the straps are cut. Complete fabrication specifications for the container are given in Taylor and Murphy, 1992.

Figure 2 is a schematic representation of the air-deployment package. Two reefing line cutters, both with 10-second timers, are used to cut the parachute and straps from the plywood box.

Ice Patrol chose a drop altitude of 300 ft. The first 10-second cutter is armed when

Figure 2.
Air Deployment Schematic



the parachute opens, shortly after departing the aircraft. It cuts the parachute free about 20-30 feet above the water surface, allowing the box to free-fall to the surface. This minimizes the opportunity for the parachute to fall on the box and interfere with the buoy self-deployment process, an event that did occur when the 2 m spar buoys were launched, albeit infrequently.

The second cutter, whose pin is pulled when the parachute cuts free, cuts a stainless steel cable that holds the straps together. This is also a 10-second cutter, thus the straps are cut free 10 seconds after the parachute cuts free. Even if the parachute cuts free after splashdown, the parachute will collapse into the water and the differential movement of the box and the parachute will pull the pin of the second cutter. Once the straps are cut, the plywood sides fall away, exposing the cardboard box to the water. If both cutters fail, the two straps holding the plywood box together will come apart. Each strap has loop with a salt tablet, arranged so that the loop will pull out of a metal buckle when the salt dissolves.

The parachutes used in the testing of the drop package were 28-foot personnel parachutes. These parachutes, which can easily take the weight of the package, were obtained free-of-charge (unpacked) because they had exceeded their useful life for personnel drops. When the parachutes were packed, the shrouds were cinched up to increase the descent rate. This issue is discussed in detail in Taylor and Murphy, 1992.

Detailed instructions for the fabrication of the entire drop package are presented in Taylor and Murphy, 1992.

Two separate tests were conducted under the supervision of the STAN Team. The tests had two goals: first, to ensure that the buoy could be safely and successfully launched from the HC-130 and, second, to ensure that the buoy would self-deploy from its air-deployment package after entry into the water. In both tests, an aircraft and a surface vessel participated. The air-deployment and the subsequent self-deployment of the buoy were recorded on video tape. The buoys used in the test drops were manufactured by MetOcean Data Systems, Inc. of Dartmouth, Nova Scotia, Canada.

During the first test, the parachute deployed and cut free as designed, however, there were two problems. First, after the buoy package left the ramp, it flew up towards (but did not hit) the tail of the airplane. Second, the cardboard box which contains the buoy floated too high on the surface for much of the water soluble tape to be wetted. After three hours in one meter seas, the buoy had not deployed out of the box. Both problems were solved with minor modifications. The first was solved by adding about 50 pounds of additional weight to the drop package. (A Nansen bottle box filled with sand was screwed to the inside of the box.) This increased the weight of the air-deployment package to about 250 pounds, which is still within the weight capability of the 28-foot parachute. The second problem was solved by cutting the top and the corners of the cardboard box, allowing the box to open as soon as the plywood falls away.

The modifications were tested during a second airdrop test, which was completely successful. The package departed the aircraft cleanly and without flying upward, the two reefing line cutters functioned as planned, and the buoy deployed out of the cardboard box in a matter of minutes.

The parachutes used in the operational air-deployment system are 28-foot cargo parachutes, which are purchased through the Federal Stock System for about $65. They are equivalent to the parachutes used in the two tests. The cost of the entire air-deployment package, including the box, is about $400, with most of the cost in the parachute and the reefing line cutters. The box is constructed as a shipping container by the buoy manufac-

turer. The parachutes are packed and rigged by Coast Guard Air Station, Elizabeth City, North Carolina, the base of the HC-130 reconnaissance aircraft used for Ice Patrol. The straps are sewn by a local sail-maker. Finally, the package is assembled by Ice Patrol marine science technicians.

Drifter Deployments

Thus far, IIP has deployed ten WOCE drifters, two in 1992 and eight in 1993. Both the 1992 drifters were deployed from ships and were eventually recovered. One buoy, 2579, was recovered after 307 days of drift, the other, 2589, after 74 days. The operational air-deployments started in 1993, with seven buoys launched from HC-130s. One buoy (2586) was deployed from a ship. None of the 1993 buoys have been recovered. Table 1 summarizes the deployments.

All the operational air deployments were filmed and in all cases the aircraft circled the drop site to ensure that the buoy came out of the package. In one case, 2584, the parachute failed to open, resulting in a 300-foot free-fall to the surface. The buoy was observed to have come out of the package and it is still transmitting, although the drogue apparently detached 125 days after deployment.

There were a few cases in which the package splashed down before the parachute detached. In these cases, the buoy was observed to have come out of the package.

Buoy 2583 stopped transmitting two days after its deployment, despite the fact that the air launch was completely successful. There was an unexplained, rapid decline in the battery voltage. The remainder of the buoys provided records that were long enough for IIP operations, with an average lifetime of about 6 months (as of 1 November 1993). According to the submergence sensor, the drogue is not surviving as long as the buoy transmits, with an average drogue life of about 4 months (again, as of 1 Nov 1993). Since the time that a buoy remains in the Ice Patrol operations area (40-52 N, 39-56 W) is 3 to 4 months, this performance is satisfactory for IIP operations. However, the issue of the premature drogue failures needs to be explored.

Buoy drift data are presented in the Ice Patrol's 1993 Oceanographic Drifting Buoy Atlas, which is available upon request.

Summary

Ice Patrol has developed a reliable and inexpensive air-deployment package for WOCE drifters. The design is relatively simple and the package seems to be robust enough to survive high-speed air-deployment. There seems to be sufficient redundancy in the self-deployment system. Two tests and observations following seven operational deployments show that the buoys are coming out of the boxes. The drifters themselves appear to be robust, even able to survive a 300-foot free-fall. They are performing well once in the water, although further work needs to be done on the matter of drogue survival. Specifically, we hope to recover more drifters to determine the causes of the drogue failures.

Ice Patrol plans to deploy twelve to fifteen WOCE drifters during 1994. Most will be launched from aircraft using its newly developed air-deployment package.

References

Sybrandy, A. L. and P. P. Niiler, 1991. WOCE/TOGA Lagrangian Drifter Construction Manual. WOCE Report Number 63. Reference 91/6 Scripps Institution of Oceanography, LaJolla, CA 92093, 58pp.

Taylor, S. and D.L. Murphy, 1992. WOCE Buoy Air-Deployment Rigging and Launch Procedures. Unpublished Manuscript, International Ice Patrol, 1082 Shennecossett Rd., Groton, CT 06340-6095, 22pp.

WOCE/TOGA Surface Velocity Programme Planning Committee, 1992. Report of the Fifth Meeting (SVP-5). WOCE Report No. 87/92, IOS Deacon Laboratory, Book Road, Wormley, Godalming, Surrey Gu8 5UB, UK, 36pp.

TABLE 1: Summary of 1992-1993 WOCE drifter deployments

ID #	Date	Position deployed		Remarks
1992				
2579	14 Jul	52°14'N	051°01'W	Still transmitting when recovered after 307 days (drogue was missing)/ drogue survived 114 days
2589	15 Aug	41°01'N	066°15'W	Still transmitting when recovered after 74 days (drogue was attached)
1993				
2585	28 Feb	44°40'N	048°51'W	Still transmitting/ drogue survived 38 days
2580	24 Mar	45°29'N	046°59'W	Still transmitting/ drogue attached
2584	06 Apr	44°45'N	047°37'W	Parachute failed to open/ still transmitting/ drogue survived 125 days
2607	18 May	48°30'N	047°00'W	Still transmitting/ drogue survived 101 days
2587	18 May	47°01'N	046°34'W	Still transmitting/ drogue attached
2576	02 Jun	47°00'N	047°20'W	Stopped transmitting 15 Oct/ drogue survived 98 days
2583	11 Jun	50°39'N	049°59'W	Stopped transmitting 13 Jun
2586	11 Jul	52°15'N	053°15'W	Deployed from USCGC BITTERSWEET/ still transmitting/ drogue attached

Note: Information presented in the preceding table is as of 1 November 1993. The determination of when the drogue detached was based on the submergence sensor showing zero or near zero submergence of the surface float.

Appendix F

IIP Iceberg Resights 1992 and 1993 Seasons

Bruce E. Viekman

International Ice Patrol receives iceberg data from several sources. Reports from IIP's own reconnaissance, from Canadian Ice Patrol and Department of Fisheries and Oceans flights (conducted by Atlantic Airways), and from ships are combined to produce iceberg warnings to mariners. An important aspect of IIP's use of ice reports is a process called a 'resight' which is where new reports are correlated with icebergs already 'on plot'. The intent of this process is to avoid interpreting every reported iceberg as an iceberg that has never been seen before. If the reported iceberg is determined to have been seen before, the forecast position of the iceberg is updated using the new data. Otherwise, the iceberg is entered as a new iceberg.

IIP began use of the iceberg Data Management and Prediction System (DMPS) at the start of the 1993 season. This system affords IIP the ability to resight icebergs graphically. The DMPS displays the icebergs on plot along with their reported size, error circle, and drift track. The system displays new sightings simultaneously with the icebergs already 'on plot.' The IIP watch officer then decides to either correlate the most recent iceberg sightings with those on plot based on size comparisons, position differences, and drift or add a new iceberg. The system used before the 1992 season required manual plotting of old icebergs to correlate them with the latest sightings. Effective use of multiple iceberg reports was therefore difficult, particularly in areas of heavy iceberg concentration. Using the new system, operators should be able to resight icebergs much more effectively.

The procedures used to resight icebergs have several effects. First, the process influences the total number of icebergs reported by IIP for the year. If resights are conducted more frequently, the number of new icebergs added to the model will decrease, thereby lowering the totals. More frequent resights should also increase the quality of IIP drift predictions of icebergs near the limits. Murphy and Anderson (1985) found that drift prediction errors increase with time in a roughly linear manner. Therefore, decreased time since sighting should result in decreased predicted position error. The experiments comparing IIP's model with observed drift were conducted by tracking a known iceberg. Operationally, the correlations are done without such positive identification.

To evaluate the changes in the resight process caused by the use of the DMPS, an investigation of resights was conducted using records from the 1992 and 1993 ice seasons. The iceberg sighting data base was used to compare the changes in resighting frequency between the 1993 ice season and the 1992 season. The geographic distribution of resights was also computed.

The 1993 ice season was much more severe than 1992. IIP uses the number of icebergs which drift south of 48N as an indication of season severity. In 1993, the third-heaviest season on record, IIP estimated that 1753 icebergs crossed this latitude, while 876 did so in 1992. The 10-year average (1983-1992) of icebergs crossing 48N is 927.

Method

The IIP iceberg sighting data base was used as the source of data for this analysis. This record contains all of the iceberg sightings which are entered into the drift model during the year. [This file is available from the National Snow and Ice Data Center, Boulder, Colorado.] It should be noted that this listing is a subset of all the sightings received by IIP during the year - the decision on which sightings are entered into the data base is made by the watch officer based on the iceberg density in the area, the quality of the reported information, and the geographic area. For example, icebergs reported close to the Newfoundland shore north of 49N have little probability of drifting into the North Atlantic shipping lanes, and may therefore not be entered into the iceberg data base.

The iceberg listing identifies each iceberg by a number, and gives the sighting position, source, description, and last predicted drift position for the target. Resights of the iceberg results in a new entry using that same iceberg number.

The iceberg listing was processed to bin all sightings by latitude/longitude block. The distance of the position correction was computed, and averages computed for all blocks where more than one resight was found.

Results

The effect of using the DMPS system is most clearly shown in the frequency with which icebergs were resighted (Table I). In 1992, a given iceberg had a 30.2% chance of an adjustment to its position occuring over its

Table I

Iceberg Resights - 1992 And 1993

Percentages are calculated based on the total number of icebergs identified for the given year.

	1992		1993	
Targets Entered in System	1618		4400	
Sightings Merged	2457		8058	
	Number	Percent	Number	Percent
Total Icebergs Resighted	488	30.2	1904	43.3
# of Icebergs resighted x times				
1	290	17.9	991	22.5
2	109	6.7	495	11.3
3	53	3.3	206	4.7
4	23	1.4	96	2.2
5	7	0.4	64	1.5
6	3	0.2	24	0.5
7	2	0.1	15	0.3
8	0		7	0.2
9	1	0.1	4	0.1
10	0		1	—
11	0		0	
12	0		0	
13	0		1	—

lifetime. Most icebergs which were resighted were updated once. In 1993, the probability of an iceberg being resighted had increased to 43.3%. As in 1992, most icebergs resighted were updated once. 20.8% of the icebergs were resighted more than once in 1993, compared with 12.3% the year before. A single iceberg was resighted 13 times in 1993 but this was an anomaly due to its location in an area of weak currents along the Newfoundland shore. Its position was such that it was repeatedly detected by Atlantic Airways flights.

The mean distance change of the iceberg position on resight in 1992 was 24.1 nm. The distance change was less than half (10.4 nm) in 1993. The decreased distance was most apparent along the east flank of the Grand Banks: in 1992 the mean distance change was approximately 25 nm, while the mean was 12 nm in 1993. The high iceberg density in 1993 contributes to this decrease as more icebergs on plot were available to correlate with the most recent sightings. Nearer the typical limits of all known ice, the distance changes were similar between years, the mean being 15-25 nm.

The latitudinal distribution of sightings and resights in the two study years was also investigated (Table II). The number of icebergs added can be determined by subtracting the number of resights from the number of sightings. In 1992, sightings were more frequently treated as new icebergs. For each 1992 resight there were 1.9 icebergs added. With the change to the DMPS, there were 1.2 icebergs added for each resight. This difference was most pronounced north of 49N, where few resights were performed in 1992. Most resights occur in the area known as 'iceberg alley', where the Labrador current flows southward along the east side of the Grand Banks.

Table II
Sightings Relative to Resights
Sightings include icebergs and radar targets.

	Sightings		Resights		Sightings/ Resights	
Latitude	1992	1993	1992	1993	1992	1993
52 - 53 N	3	63	0	18	—	3.5
51 - 52 N	260	1256	21	344	12.4	3.7
50 - 51 N	146	854	31	333	4.7	2.6
49 - 50 N	190	739	39	324	4.9	2.3
48 - 49 N	534	859	174	312	3.1	2.8
47 - 48 N	487	1259	218	637	2.2	2.0
46 - 47 N	316	1125	143	681	2.2	1.7
45 - 46 N	190	621	94	387	2.0	1.6
44 - 45 N	168	667	61	362	2.8	1.8
43 - 44 N	80	400	34	181	2.4	2.2
42 - 43 N	69	144	17	73	4.1	2.0
41 - 42 N	14	30	3	14	4.7	2.1
40 - 41 N	0	3	0	1	—	3.0
Total	2457	8020	835	3667	2.9	2.2

Discussion

The rate at which icebergs are resighted strongly influences the measures of ice season severity. If icebergs had been resighted at the same rate in 1993 as they had been in 1992, the total number of icebergs entered into the system would have reached 5250, an increase of 850. While the icebergs crossing 48N cannot be directly estimated from this process, the season would have probably surpassed 1984 (2202 icebergs) as the heaviest on record.

Other factors also influence the iceberg totals in the study years. In 1993, all reported iceberg sightings from reconnaissance were used. Before the DMPS system representative icebergs from the reports would be entered into the model, reducing the number of icebergs added. No effort has been made here to investigate the relative reconnaissance level in each year or to normalize the iceberg statistics for the use of new sensors or tactics.

The change in computer systems allows IIP to more accurately correlate new sightings with old icebergs, and more effectively determine if icebergs were previously detected. This change is the most recent in the factors affecting IIP's annual iceberg count (See Anderson, 1993, this volume, for past changes). Users of these data must consider these technological changes as a part of any analysis.

References

Murphy, D.L. and I. Anderson, 1985. An Evaluation of the International Ice Patrol Drift Model. Appendix D of Report of the International Ice Patrol in the North Atlantic. Bulletin No. 71. CG-188-40. International Ice Patrol, Avery Point, Groton, CT. 90 pp.