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**United States
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Report of the International Ice Patrol in the North Atlantic

INTERNATIONAL
ICE PATROL

1984 Season
Bulletin No. 70
CG-188-39

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Bulletin No. 70

REPORT OF THE INTERNATIONAL ICE PATROL SERVICES IN THE NORTH ATLANTIC OCEAN

Season of 1984

CG-188-39

FOREWORD

Forwarded herewith is Bulletin No. 70 of the International Ice Patrol describing the Patrol's services, ice observations and conditions during the 1984 season.

M. J. O'Brien

M. J. O'BRIEN
Acting Chief, Office of Operations

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International Ice Patrol 1984 Annual Report

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Summary

From 23 March to 7 September 1984, the *International Ice Patrol* (IIP), a unit of the U.S. Coast Guard, conducted the International Ice Patrol Service, which has been provided annually since the sinking of the RMS TITANIC on April 15, 1912. During past years, Coast Guard ships and/or aircraft have patrolled the shipping lanes off Newfoundland within the area delineated by 40°N - 52°N, 39°W - 57°W, detecting icebergs and warning mariners of these hazards. During the 1984 Ice Patrol season, Coast Guard HC-130 aircraft deployed out of Gander, Newfoundland to search for icebergs in the Grand Banks region of the North Atlantic. These aircraft flew 78 ice reconnaissance sorties, logging over 476 flight hours. New detection equipment, the AN/APS-135 Side-Looking Airborne Radar (SLAR), was introduced into Ice Patrol duty during the 1983 season. It proved to be an excellent tool for the detection of both icebergs and sea ice, and alone provided 78 percent of the 1984 sightings on IIP reconnaisance flights. A total of 2202 icebergs were estimated south of 48°N latitude, a new record. The record number of icebergs south of 48°N this year was the result of colder than normal conditions (see Environmental Conditions section) and increased iceberg detection due to the use of SLAR (see Appendix C). To evaluate the iceberg drift and deterioration models used by International Ice Patrol, an oceanographic cruise was conducted by USCGC HORNBEAM. This cruise conducted the first hydrographic survey since 1978, and included drift and deterioration studies on a medium iceberg (see Appendix B).

Introduction

This is the 70th annual report of the International Ice Patrol Service in the North Atlantic. It contains information on ice conditions and Ice Patrol operations for 1984. The U.S. Coast Guard conducts the International Ice Patrol Service in the North Atlantic under the provisions of Title 46, U.S. Code, Sections 738, 738a through 738d; and the International Convention for the Safety of Life at Sea (SOLAS), 1960, regulations 5-8. This service has been provided annually since the sinking of the RMS TITANIC on April 15, 1912. Commander, International Ice Patrol under Commander, Coast Guard Atlantic Area, directed the International Ice Patrol from offices located at Groton, Connecticut. The unit analyzes ice and environmental data, prepares the daily ice bulletins and facsimile charts, and replies to any requests for special ice information. It also controls the aerial Ice Reconnaisance Detachment and any surface patrol cutters when assigned, both of which patrol the southeastern, southern, and southwestern limits of the Grand Banks region (40°N to 52°N) and 39°W to 57°W for icebergs. The International Ice Patrol makes twice-daily radio broadcasts to warn mariners of the limits of iceberg distribution.

Vice Admiral Wayne E. Caldwell, U.S. Coast Guard, was Commander, Atlantic Area until he was relieved on 1 July 1984. Vice Admiral P.A. Yost was Commander, Atlantic Area from then until the season's end on 7 September 1984. Commander Norman C. Edwards, Jr., U.S. Coast Guard, was Commander, International Ice Patrol during the 1984 Ice Patrol season.

Two pre-season deployments were made from 31 January - 3 February and 7-14 March 1983 to determine the early season iceberg distribution. Based on these trips, regular deployments started on 21 March with the 1984 season officially opening on 22 March.

From that date until 3 September 1984, an aerial Ice Reconnaisance Detachment (ICERECDET) operated from Gander, Newfoundland one week out of every two. The season officially closed on 7 September 1984.

No U.S. Coast Guard cutters were deployed to act as surface patrol vessels this year. The USCGC HORNBEAM was deployed to provide oceanographic support to Ice Patrol from 26 June - 31 July.

During the 1984 season, an estimated 2202 icebergs drifted south of 48°N latitude. Table 1 shows monthly estimates of icebergs that crossed 48°N

Table 1. Icebergs South of 48° North

	1984	Total 1946-84	Average 1946-84	Total 1900-84	Average 1900-84
OCT	0	2	0	109	1
NOV	0	4	0	110	1
DEC	0	13	0	93	1
JAN	0	74	2	194	3
FEB	0	437	11	888	16
MAR	101	1397	36	3499	56
APR	953	4423	113	9268	150
MAY	484	3842	99	11025	169
JUN	227	2260	58	5778	92
JUL	335	900	23	2096	31
AUG	93	197	5	586	8
SEP	9	19	0	265	3
Annual total	**2202**	**13568**	**347**	**33911**	**399**

Data Collection and Dissemination

Ice Reconnaisance Detachment Deployments	No. of Flights	Number of Hours Flown
Pre-season	13	75.2
In-season	93	543.1
Post-season	2	10.7
Total	108	629.0

Note: In-season ICERECDET flights include transit and logistics flights to and from Gander during the Ice patrol season.

There were 78 sorties dedicated solely to ice reconnaisance with a total of 476.1 flight hours. They are summarized as follows:

Month	Number of Sorties	Flight Hours
FEB	3	15.5
MAR	10	60.7
APR	16	101.0
MAY	15	93.6
JUN	10	59.5
JUL	10	60.1
AUG	12	74.8
SEP	2	10.9
TOTAL	78	476.1

Table 2.
Aircraft Deployments from 1 October 1983 to 30 September 1984

During the 1984 Ice Patrol year (from 1 October through 30 September 1984), 108 aircraft sorties were flown in support of the International Ice Patrol. These included pre-season flights, ice observation and logistics flights during the season, and post-season flights. Pre-season flights determined iceberg concentrations north of 48°N, necessary to estimate the time when icebergs would threaten the North Atlantic shipping lanes in the vicinity of the Grand Banks of Newfoundland. During the active season, ice observation flights located the southwestern, southern, and southeastern limits of icebergs. Logistics flights were necessary for unusual aircraft maintenance. Post-season flights were made to retrieve parts and equipment from Gander and to close out all business transactions from the season.

U.S. Coast Guard aircraft, deployed from Coast Guard Air Station Elizabeth City, North Carolina, conducted all the aircraft missions. SLAR-equipped HC-130 aircraft were utilized exclusively for aerial ice reconnaisance, HU-25A aircraft were used on two logistics flights, and the VC-4A aircraft was utilized for post season deployment. Table 2 shows aircraft utilization during the 1984 season.

U.S. Coast Guard Communications Station Boston, Massachusetts, NMF/NIK, was the primary radio station used for the dissemination of the daily ice bulletins and facsimile charts after preparation by the Ice Patrol office in Groton. Other transmitting stations for the 0000Z and 1200Z ice bulletins included Canadian Coast Guard Radio Station St. John's/VON, Canadian Forces Radio Station Mill Cove/CFH, and U.S. Navy LCMP Broadcast Stations Norfolk/NAM; Thurso, Scotland; and Keflavik, Iceland.

Canadian Forces Station Mill Cove/CFH as well as AM Radio Station Bracknell/GFE, United Kingdom are radio facsimile broadcasting stations which used Ice Patrol limits in their broadcasts. Canadian Coast Guard Radio Station St. John's/VON provided special broadcasts.

The International Ice Patrol requested that all ships transiting

Table 3
Iceberg and SST Reports

Number of ships furnishing Sea Surface Temperature (SST) reports	86
Number of SST reports received	353
Number of ships furnishing ice reports	220
Number of ice reports received	586
First Ice Bulletin	230000Z MAR 84
Last Ice Bulletin	071200Z SEP 84
Number of facsimile charts transmitted	169

the area of the Grand Banks report ice sightings, weather, and sea surface temperatures via U.S. Coast Guard Communications Station Boston, NMF/NIK. Response to this request is shown in Table 3, and Appendix A lists all contributors. Commander, International Ice Patrol extends a sincere thank you to all stations and ships which contributed.

Table 4
Sources of International Ice Patrol Iceberg Reports

Sighting Source	No. of Sightings	% of Total
Coast Guard SLAR	2487	49.3
Coast Guard Visual	722	14.3
Canadian Radar	10	0.2
Canadian Visual	48	1.0
Commercial Radar	367	7.3
Commercial Visual	1157	22.9
Mobil Oil Canada, LTD	171	3.4
Other	31	0.6

Environmental Conditions, 1984 Season

Weather in Labrador and east Newfoundland during the 1984 International Ice Patrol season tended to be cooler and wetter than normal (Table 5). The weather stations listed were selected to give a cross section of weather patterns throughout the province. Months that ran contrary to the cool, wet trend were February and May, which were warmer than normal, and July, which was warmer and drier than normal. The overall wet, cool trend had the effect of allowing sea ice to persist longer than normal in the Davis Strait and Labrador Sea, thereby offering some protection to icebergs in that region.

January: The Iceland Low was deeper than normal during January and the distribution of pressure funnelled in cold continental air (Figure 1), causing the air temperatures to be well below normal (Table 5).

February: The Iceland Low was again deeper than normal, but pressure patterns allowed warm, moist marine air to flow over the Maritimes (Figure 2) and temperatures and precipitation were above normal.

March: Average surface flow during the month was almost the opposite of the normal pattern (Figure 3) with easterly and northeasterly winds, which brought cool, moist marine air over the Grand Banks and the Maritimes, resulting in slightly lower than normal temperatures and greater than normal precipitation.

April: The unusual high pressure system over Labrador in April (Figure 4), coupled with lows south of the Avalon Peninsula and over Iceland, caused northeasterly flow across the Labrador coast and easterly flow across Newfoundland and the Grand Banks, with above average precipitation on the Avalon Peninsula (St. John's) and below average temperatures throughout the region (Table 5).

May: Southwesterly flow over Newfoundland and Labrador (Figure 5) brought in marine air and raised temperatures and precipitation above normal.

June: Under the influence of low pressure over the Labrador Sea (Figure 6), southerly flow over the region brought in marine air which was cooler and moister than the continental air normal for June.

July: With near normal pressures (Figure 7), precipitation was slightly below normal and temperatures slightly above normal during July, suggesting more of a continental influence than normal.

August: With the cooling of the northern continental air mass that normally takes place in August, a stronger than normal marine influence (Figure 8) brought warmer temperatures and more precipitation over the region.

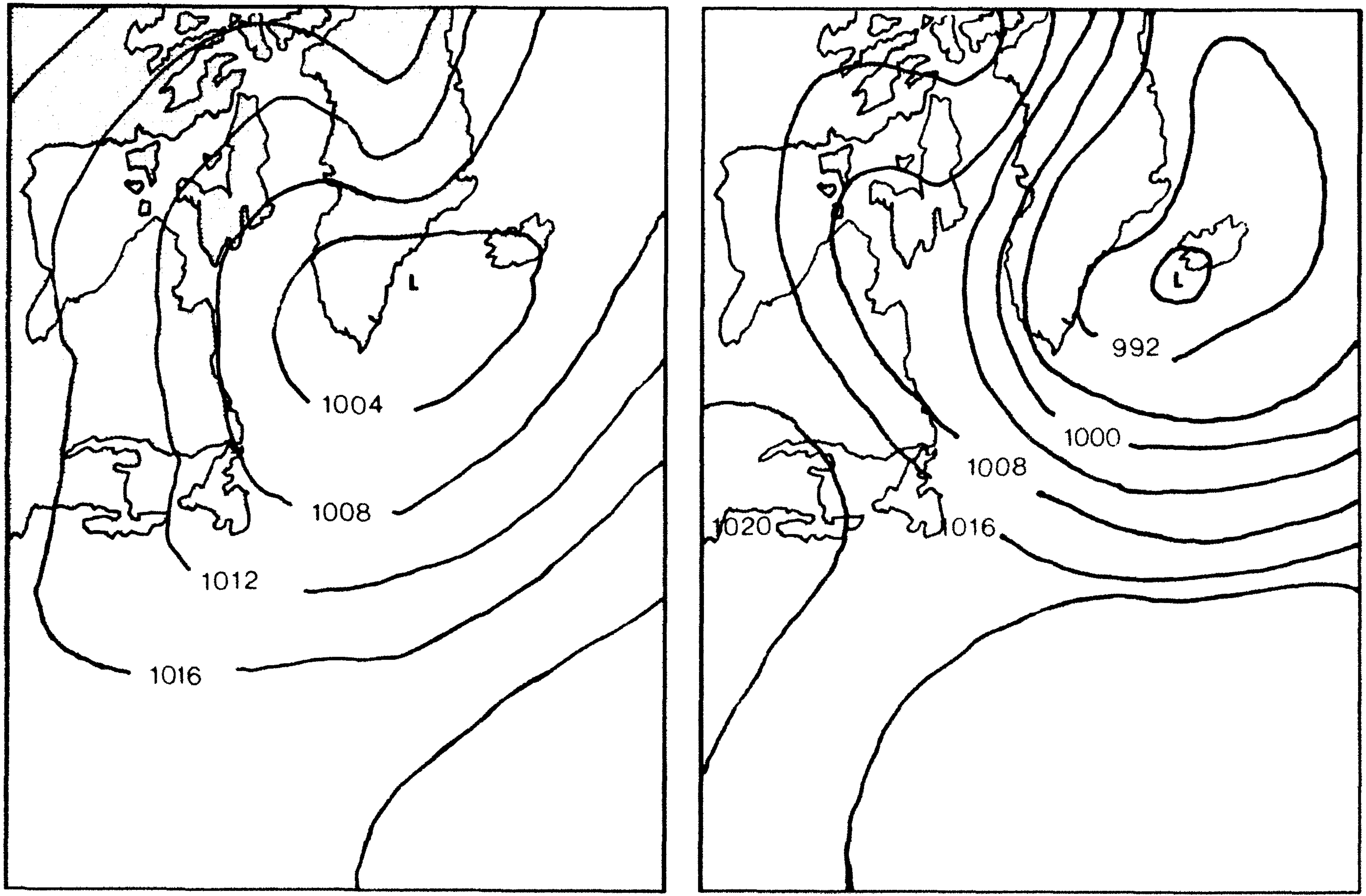
September: The Bermuda High was farther south than normal in September (Figure 9), bringing marine air into the area and causing above normal precipitation with near normal temperatures.

Table 5
Environmental Conditions for 1984 International Ice Patrol Season

		Temp °C				
	Station	Monthly Mean	Diff. from Norm.	Total Precipitation (mm)	% of Normal Precipitation	% of Normal Snowfall
OCT 1983	Hopedale	1.8	-0.6	47.0	75	73
	Goose	2.6	-0.1	91.3	119	87
	Gander	6.9	0.9	42.2	40	25
	St. John's	7.7	0.8	214.6	147	27
NOV	Hopedale	-3.8	-0.6	99.1	173	159
	Goose	-4.9	-1.1	155.1	206	264
	Gander	1.3	0.5	126.4	118	168
	St. John's	2.4	-1.0	118.9	73	84
DEC	Hopedale	-13.6	-2.9	109.9	194	181
	Goose	-15.3	-2.3	126.7	74	215
	Gander	-4.4	-0.6	84.4	78	92
	St. John's	-1.5	0.0	111.7	69	53
JAN 1984	Hopedale	-22.4	-6.6	34.4	55	48
	Goose	-23.0	-6.6	51.8	70	82
	Gander	-9.4	-3.2	157.7	145	158
	St. John's	-5.5	-1.6	188.8	121	65
FEB	Hopedale	-17.7	-2.6	111.6	223	174
	Goose	-14.4	0.1	90.7	150	219
	Gander	-4.7	2.1	142.7	143	67
	St. John's	-1.9	2.6	151.1	108	10
MAR	Hopedale	-12.1	-1.6	100.1	181	149
	Goose	-10.3	-1.7	82.9	115	116
	Gander	-3.9	-0.4	174.4	158	160
	St. John's	-1.6	0.7	142.7	108	173
APR	Hopedale	-6.9	-2.0	25.0	54	54
	Goose	-3.6	-1.9	50.8	83	108
	Gander	-0.6	-1.5	97.8	105	79
	St. John's	-0.2	-1.4	235.2	203	51
MAY	Hopedale	1.8	0.4	68.0	134	119
	Goose	5.8	0.8	89.6	140	143
	Gander	8.9	2.7	92.2	132	31
	St. John's	8.3	2.9	156.0	153	*
JUN	Hopedale	4.7	-1.7	71.8	112	126
	Goose	9.3	-2.0	120.6	130	432
	Gander	9.4	-2.4	115.9	144	36
	St. John's	9.9	-1.0	144.0	168	*
JUL	Hopedale	9.6	-0.9	178.3	211	*
	Goose	16.8	1.0	91.8	87	*
	Gander	18.0	1.5	63.2	92	*
	St. John's	17.9	2.4	41.4	50	*
AUG	Goose	23.0	3.7	23.6	23	*
	Gander	16.6	1.0	181.8	187	*
	St. John's	17.3	2.0	204.3	168	*
SEP	Nain	5.1	-----	134.3	-----	-----
	Goose	13.0	-0.7	121.3	137	*
	Gander	14.9	-0.7	113.4	140	*
	St. John's	16.9	1.0	157.8	141	*

* No snowfall recorded during this month.

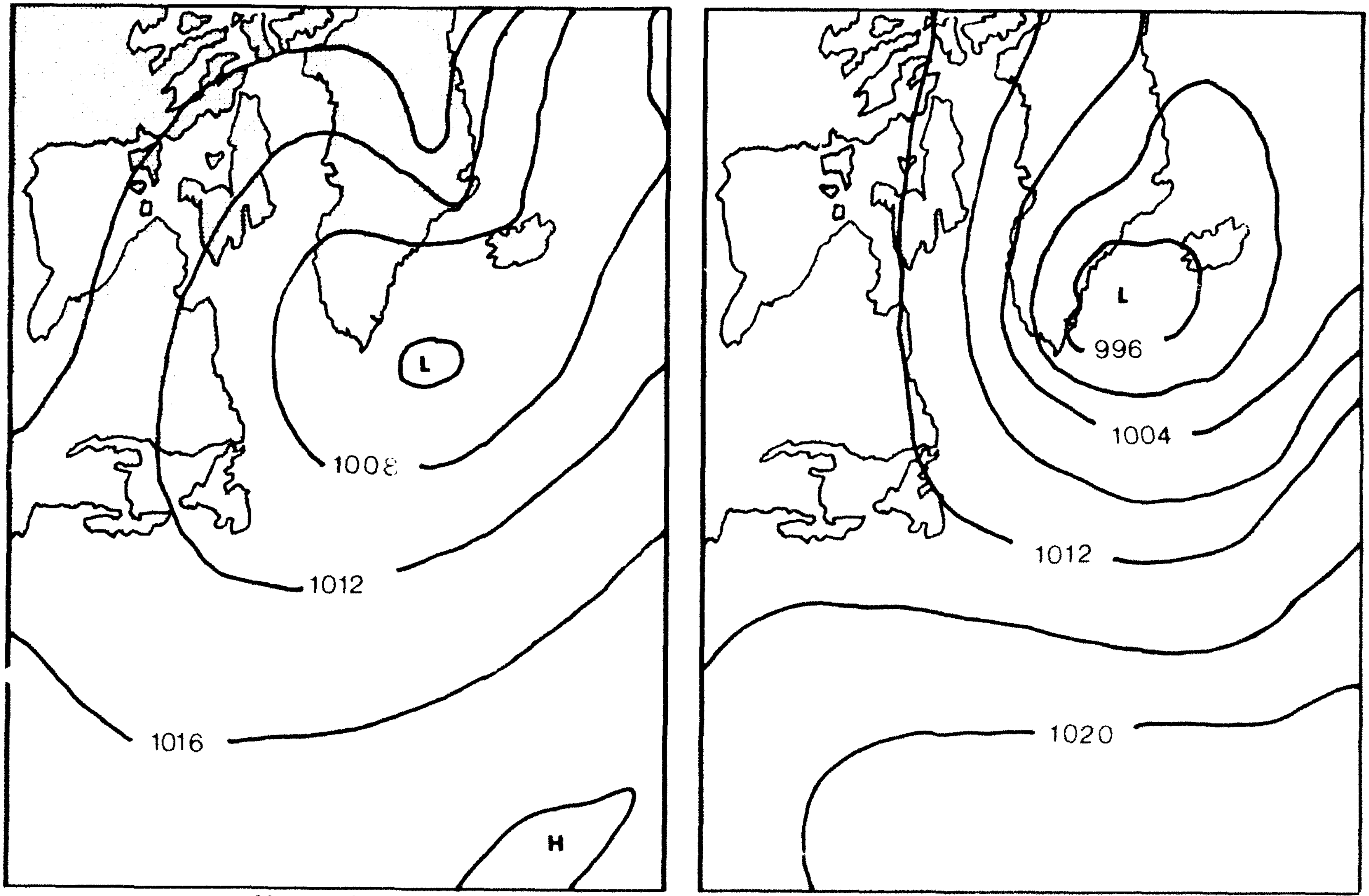
NOTE: In August 1984, the Canadian weather reporting at Hopedale was discontinued. The new station is at Nain on the Labrador coast, approximately 150km northwest of Hopedale.



Normal

January 1984

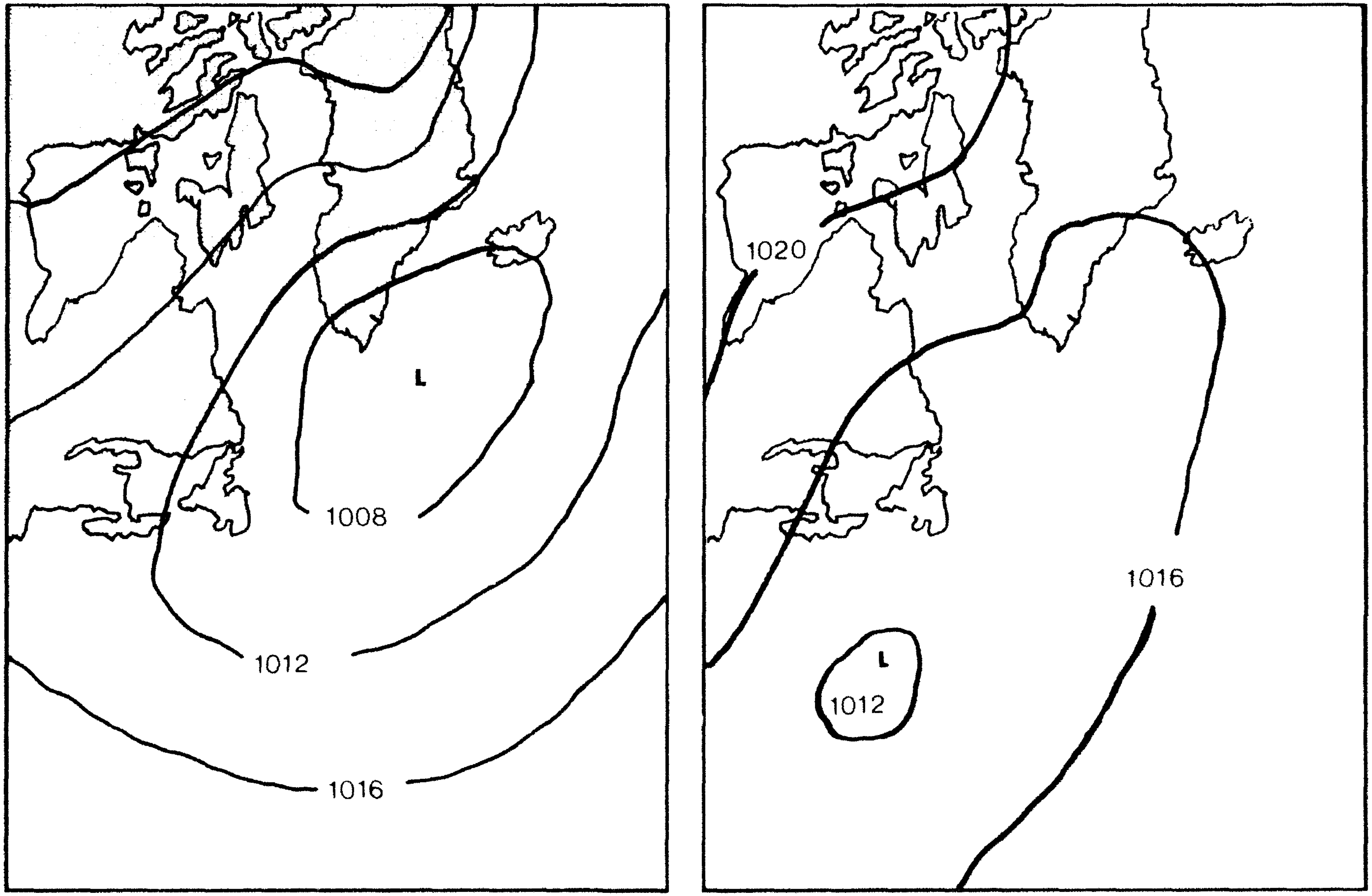
Figure 1



Normal

February 1984

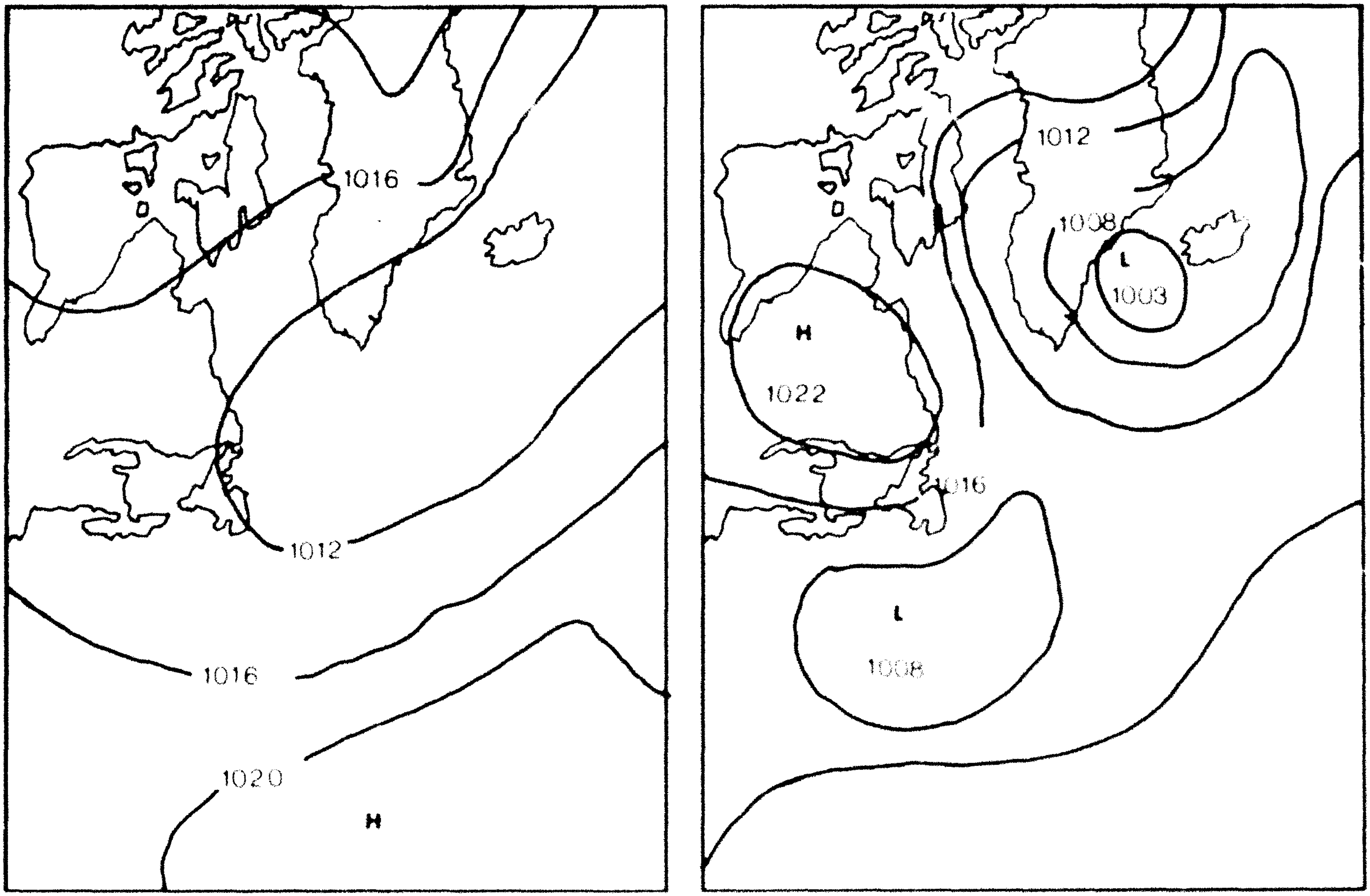
Figure 2



Normal

March 1984

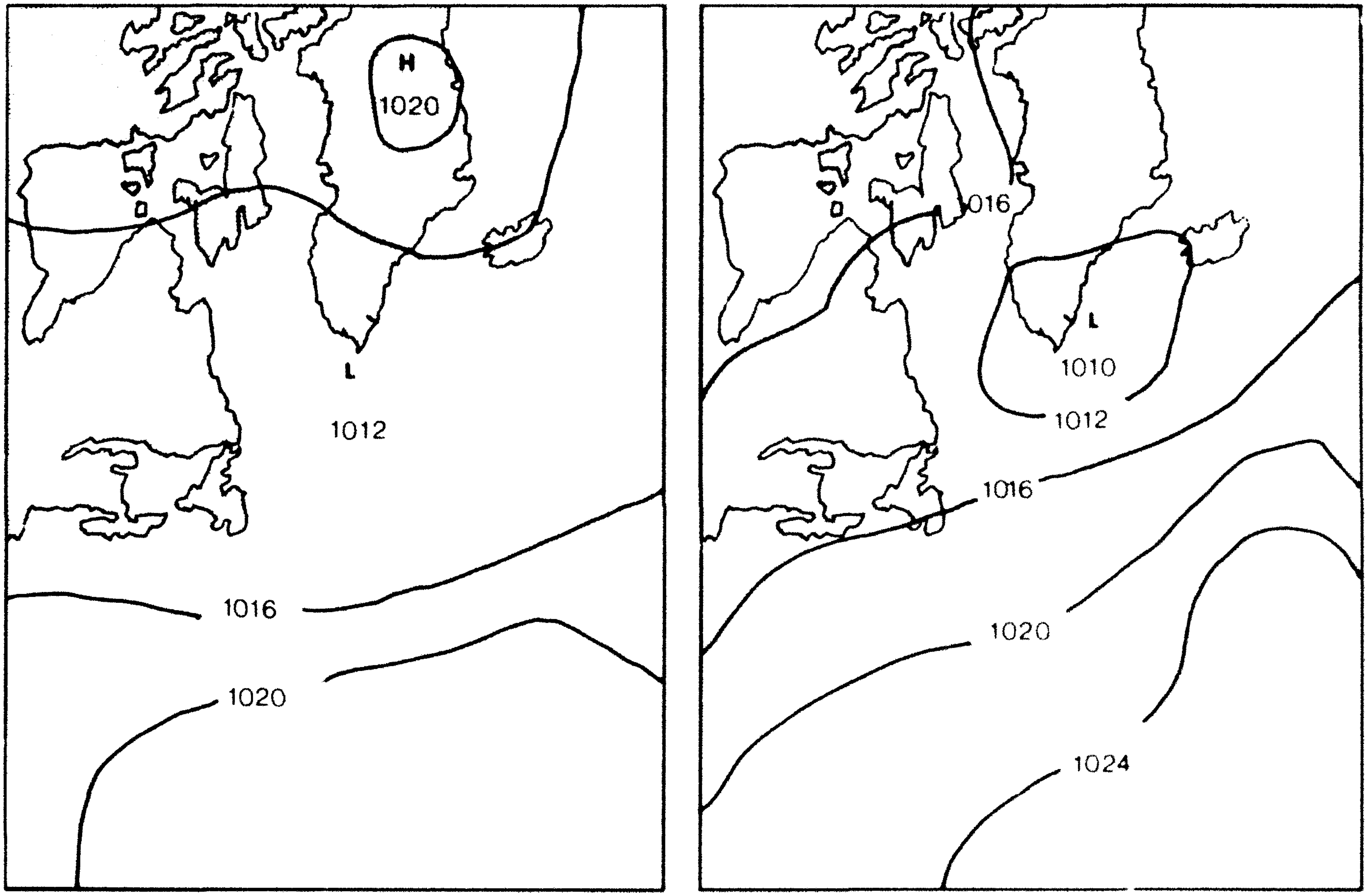
Figure 3



Normal

April 1984

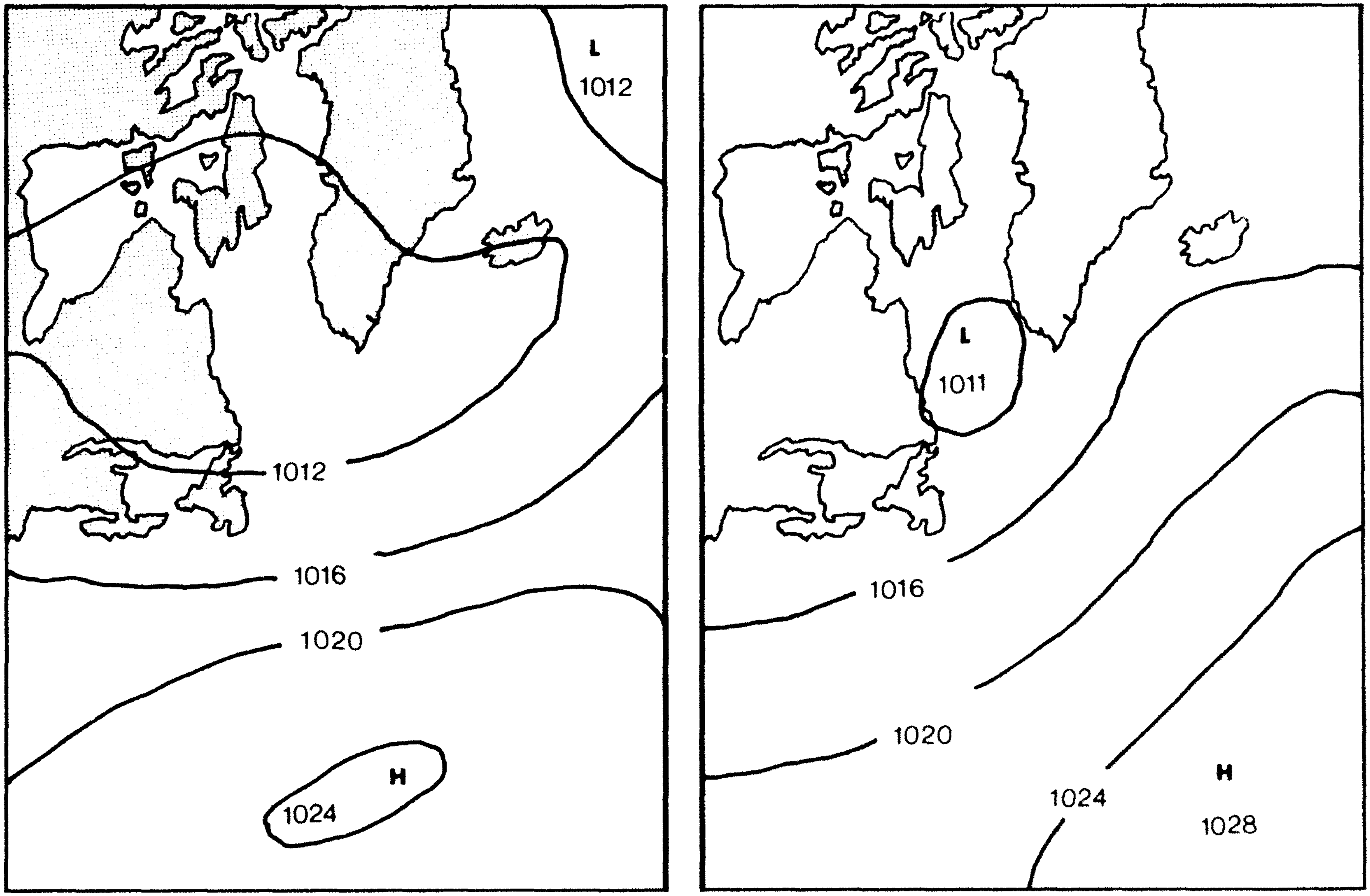
Figure 4



Normal

May 1984

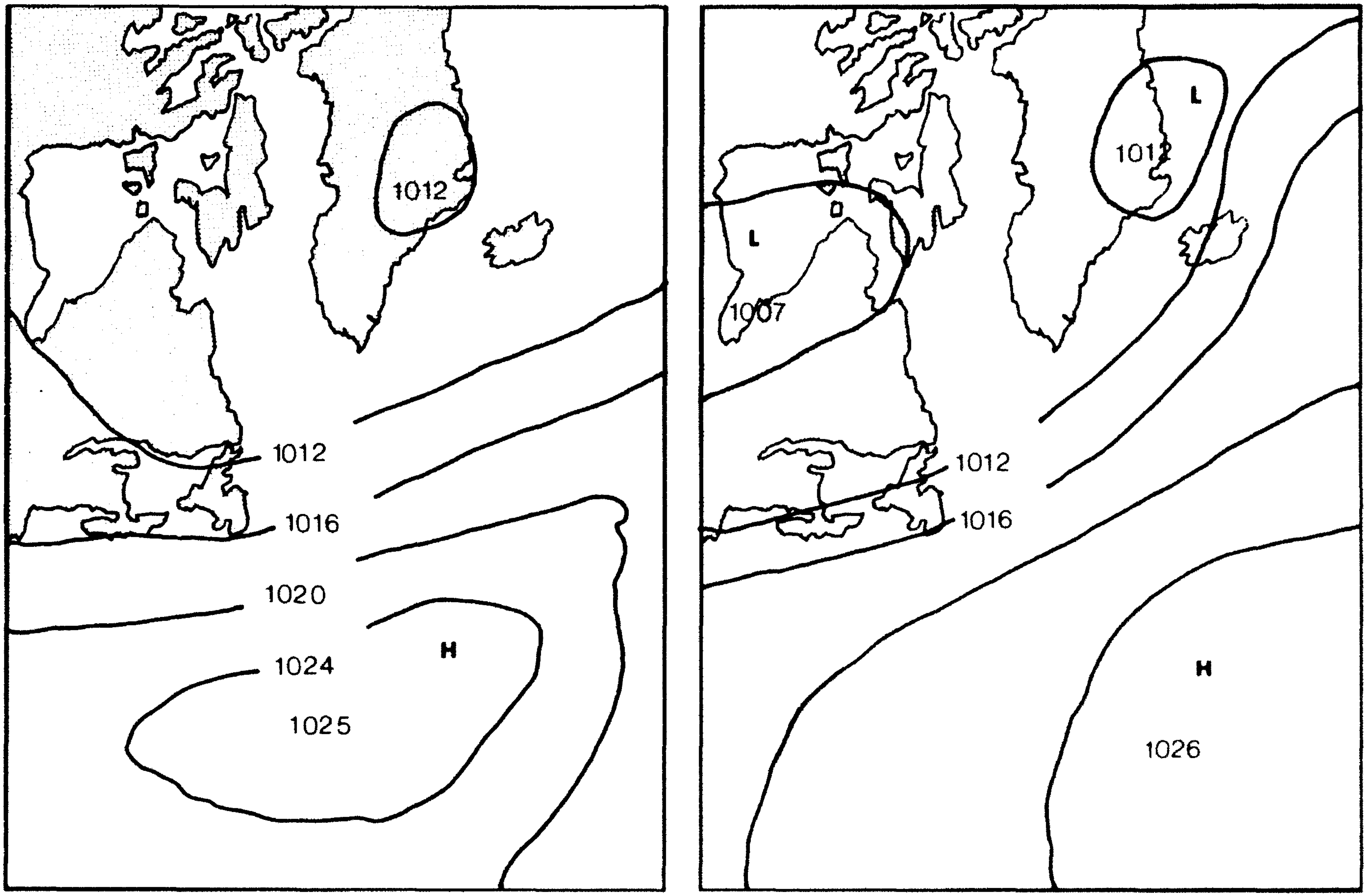
Figure 5



Normal

June 1984

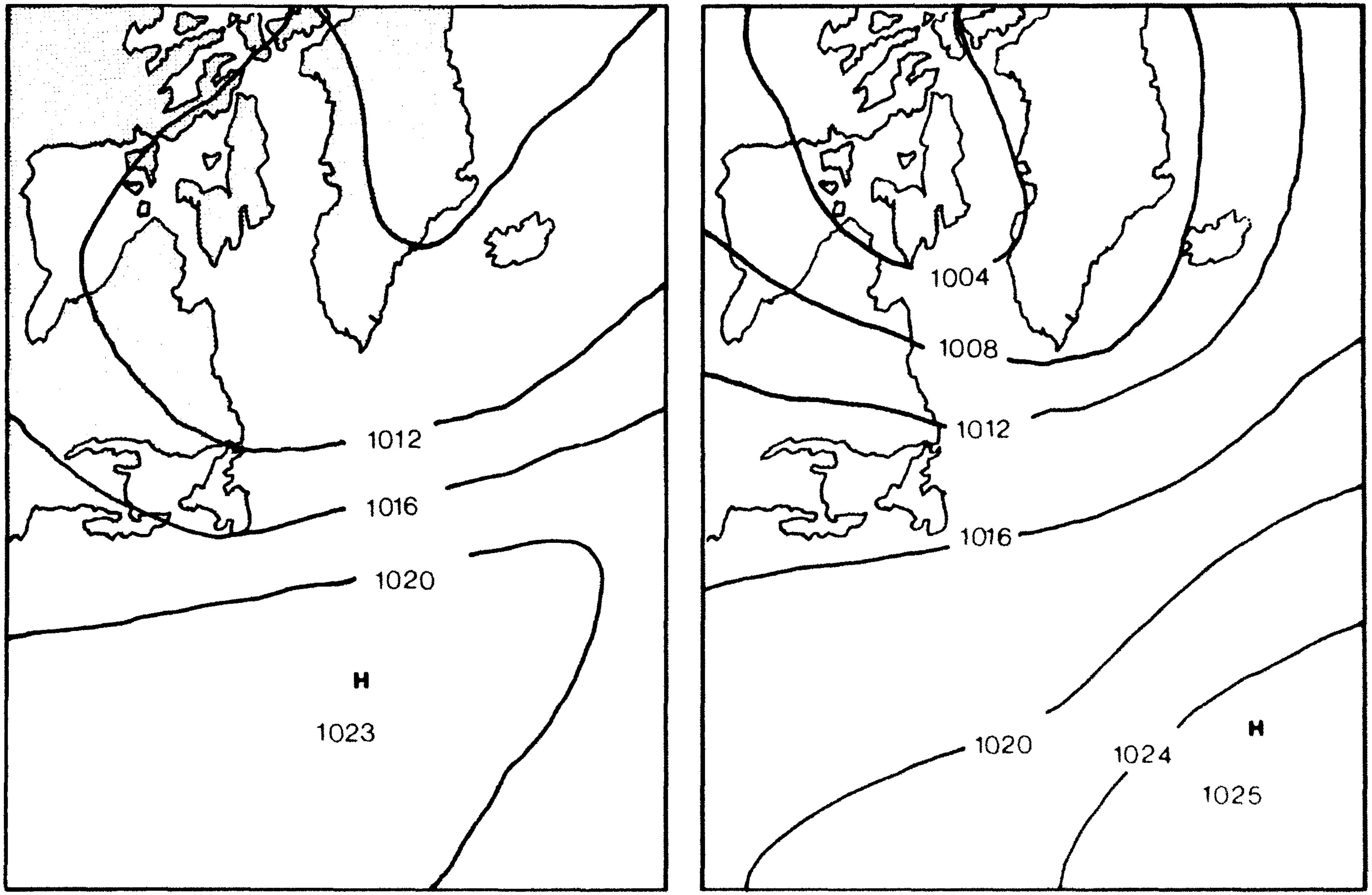
Figure 6



Normal

July 1984

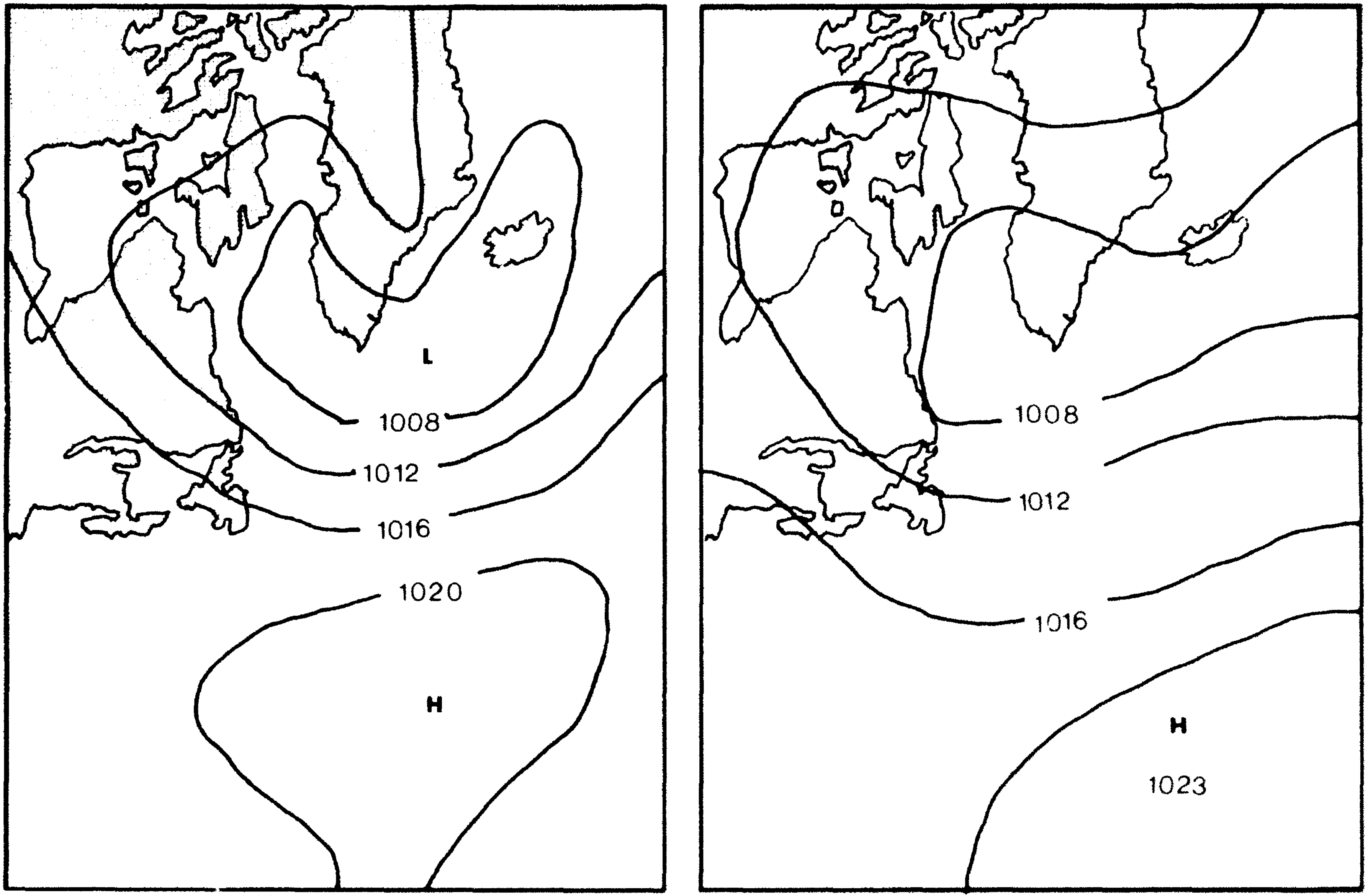
Figure 7



Normal

August 1984

Figure 8



Normal

September 1984

Figure 9

Ice Conditions 1984 Season

October - November 1983: Temperatures were near normal and no sea ice formed south of 58°N during October and November (Figures 10 and 11). By the end of November, Hudson Strait and the mouth of Ungava Bay were closed by sea ice with the southern part of Ungava Bay remaining ice-free. Iceberg sightings south of 52°N reported to International Ice Patrol during October were near the entrance to the Straits of Belle Isle and no sightings were reported south of 52°N during November.

December 1983: Early in the month, sea ice along the coast of Labrador was as far south as Lake Melville. By mid-month (Figure 12), sea ice was approaching, and by the end of the month had closed the Straits of Belle Isle. Seven icebergs were reported to International Ice Patrol south of 52°N during December, all in the vicinity of the Straits of Belle Isle.

January 1984: By mid-month (Figure 13), ice along the coast was south of Cape Bonavista. The Iceland Low was deeper than normal during January, and the distribution of pressure funnelled in cold continental air (Figure 1), causing air temperatures to be well below normal (Table 5). No new iceberg sightings were reported to International Ice Patrol south of 52°N during January.

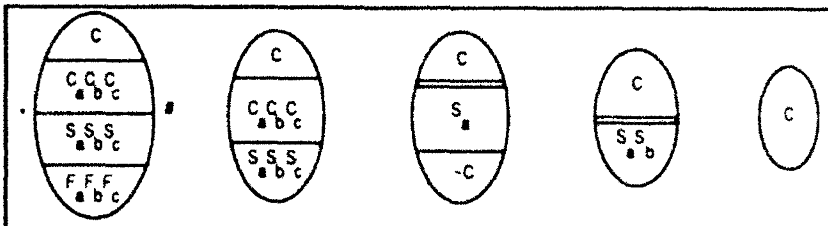
February 1984: Sea ice was as far south as Cape St. Francis throughout the month with a seaward penetration late in the month over the Grand Banks nearly reaching 46°N (Figure 14). the Iceland Low was again deeper than normal, but pressure patterns allowed warmer marine air to flow over the Maritimes (Figure 2), raising temperatures above normal. The first pre-season International Ice Patrol deployment took place 31 January - 3 February. Reconnaisance flights sighted 50 icebergs south of 52°N, one of which was south of 49°N. The International Ice Patrol received only one ship sighting south of 52°N during February.

March 1984: Sea ice remained near Cape St. Francis throughout the month with heavy coverage over the Grand Banks (Figure 15). Average surface winds during the month were almost opposite the normal pattern (Figure 3), with the easterly and northeasterly flow holding the sea ice and icebergs toward the Newfoundland and Labrador coasts. The second pre-season deployment, 7-13 March, resulted in 54 sightings south of 52°N, 18 of which were south of 48°N. A second deployment was made 21-30 March with the 1984 Ice Patrol season officially opening on 23 March. Figure 22 shows the limits of all known ice south of 48°N. At the end of the month, 156 icebergs were on plot at the International Ice Patrol office in Groton, Connecticut.

April 1984: Sea ice continued to persist along the coast as far south as Cape St. Francis throughout the month (Figure 16). The unusual high pressure system over Labrador in April (Figure 4), coupled with low pressure over Iceland, brought northerly flow into the Maritimes and lower than normal temperatures prevailed (Table 5). Under the influence of northerly winds and retreat of the sea ice westward, April was the heaviest iceberg month with 1043 icebergs sighted, of which 953 passed south of 48°N. The first ICERECDET deployment for the month was extremely busy, reporting large numbers of icebergs daily while participating in both an airborne radar iceberg detection experiment and ice patrols over a two week period. On 15 April 1984, a memorial wreath was dropped at the site of the HMS TITANIC sinking (41°16'N 51°W) to commemorate the nearly 1500 lives lost on 15 April 1912. At the end of the month, 156 icebergs were on plot at the International Ice Patrol.

May 1984: Sea ice in Davis Strait retreated to the west under the warm air temperatures of May, and at the same time receded northward along the the east coast of Greenland (Figure 17). In contrast, near normal weather conditions resulted in a light westerly flow over the Newfoundland and Labrador coasts that did little to affect sea ice, which remained as far south as Cape St. Francis throughout the month. In May, 1037 icebergs were sighted, of which 484 passed south of 48°N. At the end of the month, 198

Table 6. Explanation of Sea Ice Symbology used in Figures 10-21



C = Total ice concentration in the area in tenths.

$C_a C_b C_c$ = Concentration of thickest (C_a), 2nd thickest (C_b), and 3rd thickest (C_c)

$S_a S_b S_c$ = Stage of development of thickest (S_a), 2nd thickest (S_b), and 3rd thickest (S_c)

-C = Concentration of ice within areas of strips and patches

$F_a F_b F_c$ = *Floe size of thickest (F_a), 2nd thickest (F_b), and 3rd thickest (F_c).*

Stage of Development	
0	No stage of development
1	New ice
2	Nilas, ice rind
3	Young ice
4	Grey ice
5	Grey-white ice
6	First-year ice
7	Thin first-year ice
8	Thin first-year ice, 30-50 cm
9	Thin first-year ice, 50-70 cm
1·	Medium first-year ice
4·	Thick first-year ice
7·	Old ice
8·	Second-year ice
9·	Multi-year ice
▲	Icebergs
•	A trace of ice thicker than S_a
#	Fourth type, if $C_a C_b C_c$ do not add up to C

Floe Sizes	
0	Pancake ice
1	Brash, small ice cake
2	Ice cake
3	Small floe
4	Medium floe
5	Big floe
6	Vast floe
7	Giant floe
8	Growlers and floebergs
9	Icebergs
/	Undetermined or unknown

icebergs were on plot at the International Ice Patrol. Icebergs on plot at the International Ice Patrol were widely distributed by mid-month and a second two-week ICERECDET was conducted. By month's end, several drifted outside the Ice Patrol area (west of 57°W longitude) and others extended the southernmost limits south of 40°N latitude (Figure 27).

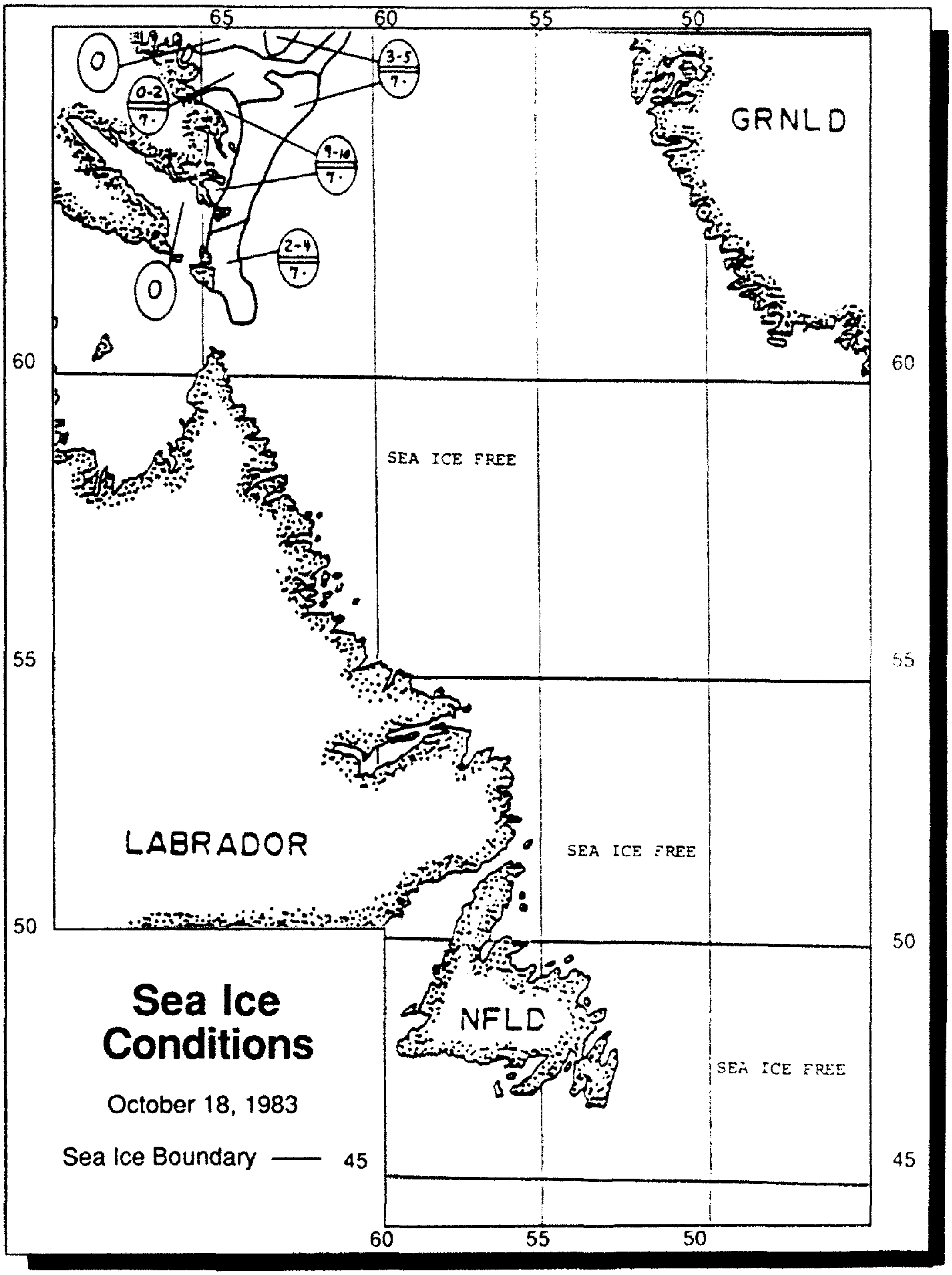
June 1984: As seen in Table 5, June was colder than normal and sea ice remained in the western part of Davis Strait and off the Straits of Belle Isle (Figure 18). The number of icebergs on plot decreased during June, although the limits of all known ice remained well to the south and east, held there by widely scattered icebergs (Figures 28 and 29). The southernmost iceberg on plot for the season came on 6 June at 40°01'N 45°51'W. There were 555 icebergs sighted in June, of which 227 drifted south of 48°N and several of these drifted outside the Ice Patrol area (east of 39°W or west of 57°W longitude). At the end of the month, 149 were on the International Ice Patrol plot and widely scattered.

July 1984: Under the influence of warm but near-normal weather during July, the sea ice retreated north of 54°N by mid-month. Although the number of icebergs on plot at the International Ice Patrol decreased throughout the month, the limits of all known ice continued to be much farther south and east than normal due to widely scattered icebergs at the limits (Figures 30 and 31). Of the 975 icebergs sighted and reported to the International Ice Patrol in July, 335 passed south of 48°N. Both numbers are greater than those of June, with the increase due to the release of icebergs by the retreating ice pack.

August 1984: With air temperatures somewhat above normal, sea ice continued to retreat in August (Figure 20). Increasing sea surface temperatures accelerated iceberg melt and caused the limits of all known ice to move north (Figures 32 and 33). Of the 251 icebergs sighted in August, 93 passed south of 48°N and 46 remained on plot at the end of the month.

September 1984: Sea ice continued to retreat rapidly, and by 18 September had disappeared from Davis and Hudson Straits (Figure 21) and completely melted in Baffin Bay to conclude this ice year. By the end of the 1984 International Ice Patrol season on 7 September, 124 icebergs had been sighted in September with only 9 drifting south of 48°N and 24 remaining on plot at the end of the season (Figure 34).

Figure 10

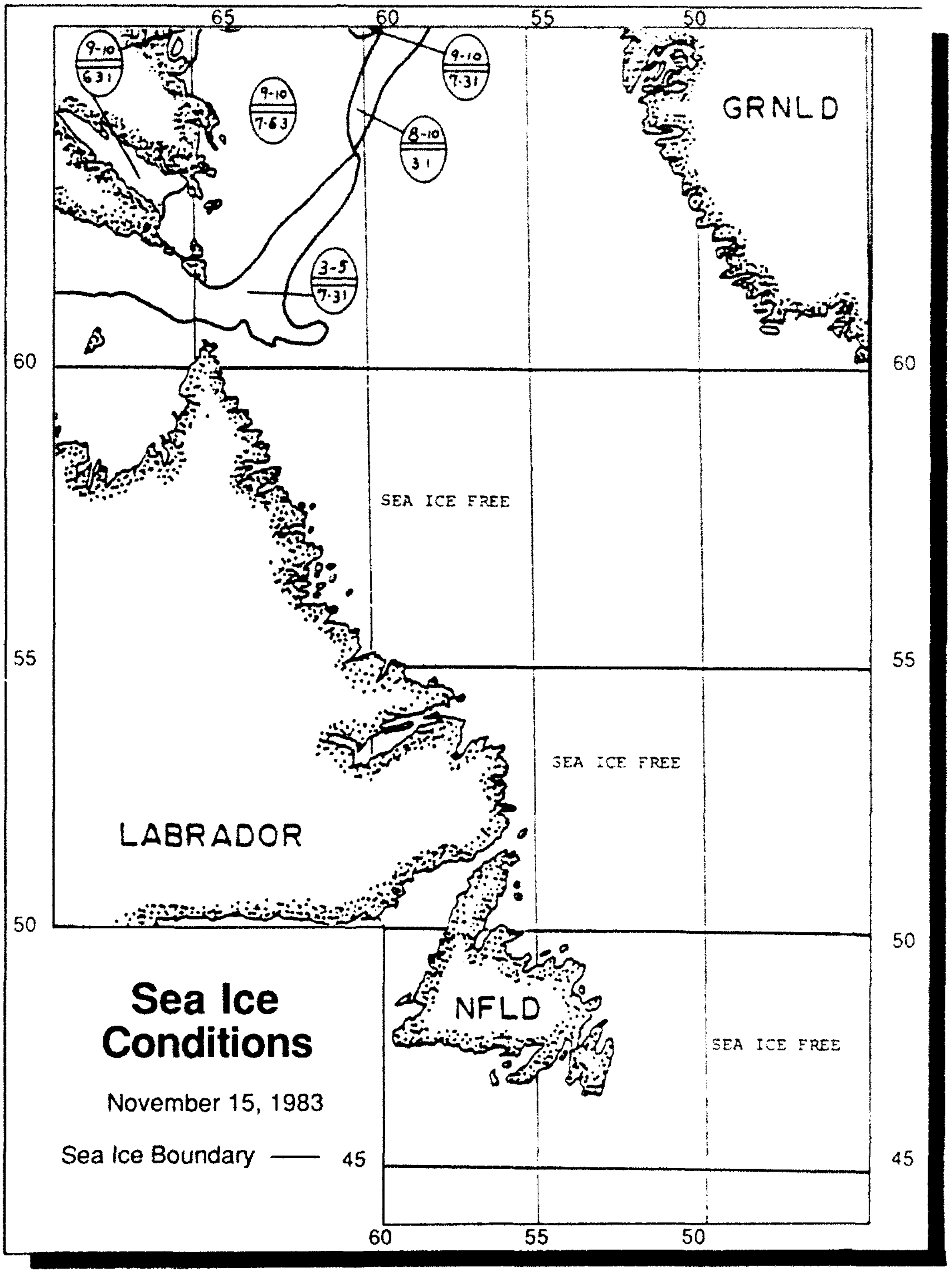


Sea Ice Conditions

October 18, 1983

Sea Ice Boundary ——

Figure 11

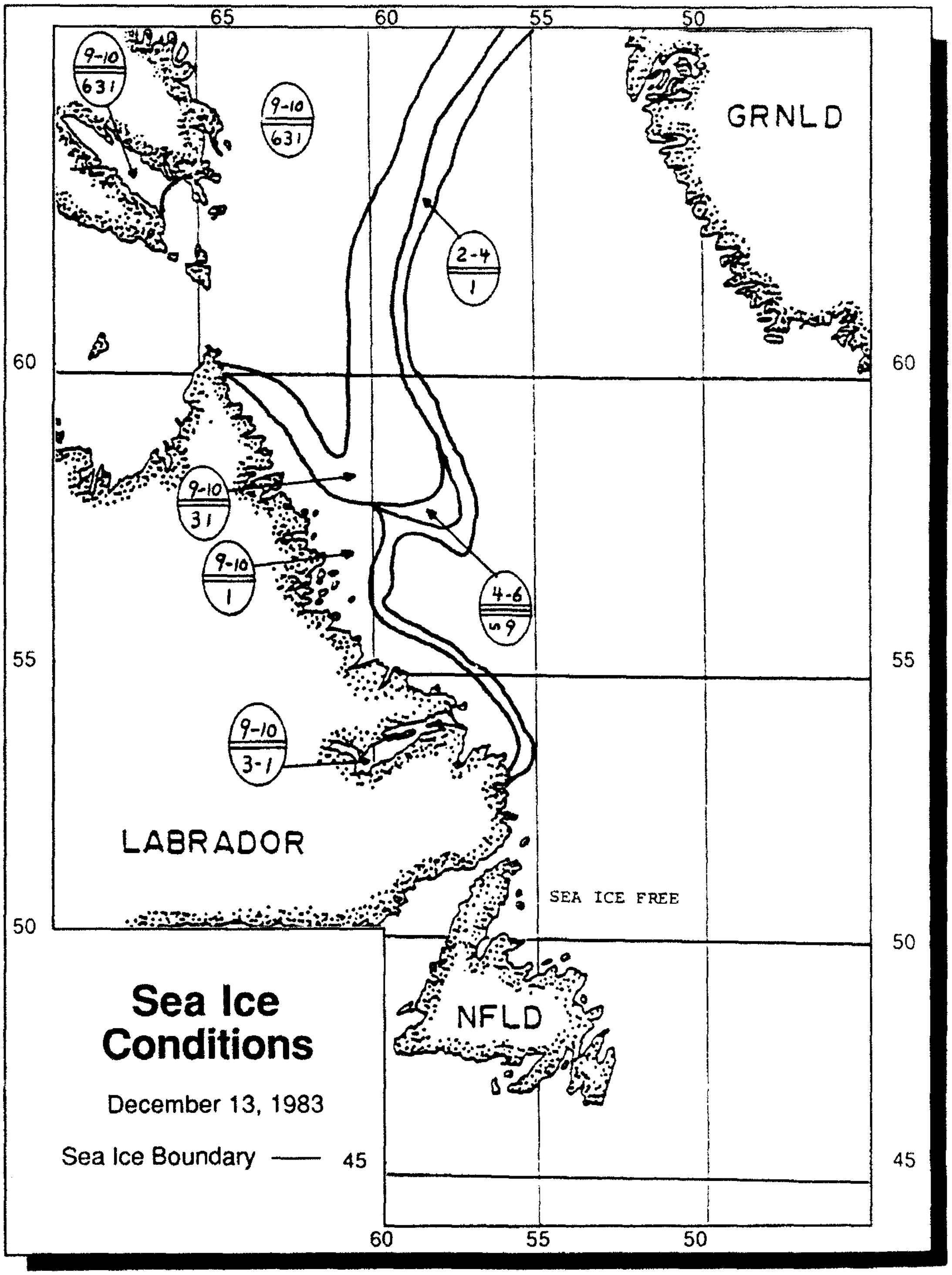


Sea Ice Conditions

November 15, 1983

Sea Ice Boundary ——

Figure 12

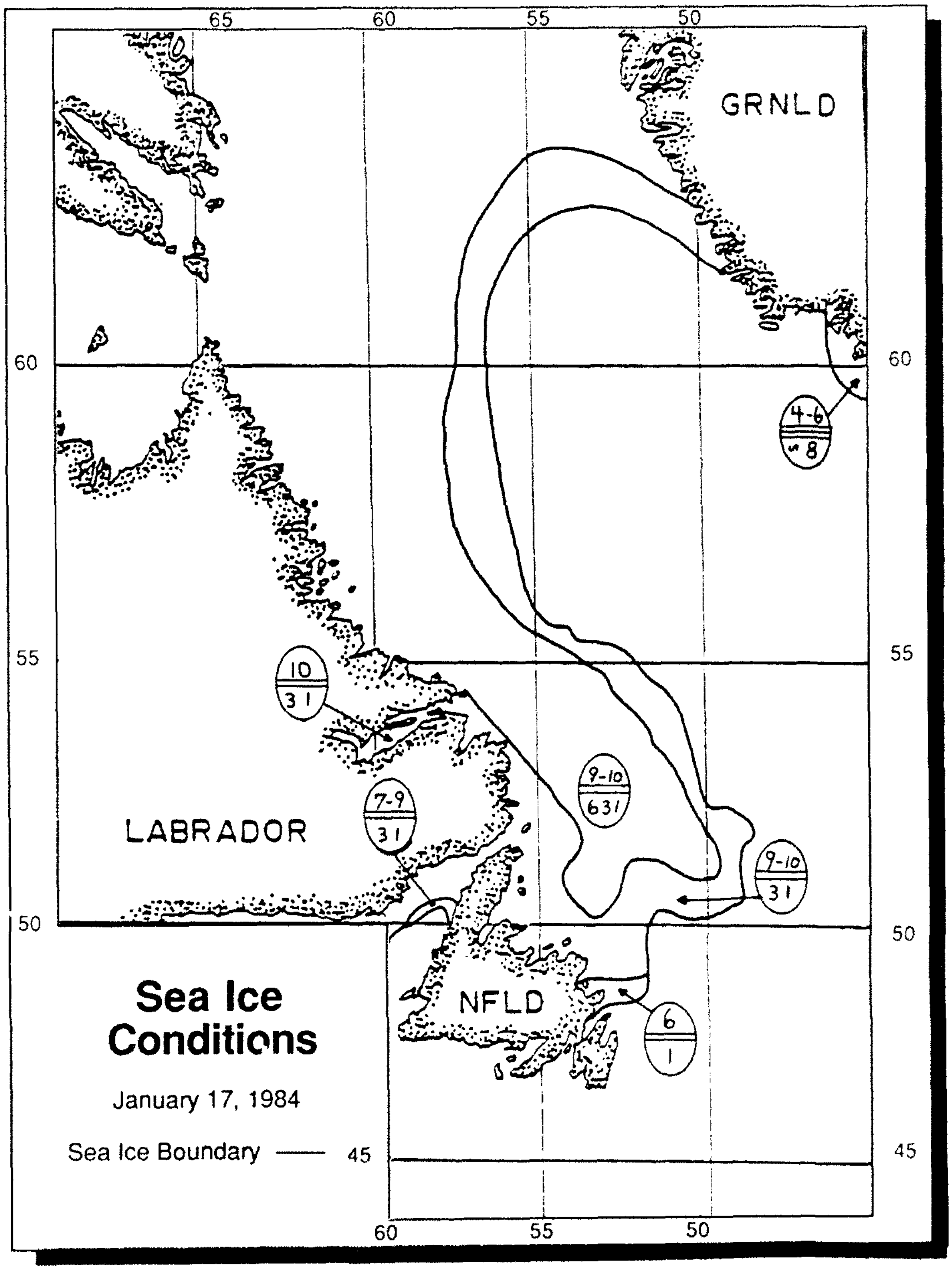


Sea Ice Conditions

December 13, 1983

Sea Ice Boundary ——

Figure 13

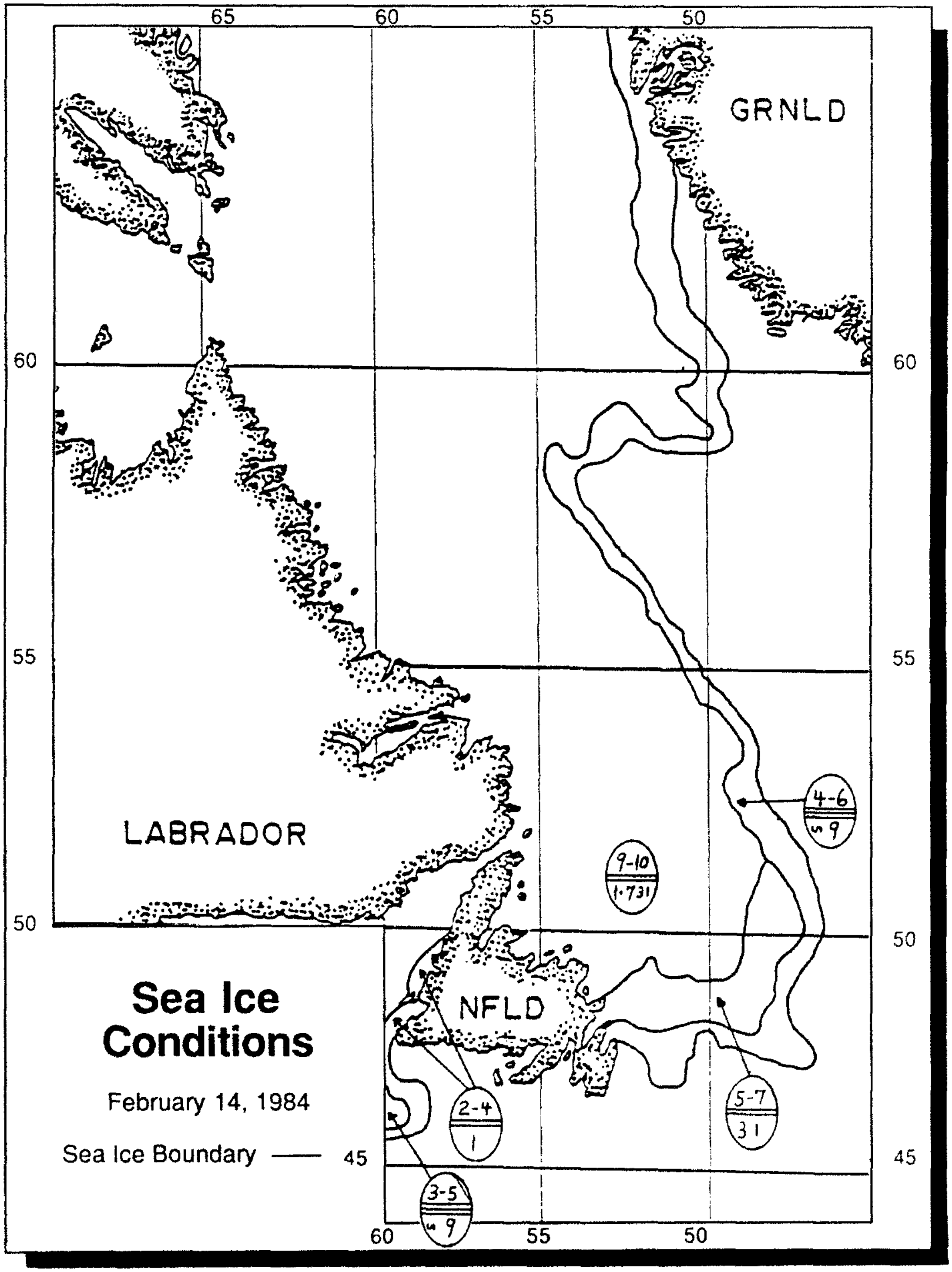


Sea Ice Conditions

January 17, 1984

Sea Ice Boundary ——

Figure 14

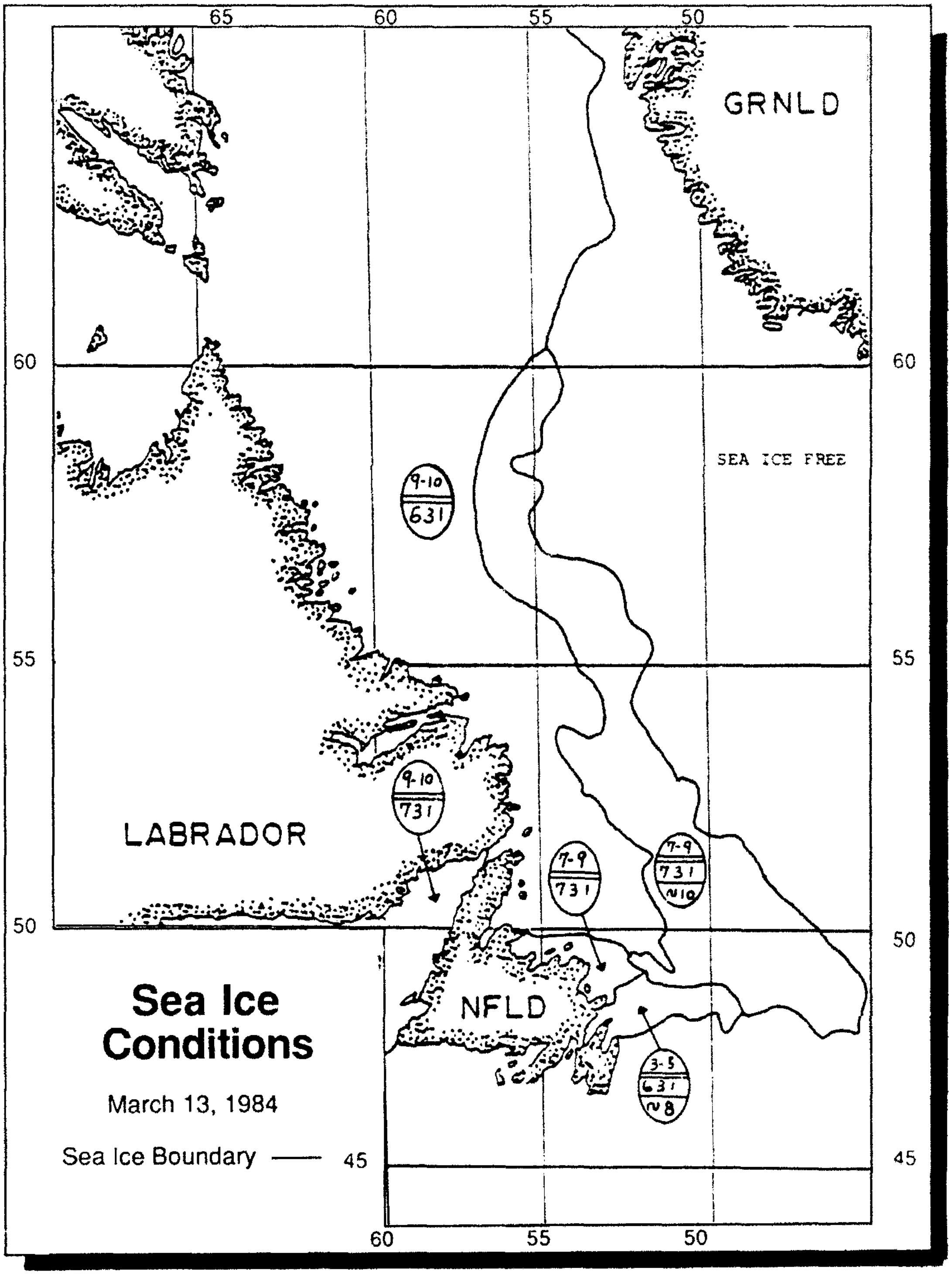


Sea Ice Conditions

February 14, 1984

Sea Ice Boundary ——

Figure 15

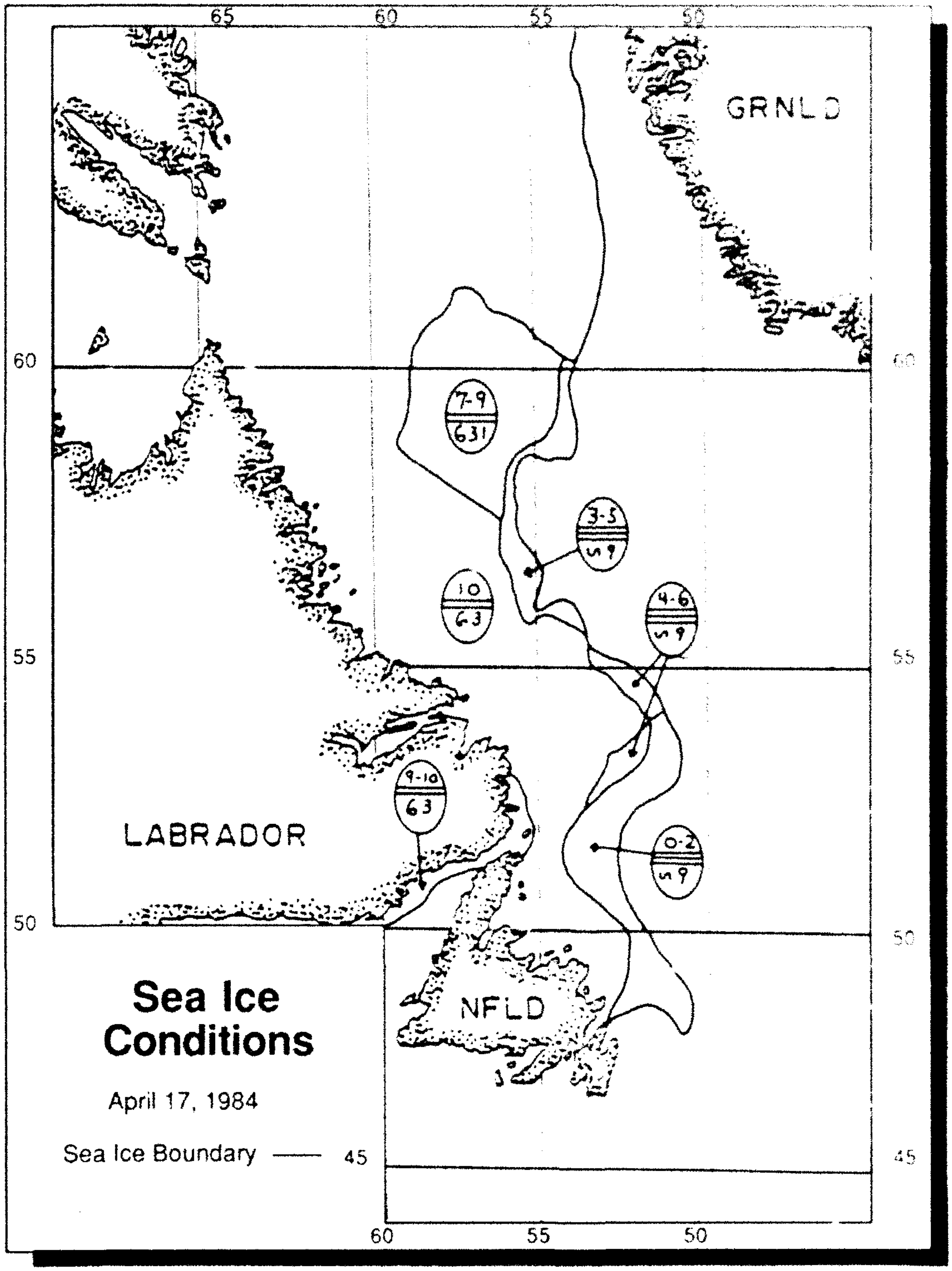


Sea Ice Conditions

March 13, 1984

Sea Ice Boundary ——

Figure 16

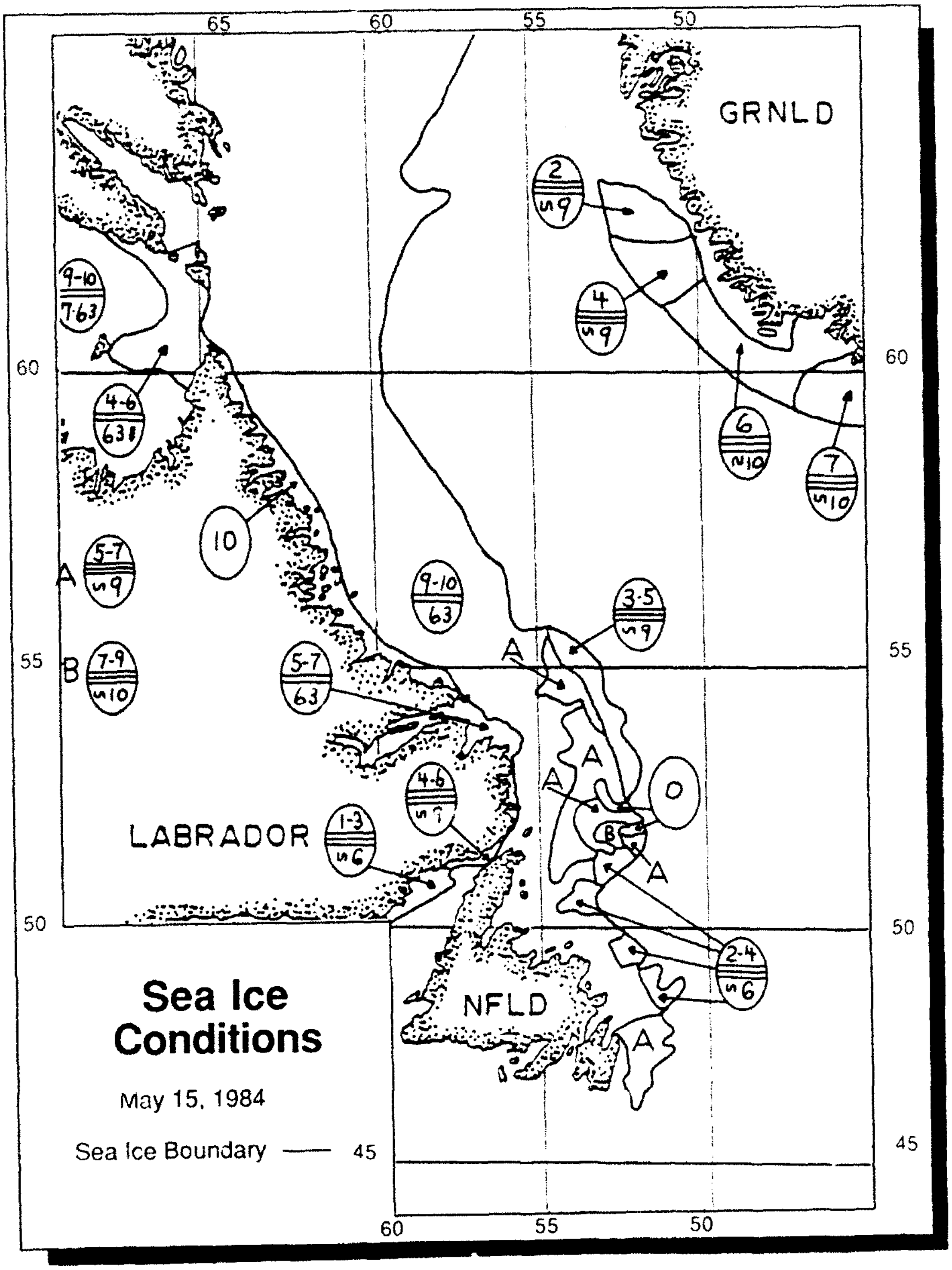


Sea Ice Conditions

April 17, 1984

Sea Ice Boundary ——

Figure 17

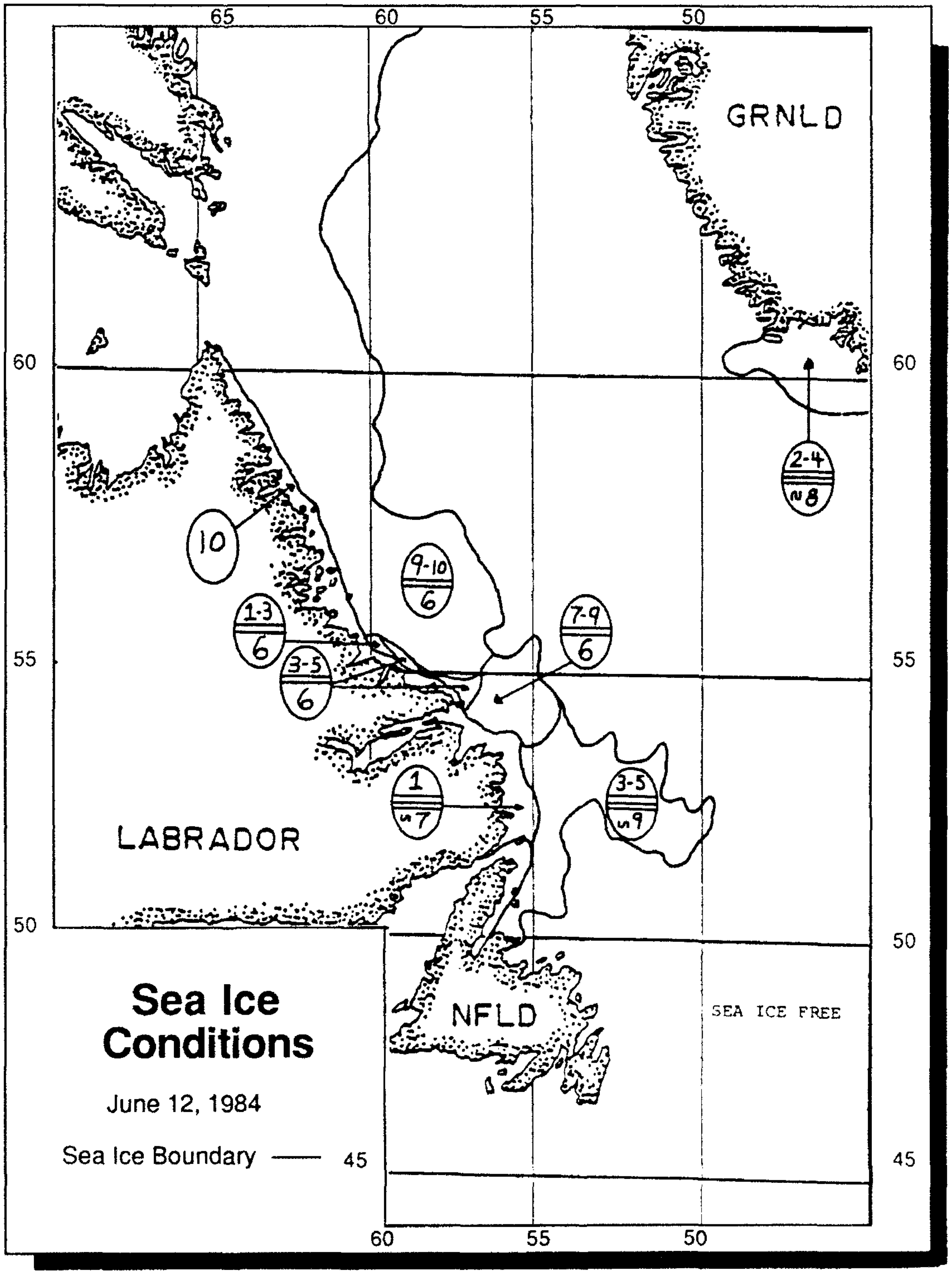


Sea Ice Conditions

May 15, 1984

Sea Ice Boundary ——

Figure 18

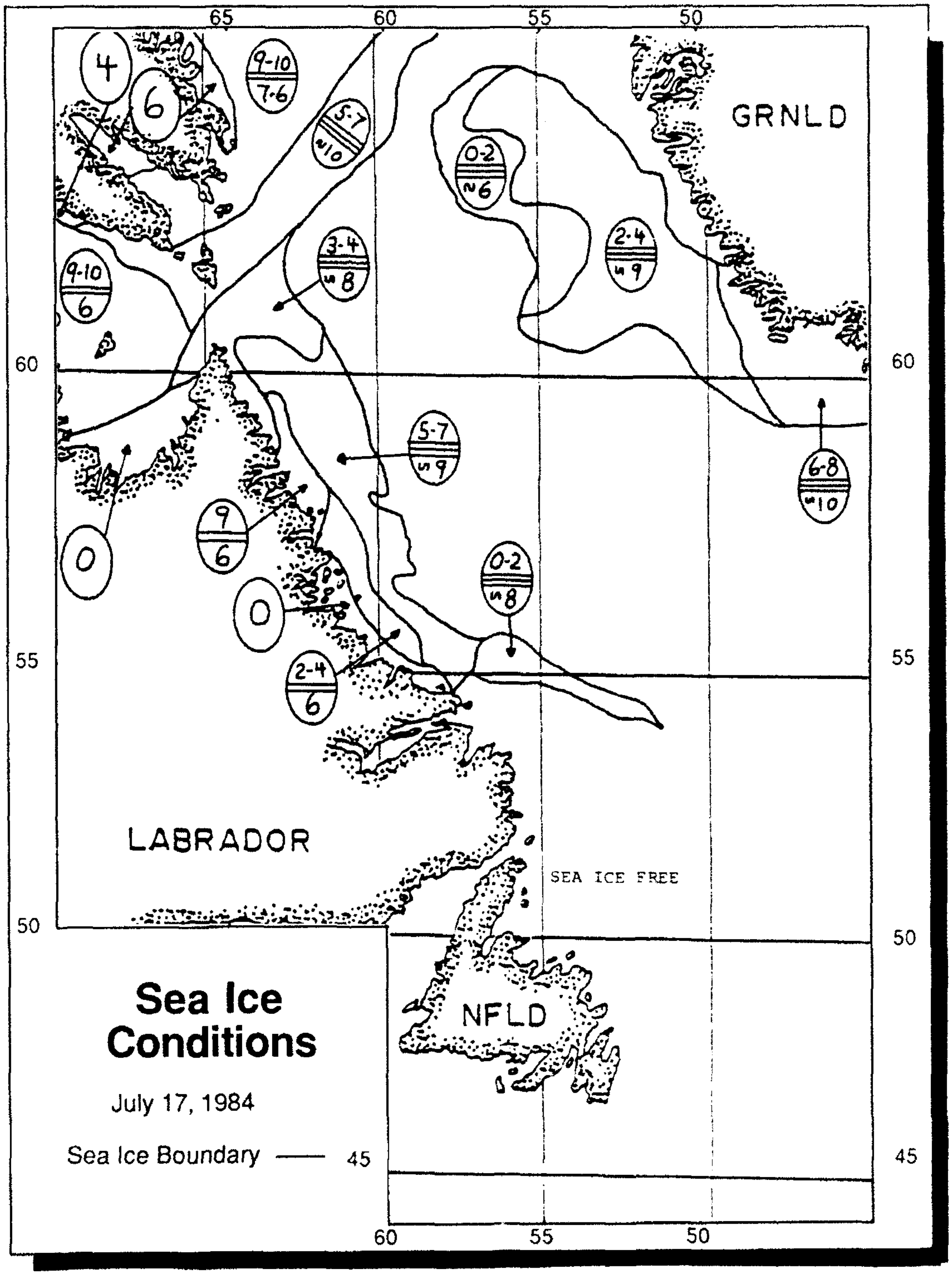


Sea Ice Conditions

June 12, 1984

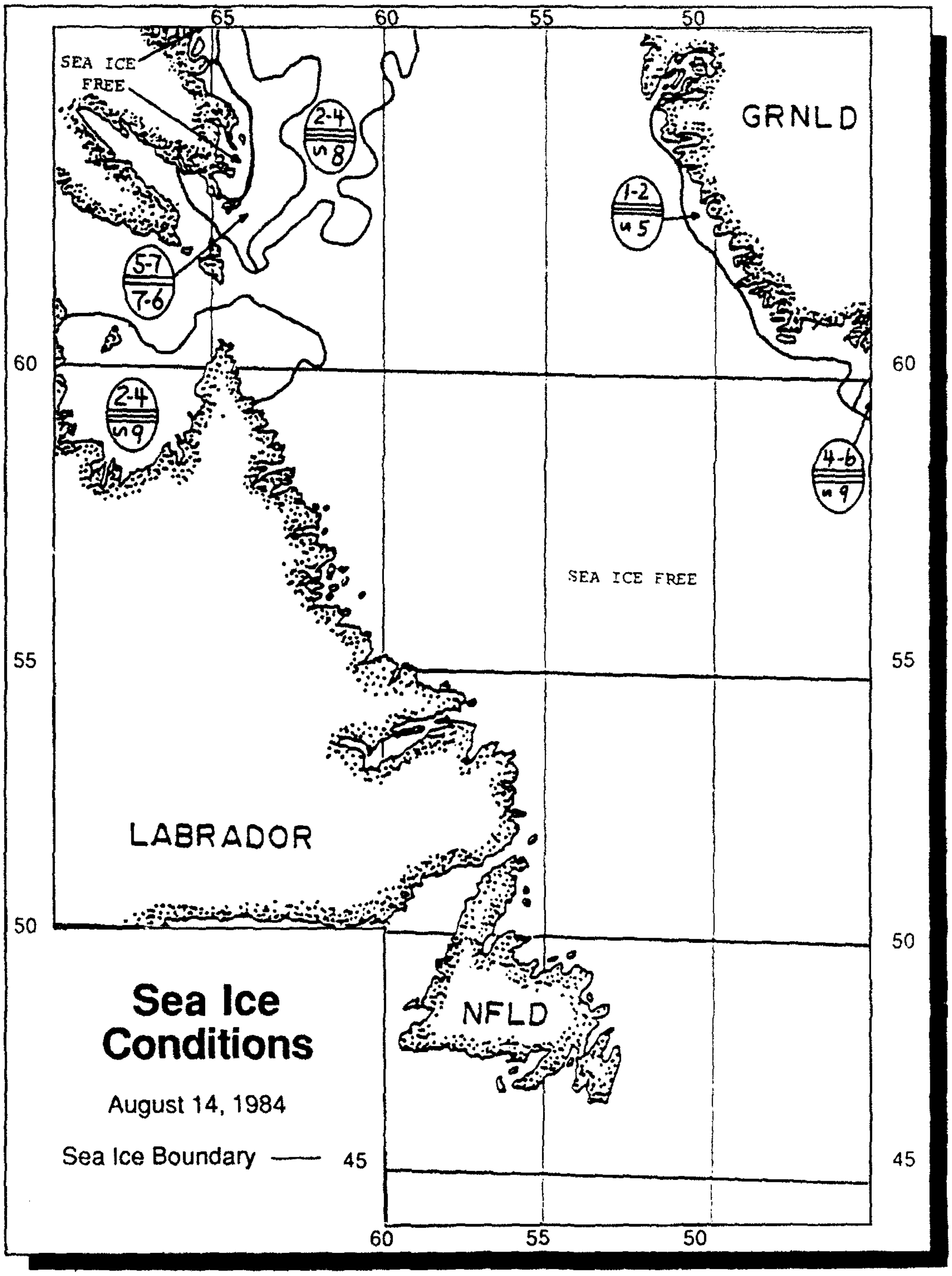
Sea Ice Boundary ——

Figure 19



65
60
55
50
GRNLD
LABRADOR
NFLD
SEA ICE FREE
4
6
9-10 / 7-6
5-7 / ~10
0-2 / ~6
2-4 / ~9
9-10 / 6
3-4 / ~8
5-7 / ~9
6-8 / ~10
0
9 / 6
0
0-2 / ~8
2-4 / 6
Sea Ice Conditions
July 17, 1984
Sea Ice Boundary ——
45

Figure 20

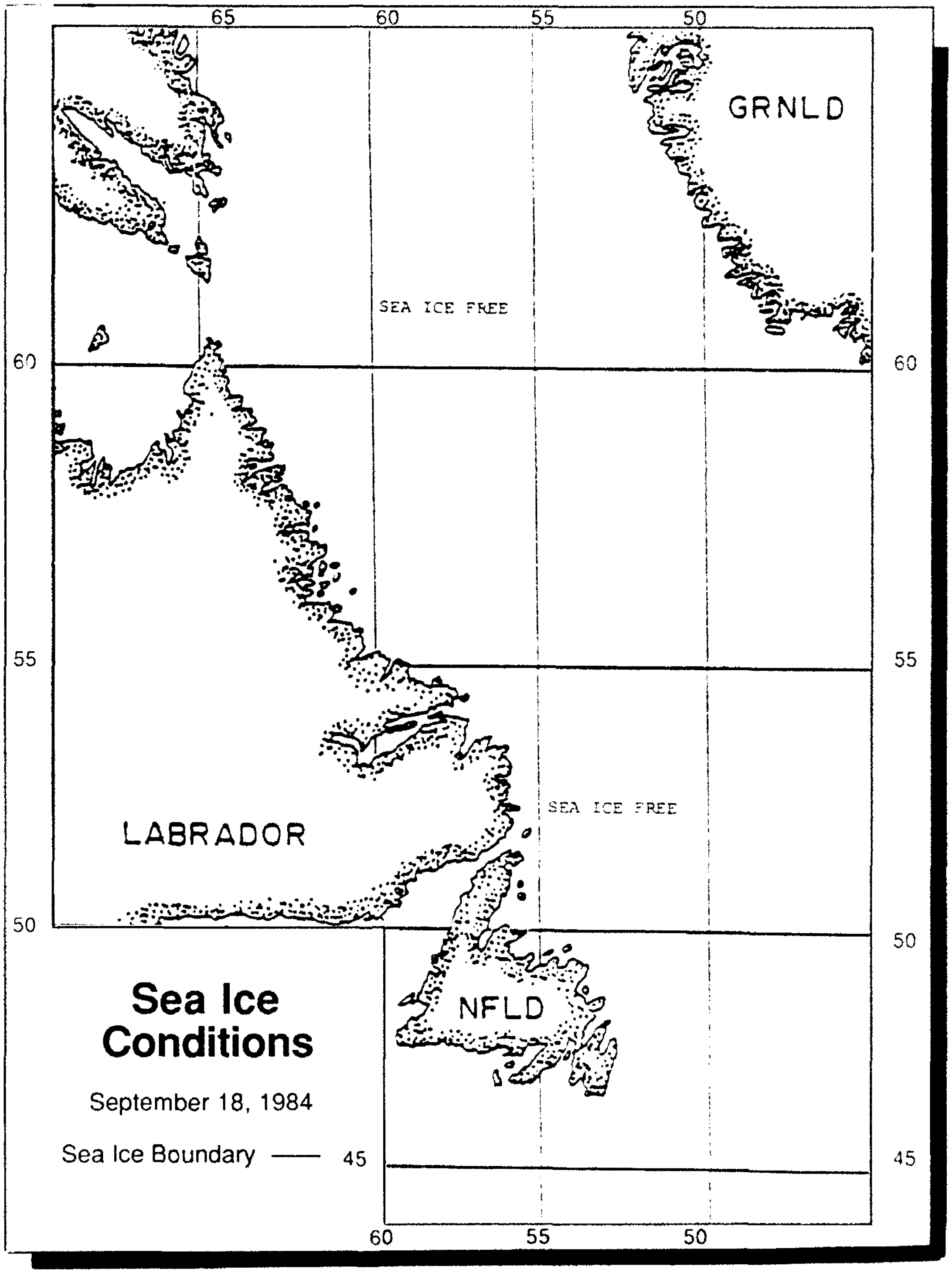


Sea Ice Conditions

August 14, 1984

Sea Ice Boundary ——

Figure 21

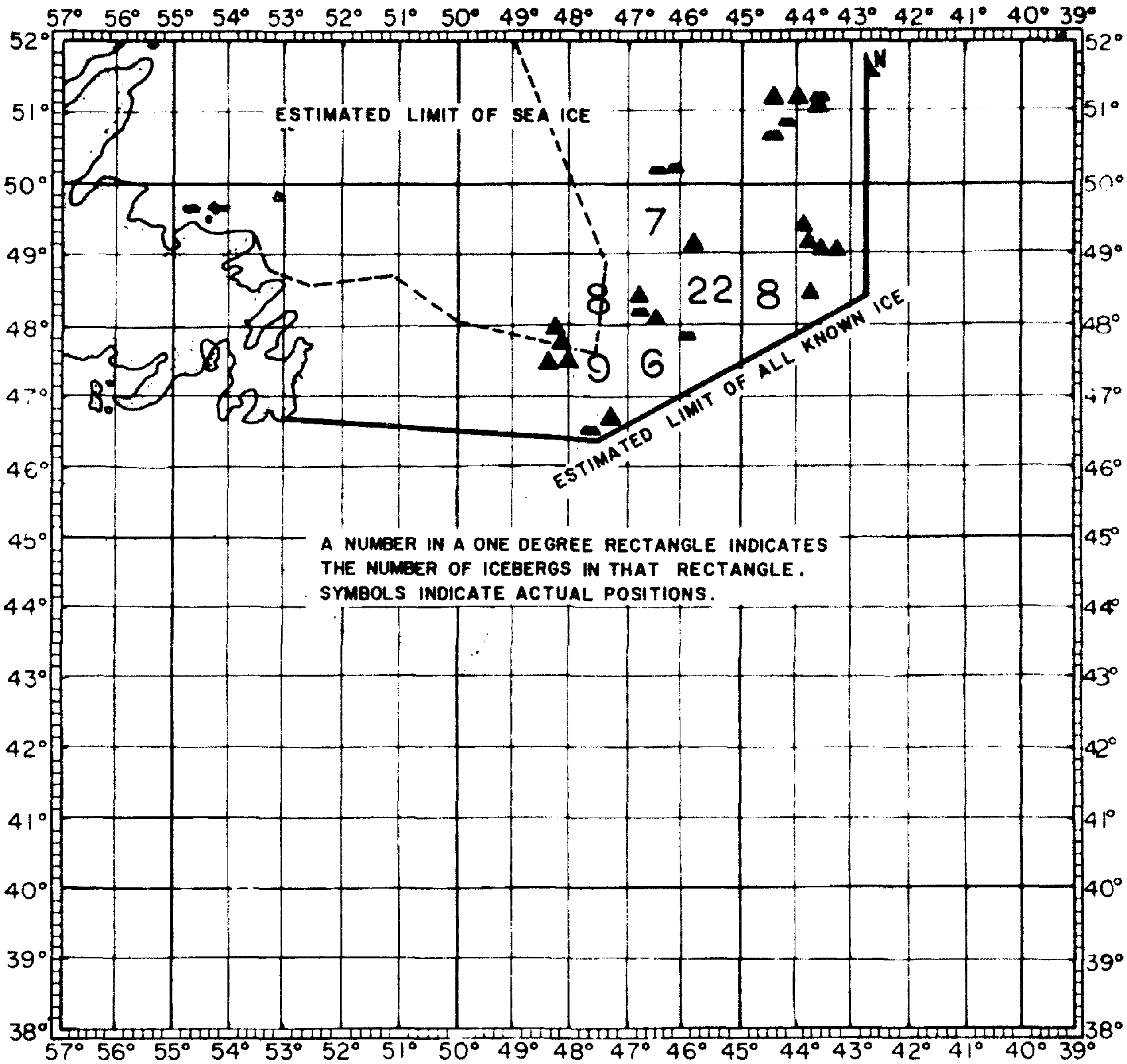


Sea Ice Conditions

September 18, 1984

Sea Ice Boundary ——

Figure 22

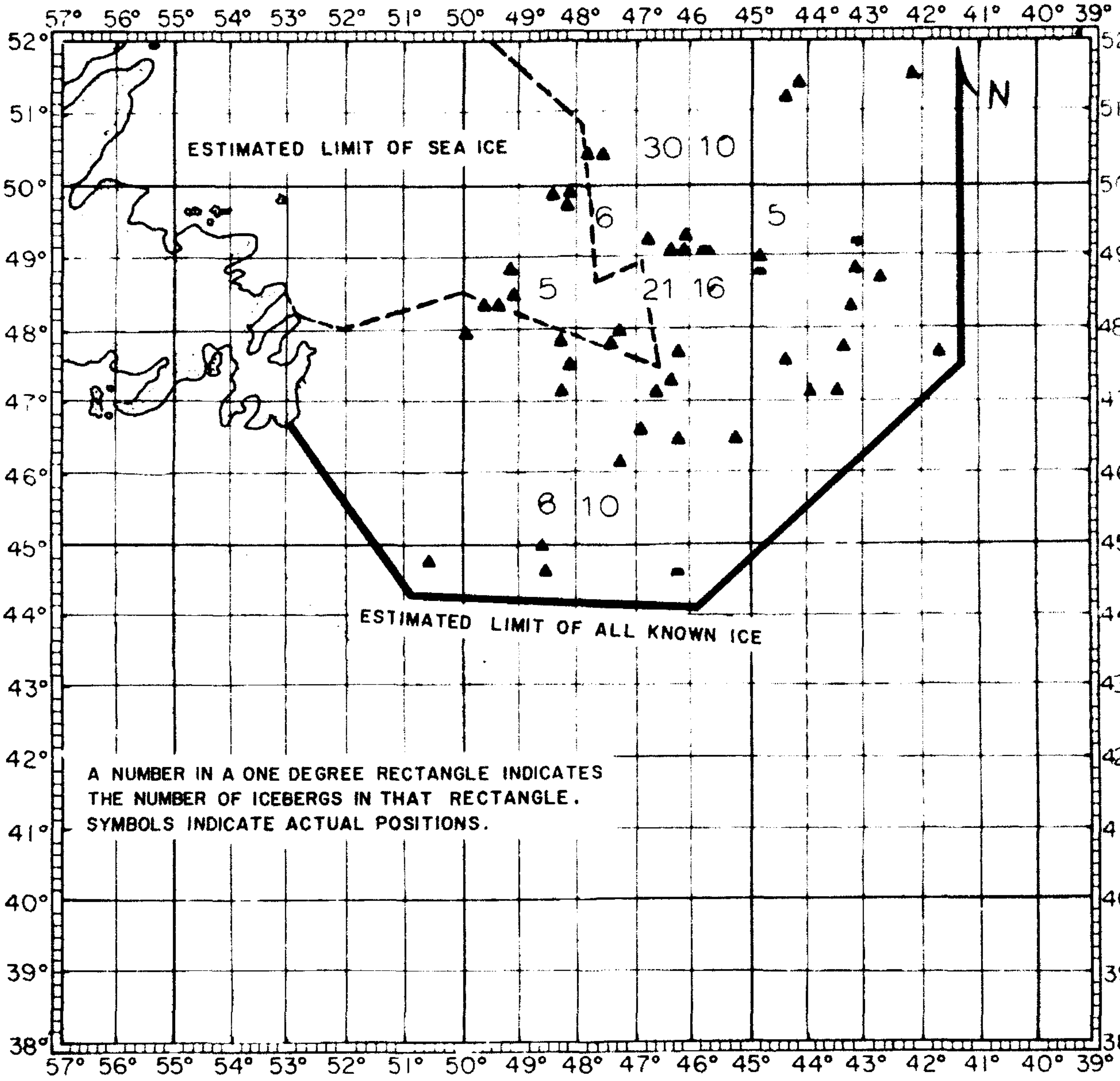


A NUMBER IN A ONE DEGREE RECTANGLE INDICATES THE NUMBER OF ICEBERGS IN THAT RECTANGLE. SYMBOLS INDICATE ACTUAL POSITIONS.

▲ BERG
● GROWLER
X RADAR TARGET/CONTACT

FOR 1200 GMT 23 MAR 84
BASED ON OBSERVED AND
FORECAST CONDITIONS

Figure 23

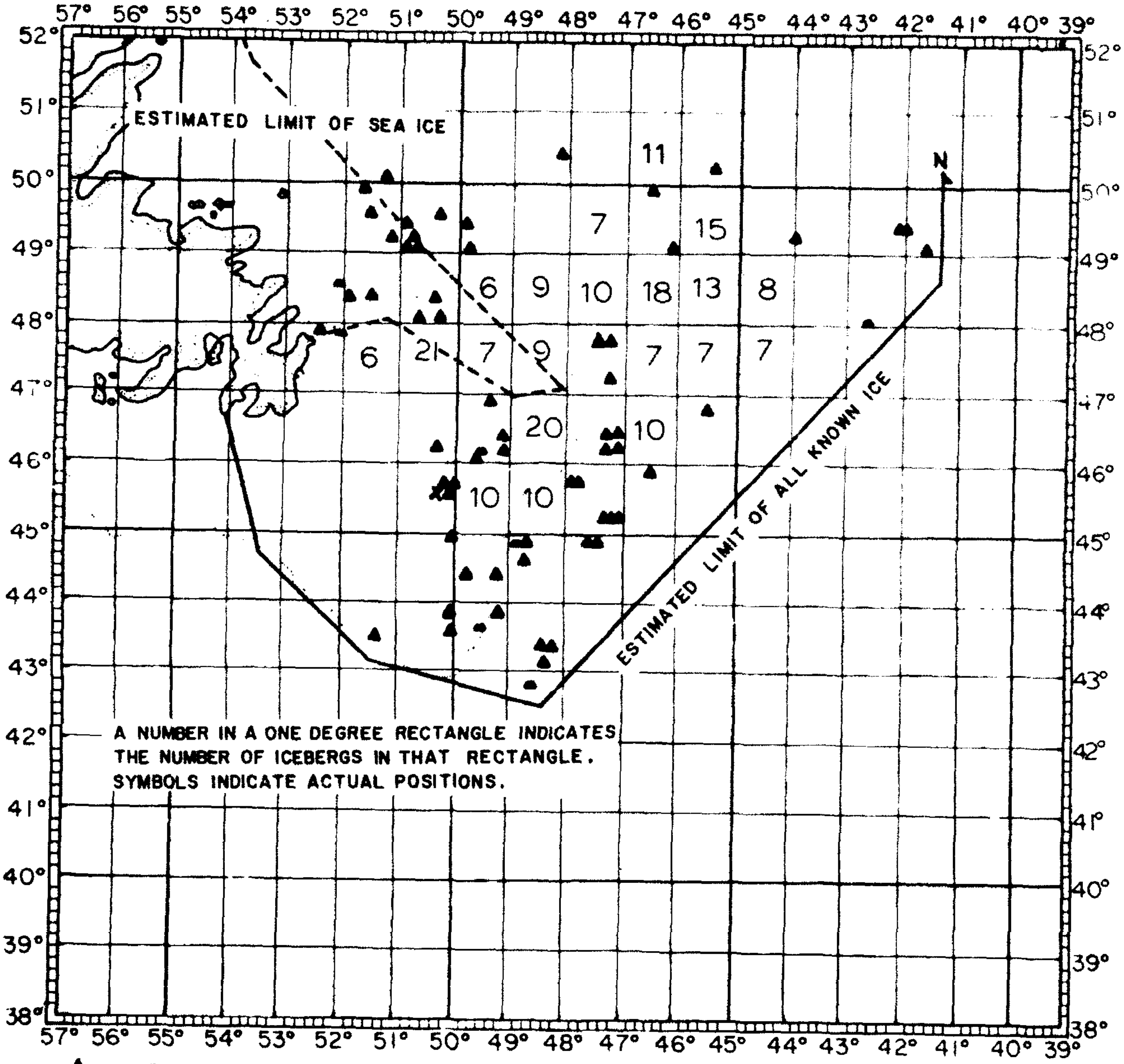


A NUMBER IN A ONE DEGREE RECTANGLE INDICATES THE NUMBER OF ICEBERGS IN THAT RECTANGLE. SYMBOLS INDICATE ACTUAL POSITIONS.

▲ BERG
▴ GROWLER
X RADAR TARGET/CONTACT

FOR 1200 GMT 30 MAR 84
BASED ON OBSERVED AND
FORECAST CONDITIONS

Figure 24

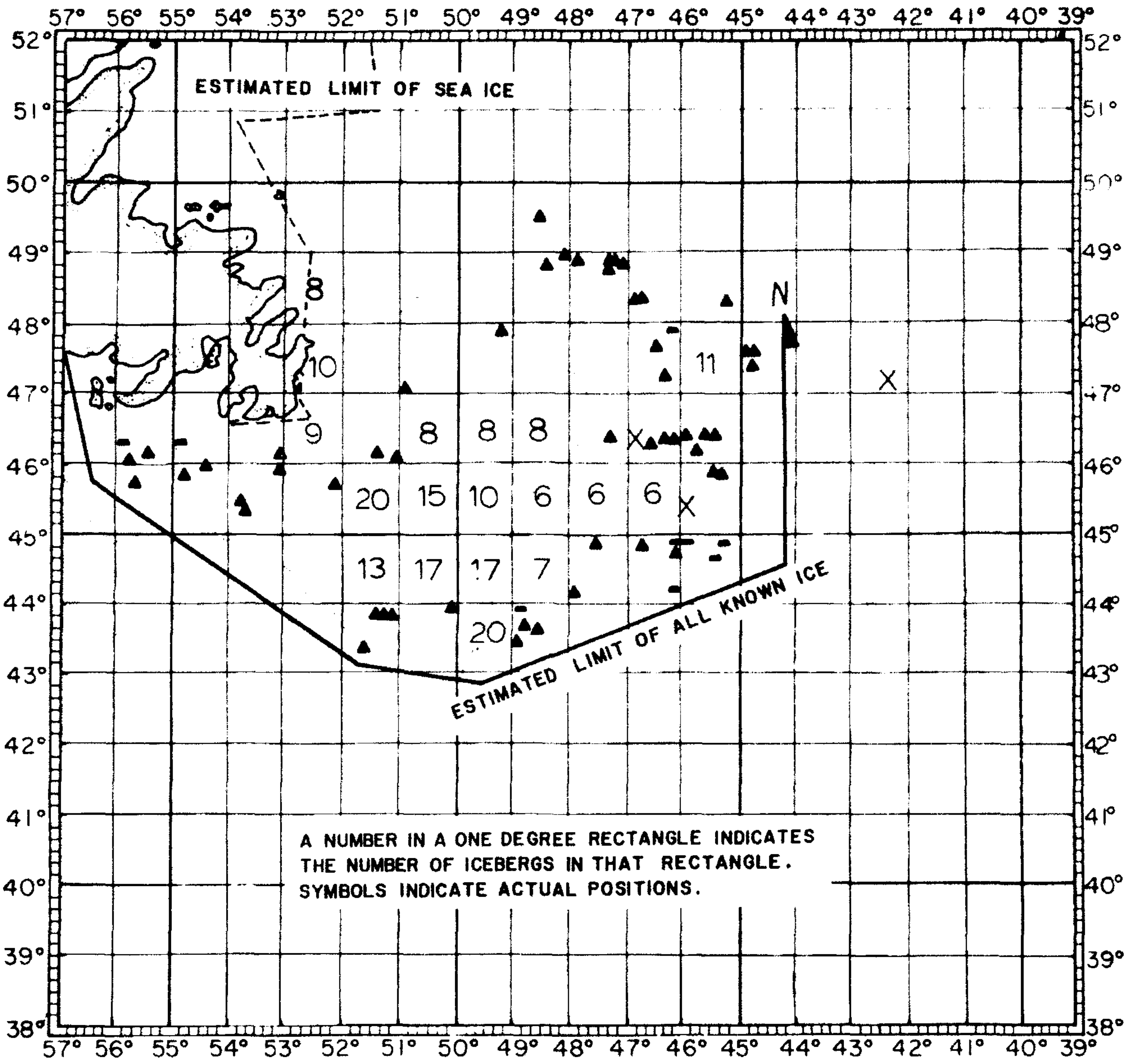


A NUMBER IN A ONE DEGREE RECTANGLE INDICATES THE NUMBER OF ICEBERGS IN THAT RECTANGLE. SYMBOLS INDICATE ACTUAL POSITIONS.

▲ BERG
☗ GROWLER
X RADAR TARGET/CONTACT

FOR 1200 GMT 15 APR 84
BASED ON OBSERVED AND
FORECAST CONDITIONS

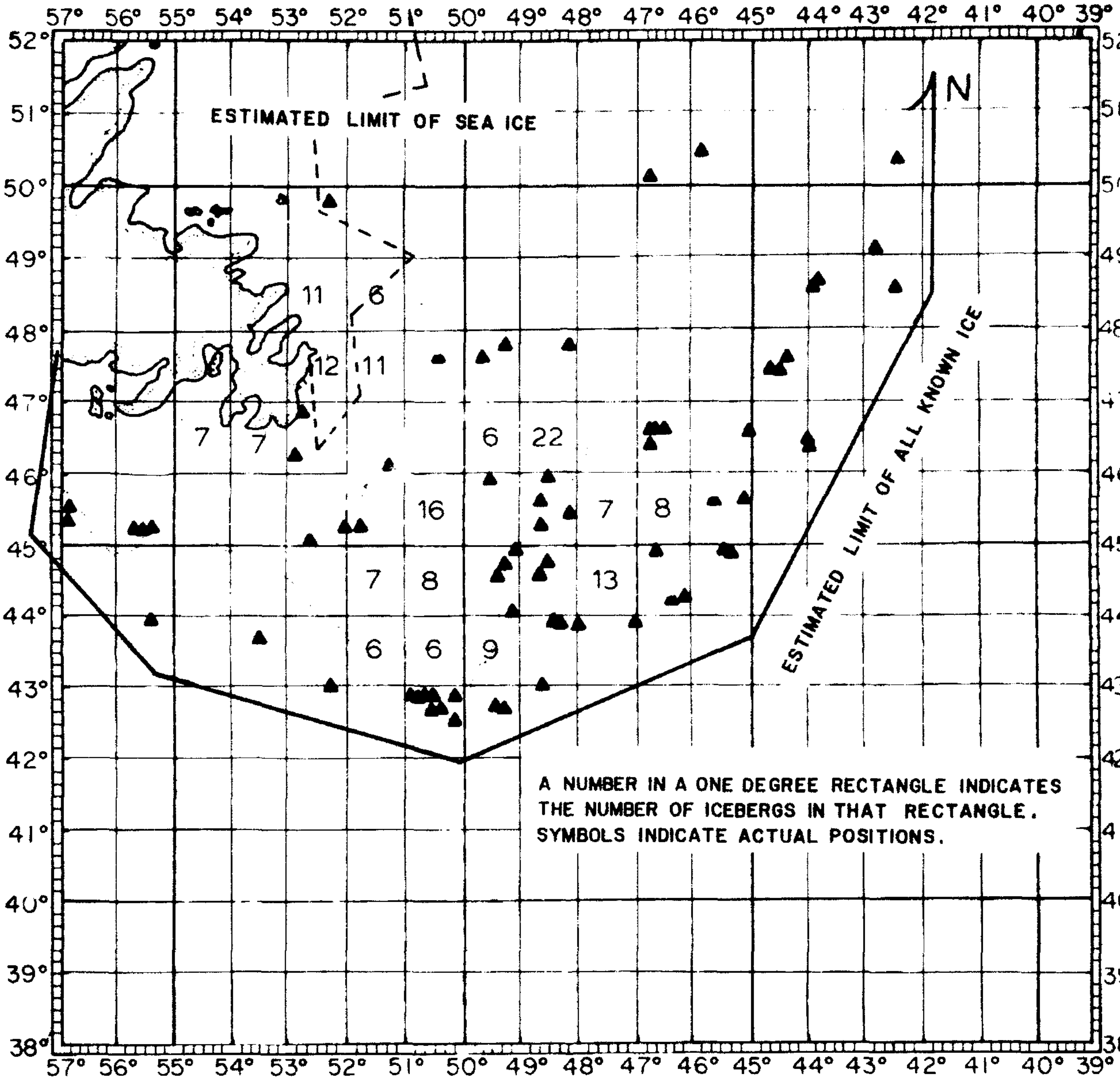
Figure 25



▲ BERG
▲ GROWLER
X RADAR TARGET/CONTACT

FOR 1200 GMT 30 APR 84
BASED ON OBSERVED AND
FORECAST CONDITIONS

Figure 26



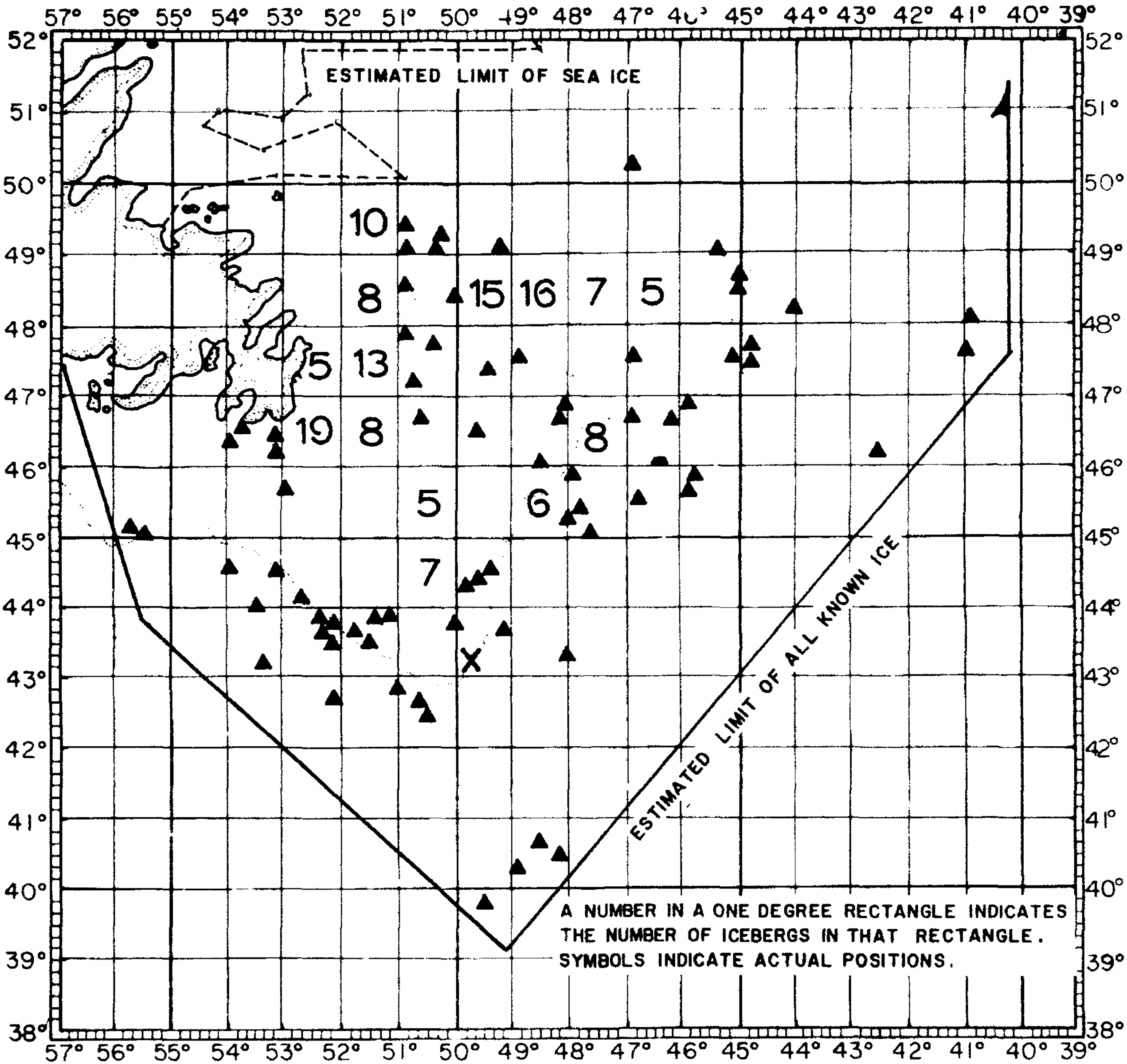
▲ BERG

● GROWLER

X RADAR TARGET/CONTACT

FOR 1200 GMT 15 MAY 84
BASED ON OBSERVED AND
FORECAST CONDITIONS

Figure 27

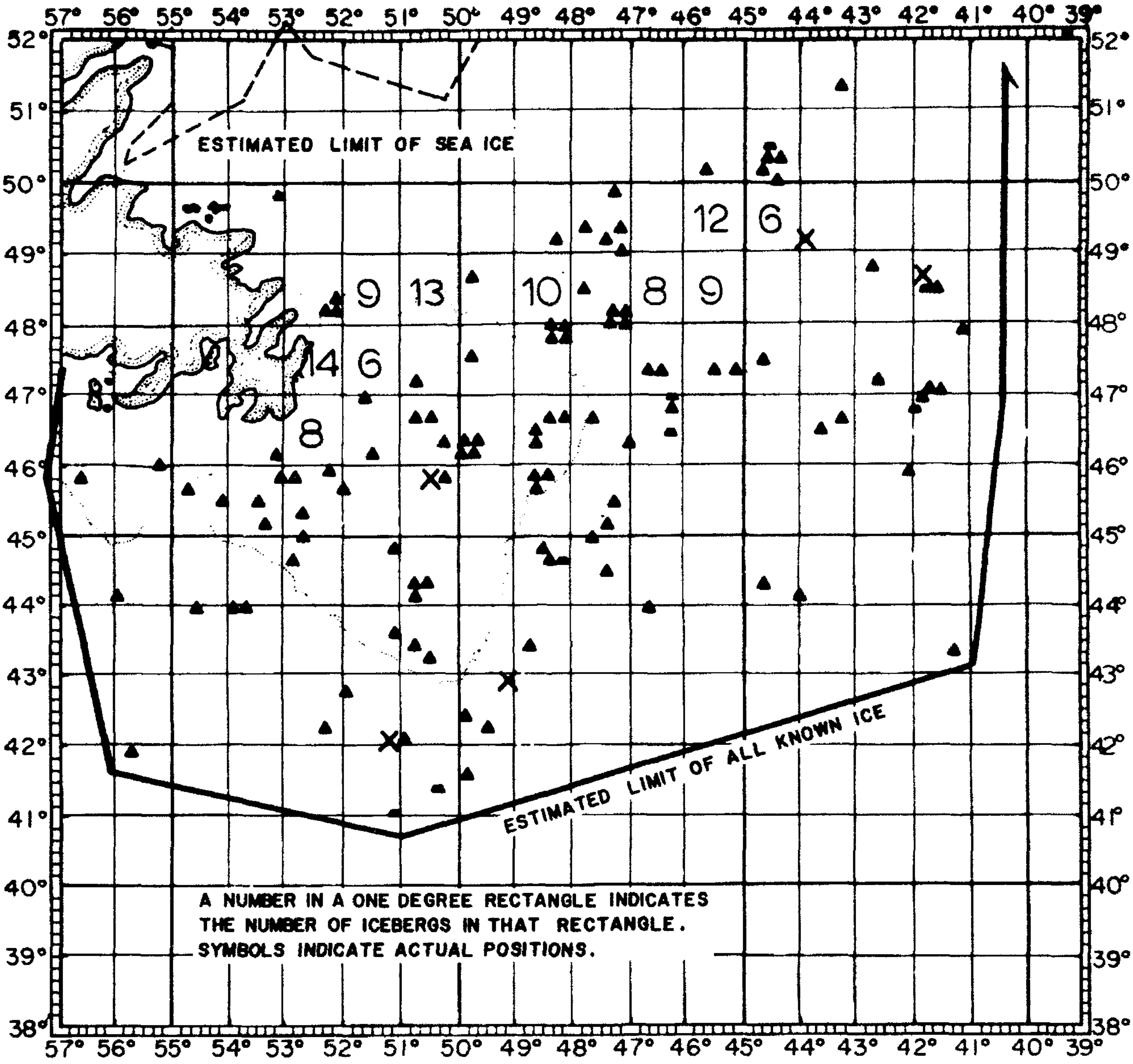


A NUMBER IN A ONE DEGREE RECTANGLE INDICATES THE NUMBER OF ICEBERGS IN THAT RECTANGLE. SYMBOLS INDICATE ACTUAL POSITIONS.

▲ BERG
● GROWLER
X RADAR TARGET/CONTACT

FOR 1200 GMT 30 MAY 84
BASED ON OBSERVED AND
FORECAST CONDITIONS

Figure 28

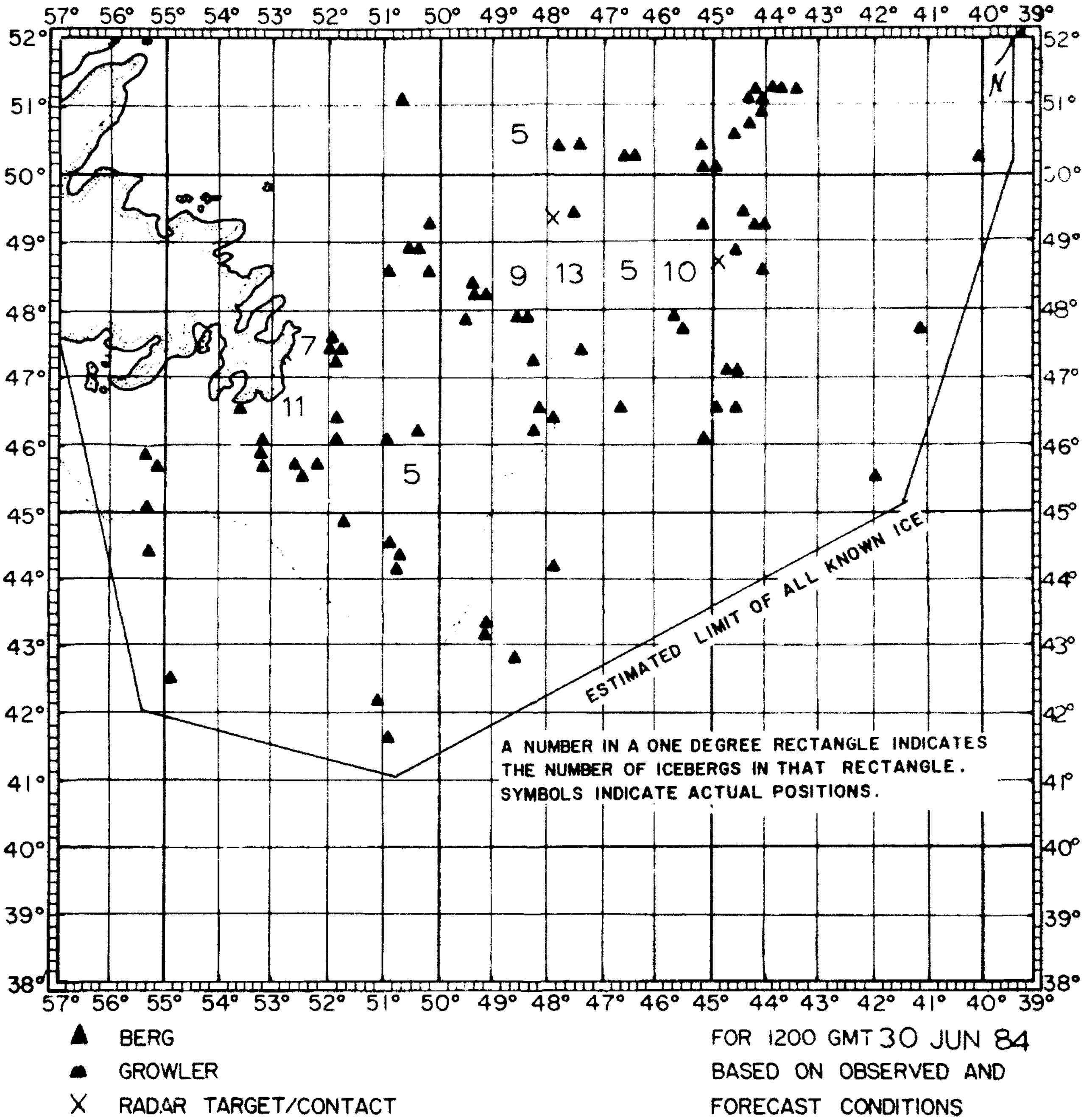


A NUMBER IN A ONE DEGREE RECTANGLE INDICATES THE NUMBER OF ICEBERGS IN THAT RECTANGLE. SYMBOLS INDICATE ACTUAL POSITIONS.

▲ BERG
● GROWLER
X RADAR TARGET/CONTACT

FOR 1200 GMT 15 JUN 84
BASED ON OBSERVED AND
FORECAST CONDITIONS

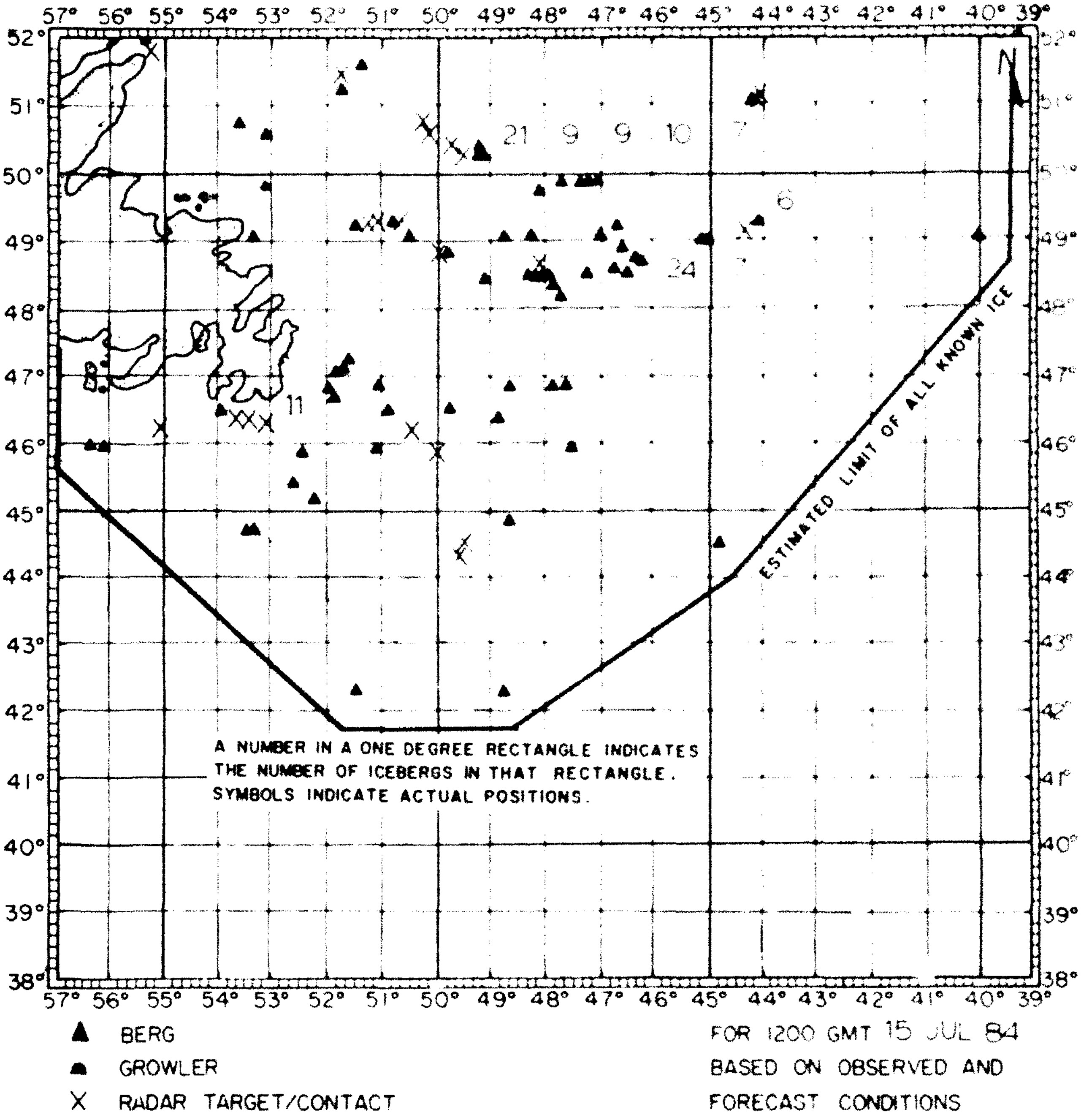
Figure 29



A NUMBER IN A ONE DEGREE RECTANGLE INDICATES THE NUMBER OF ICEBERGS IN THAT RECTANGLE. SYMBOLS INDICATE ACTUAL POSITIONS.

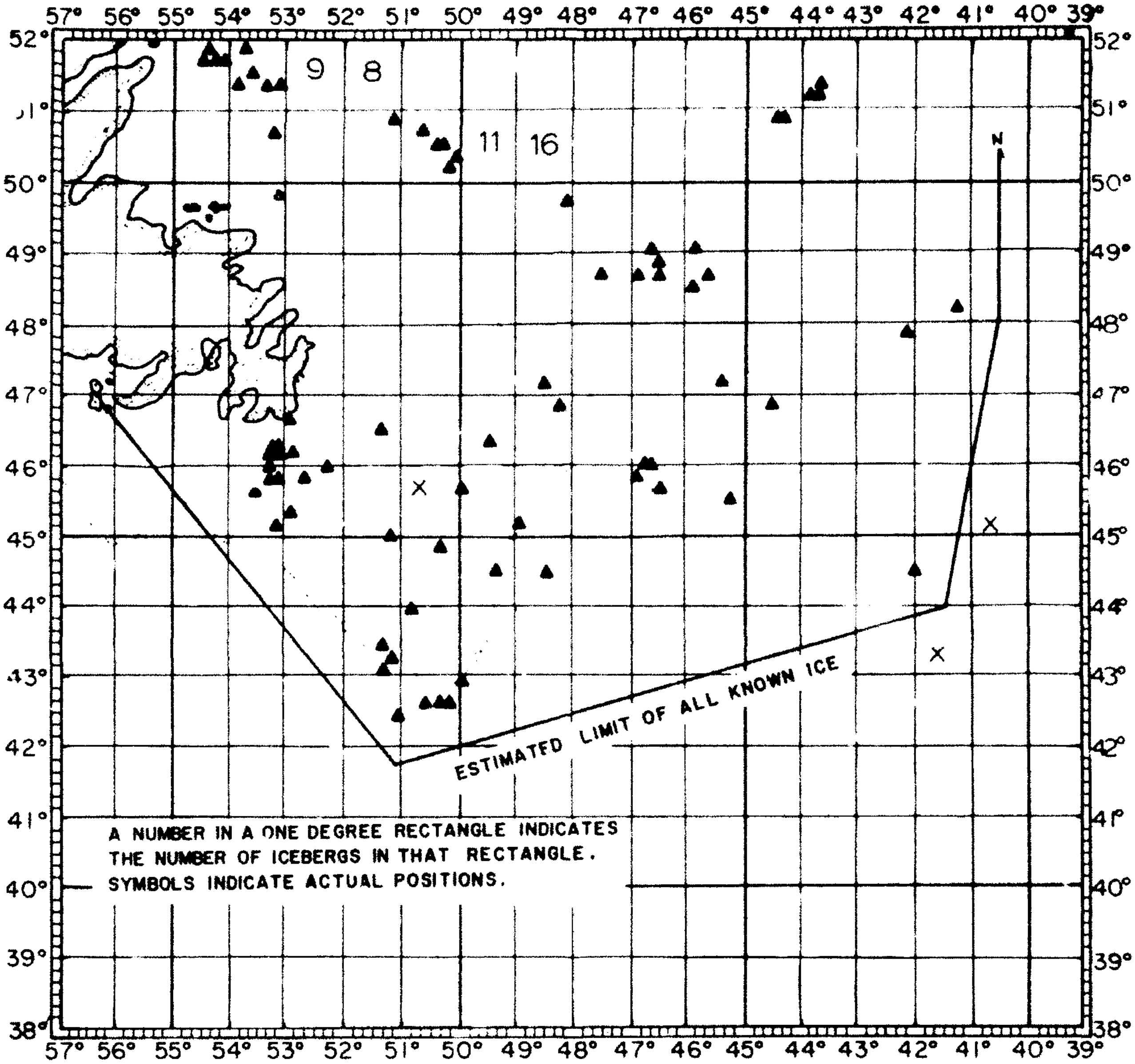
FOR 1200 GMT 30 JUN 84
BASED ON OBSERVED AND
FORECAST CONDITIONS

Figure 30



FOR 1200 GMT 15 JUL 84
BASED ON OBSERVED AND
FORECAST CONDITIONS

Figure 31



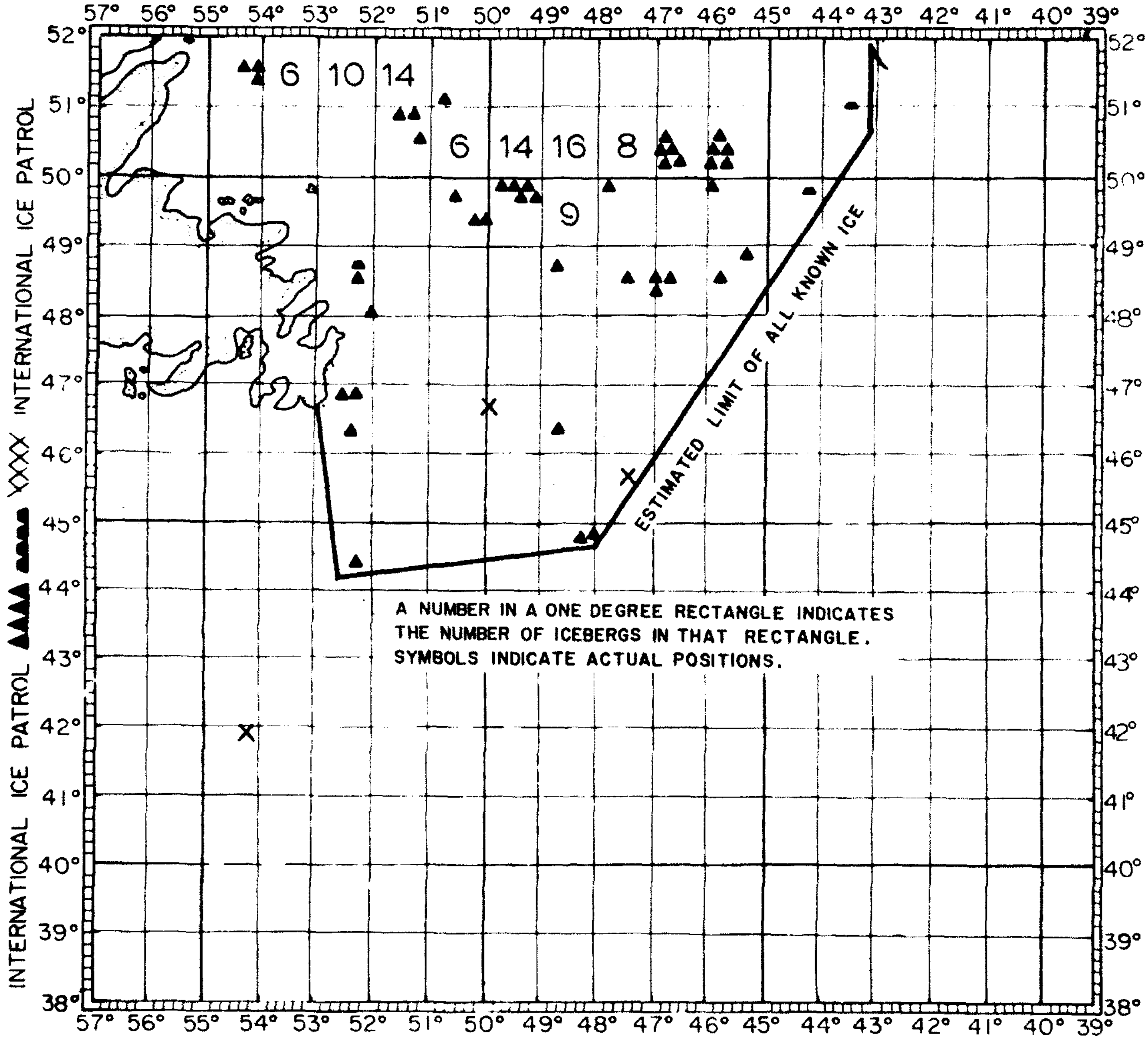
▲ BERG

● GROWLER

X RADAR TARGET/CONTACT

FOR 1200 GMT 30 JUL 84
BASED ON OBSERVED AND
FORECAST CONDITIONS

Figure 32

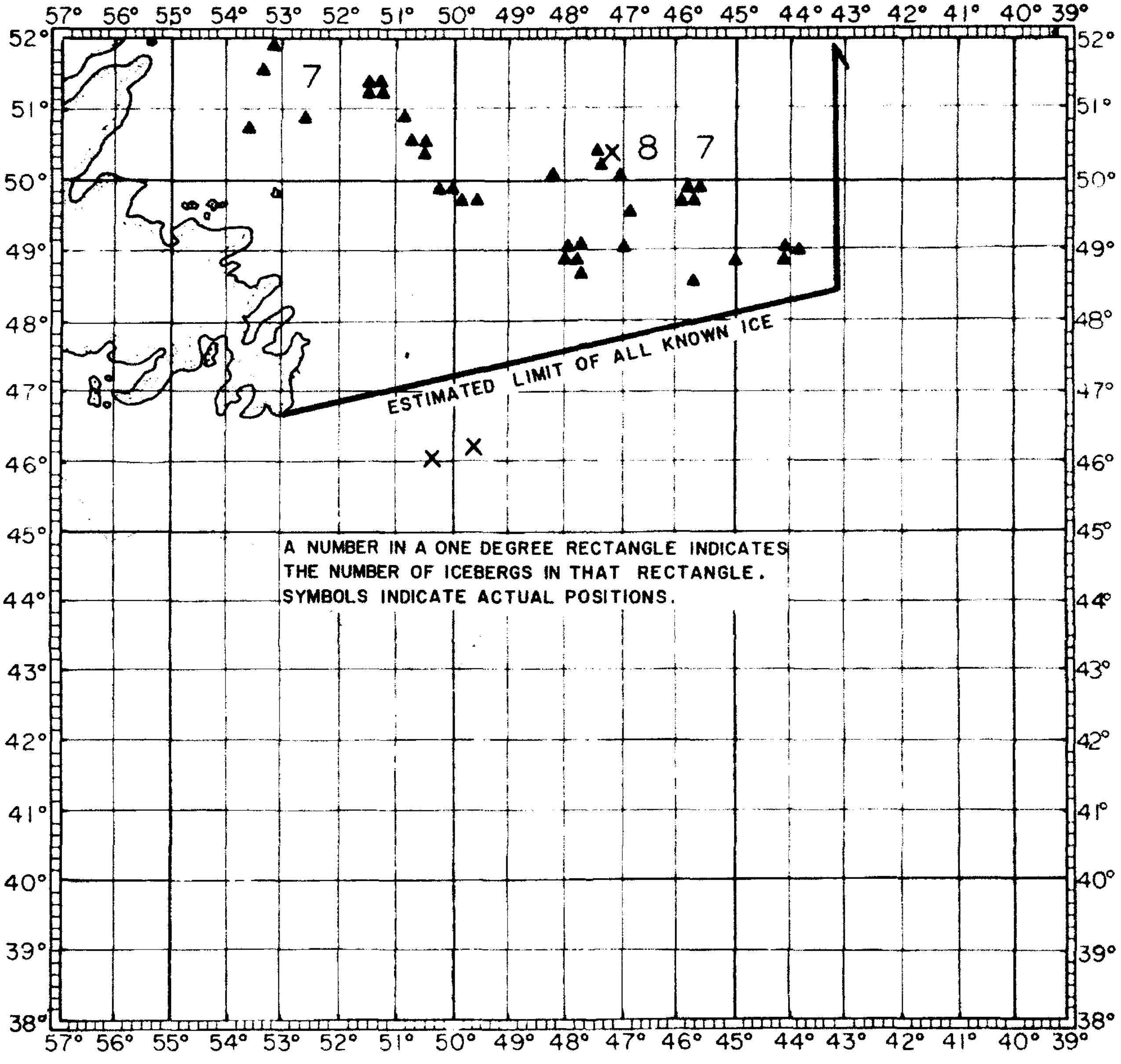


A NUMBER IN A ONE DEGREE RECTANGLE INDICATES THE NUMBER OF ICEBERGS IN THAT RECTANGLE. SYMBOLS INDICATE ACTUAL POSITIONS.

▲ BERG
● GROWLER
X RADAR TARGET/CONTACT

FOR 1200 GMT 15 AUG 84
BASED ON OBSERVED AND
FORECAST CONDITIONS

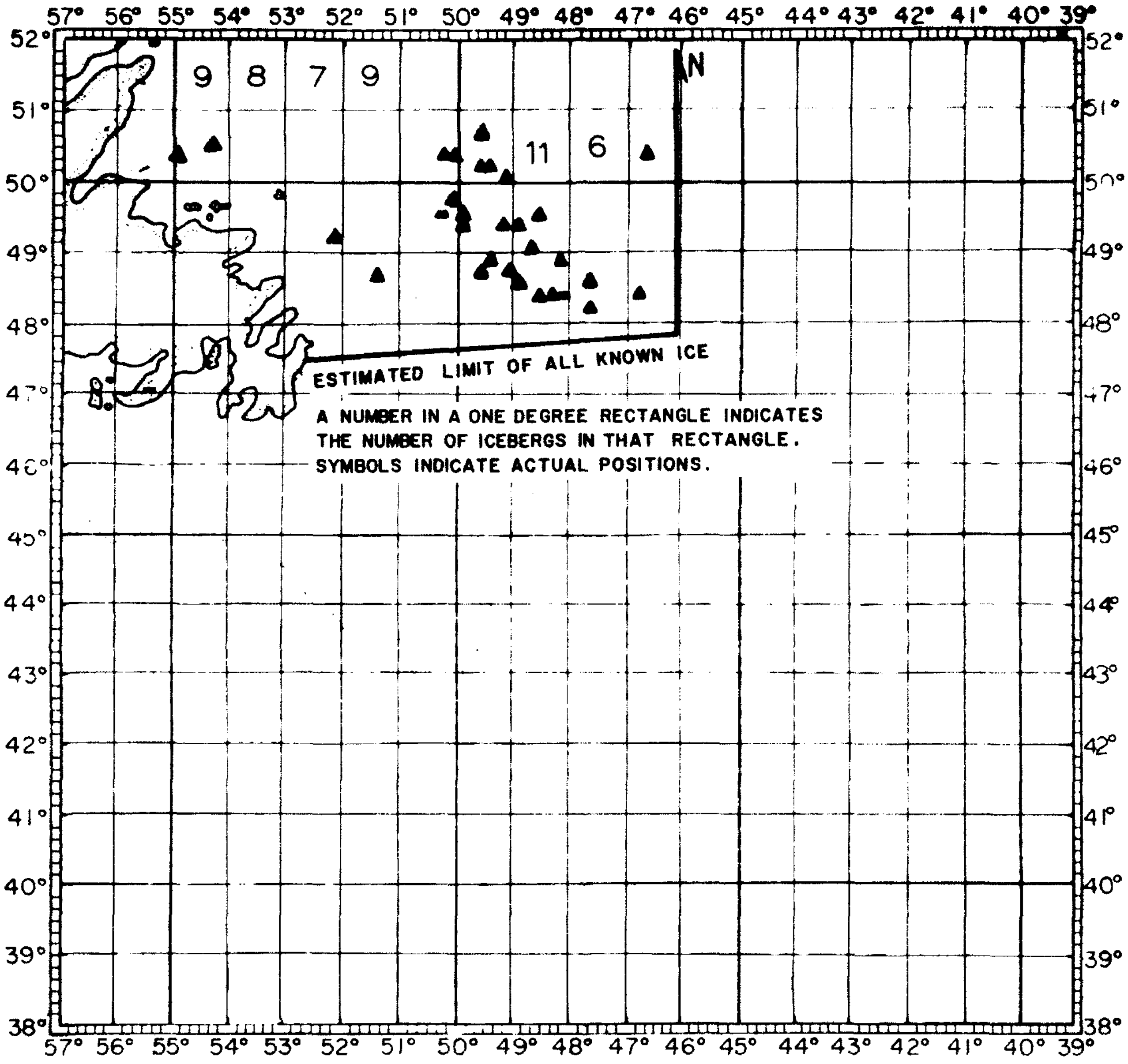
Figure 33



▲ BERG
● GROWLER
X RADAR TARGET/CONTACT

FOR 1200 GMT 30 AUG 84
BASED ON OBSERVED AND
FORECAST CONDITIONS

Figure 34



A NUMBER IN A ONE DEGREE RECTANGLE INDICATES THE NUMBER OF ICEBERGS IN THAT RECTANGLE. SYMBOLS INDICATE ACTUAL POSITIONS.

▲ BERG
▴ GROWLER
X RADAR TARGET/CONTACT

FOR 1200 GMT 07 SEP 84
BASED ON OBSERVED AND
FORECAST CONDITIONS

Discussion of Iceberg and Environmental Conditions

The number of icebergs that pass south of 48°N in the International Ice Patrol area each year is the measure by which International Ice Patrol has judged the severity of each season since 1912 (Table 1). With 2202 icebergs south of 48°N, 1984 is the record year with the previous maximum in 1972 being 1587. This record number and the near-record for 1983 (1349, fourth highest on record) are partially the result of International Ice Patrol's increased iceberg detection capability due to the introduction of the AN/APS-135 Side-Looking Airborne Radar (SLAR) to ice reconnaisance flights. The impact of SLAR on International Ice Patrol iceberg detection is examined in Appendix C.

During the period 2-7 April 1984, the International Ice Patrol participated in an airborne radar iceberg detection evaluation called Bergsearch '84. This experiment was sponsored by the Environmental Studies Revolving Funds (ESRF) administered by the Canada Oil and Gas Lands Administration (COGLA). The AN/APS-135 SLAR was tested along with two APS-94 SLAR's and the two synthetic aperture radars (SAR's) to assess the capabilities of these modern airborne imaging radars in the detection of icebergs in open water. The Ice Patrol conducted 71 passes on five sorties over iceberg-infested waters while ground truth was provided by the M/V POLARIS and visual confirmations were made by a King Air aircraft. The detection data were taken with light to moderate sea conditions of less than 4 meters and included target type (icebergs, sea ice, ships), iceberg size, aircraft altitude, aspect angle relative to the wind (sea), and depression angle. Since the emphasis was placed upon determining the detection of smaller pieces of ice (growlers and small icebergs), the analysis, which was conducted by CANPOLAR Consultants Ltd. under contract to ESRF, dealt with primarily icebergs less than 30 meters long. Because the Ice Patrol has been using the new SLAR for two seasons, this evaluation was of considerable interest. Preliminary results indicate that the APS-135 SLAR has a detection probability of approximately 65% for 10-30m icebergs, and better than 95% for icebergs over 30m in length at sea states moderate and less (Rossiter, 1984). Also, the repeatability of sighting these icebergs fluctuates less than +/- 10%. As suspected, the detectability of icebergs appears to decrease with increasing sea state, particularly for smaller targets. For growlers ($<100m^2$), the detection probability is very small (<5%), for they are often substantially submerged, hidden in the sea return or shadowed by the image of a parent iceberg. Of the 2202 icebergs sighted this past season, 83% were small, medium, large, or very large icebergs. Other sightings, which were not visually confirmed, may have been undersized from the SLAR imagery as growlers, since the experiment illustrated that iceberg shape and size cannot be readily measured. In patrolling the southern, southeastern, and southwestern limits of the Grand Banks with SLAR during 1983 and 1984, the iceberg detection capability has improved greatly (see Appendix C) over prior visual search years. SLAR has provided a more efficient Ice Patrol, since visual reconnaisance flights were conducted only 50% of the time, covering much smaller search areas with visibility partially obscured by fog or low clouds. Since the SLAR capability of detecting and identifying icebergs is unknown for more severe weather conditions, future experiments will need to be conducted.

Since the number of icebergs calved each year by Greenland's glaciers is in excess of 10,000 (Knutson, 1978), a sufficient number of icebergs exist in Baffin Bay during any year. Therefore, annual fluctuations in the generation of Arctic Icebergs is not a significant factor in the number of icebergs passing south of 48°N annually. The factors that determine the number of icebergs passing south of 48°N each season can be divided into those affecting iceberg transport (currents, winds, and sea ice) and those affecting iceberg deterioration (wave action, sea surface temperature, and sea ice).

Sea ice acts to impede the transport of icebergs by winds and currents and also protects icebergs from wave action, the major agent of iceberg deterioration. Although it slows current and wind transport of icebergs, sea ice is itself an active medium, for it is continually moving toward the ice edge where melt occurs. Therefore, icebergs in sea ice will eventually reach open water unless grounded. The melting of sea ice itself is affected by snow cover (which slows melting) and air and sea water temperatures. As sea ice melt accelerates in the spring and early summer, trapped icebergs are rapidly released and then become subject to normal transport and deterioration.

Under the influence of northerly winds over Davis Strait and the Labrador Sea, a large number of icebergs entered the International Ice Patrol area in April, making it the heaviest iceberg month of the 1984 season. Light westerly flow during May, which did little to assist the southward transport of icebergs, and the persistance of sea ice off Newfoundland and Labrador throughout the month resulted in a reduced number of icebergs entering open water. The sea ice remained south of 52°N until mid-June, retarding iceberg drift and preserving the icebergs longer than normal (see SST chart for June 1984 in Appendix B).

During late June and early July, the sea ice retreated dramatically and the number of icebergs south of 48°N significantly increased in July. The sharp decrease in the number of icebergs in August and September was the result of the increase in air temperatures (Table 5) and the warming of surface waters on the Grand Banks, both of which accelerated iceberg melt.

References

Rossiter, J.R., L.D. Arsenault, A.L. Gray, E.V. Guy, D.J. Lapp, R.O. Ramseier, E. Wedler, (1984); Detection of Icebergs by Airborne Imaging Radars, Proceedings of the 9th Canadian Symposium on Remote Sensing, St. John's, Newfoundland

Knutson, K.N. and T.J. Neill, (1978); Report of the International Ice Patrol Service in the North Atlantic Ocean for the 1977 Season, CG-188-32, U.S. Coast Guard, Washington, DC.

Acknowledgements

Commander, International Ice Patrol acknowledges the assistance and information provided by the Canadian Department of the Environment, the U.S. National Weather Service, the U.S. Naval Weather Service, and the U.S. Coast Guard Research and Development Center.

We extend our sincere appreciation to the staffs of the Canadian Coast Guard Radio Station St. John's, Newfoundland/VON and the Gander Weather Office and to the personnel of U.S. Coast Guard Air Station Elizabeth City and the USCGC HORNBEAM for their excellent support during the 1984 International Ice Patrol season.

Appendix A

International Ice Patrol SST and Ice Reports for 1984

Ship's Name	Country of Registry	Ice Reports	SST Reports
Acadian Gail	Canada	2	
Achilles	Singapore	5	4
Admiral Farhi Engin	Turkey	1	
Aegis Britannic	Panama		1
Aeneas	Trinidad	2	
Agip Abruzzo	Italy	2	7
Akizuki Maru	Japan		8
Akranes	Iceland	3	
Albright Explorer	United Kingdom	9	1
Alexander Schroeder	Germany	1	
Alrazak	France		1
Ambassador	United Kingdom	7	
Anangel Ares	Greece	2	2
Anboto	Liberia	4	
Andes Traders	United Kingdom	2	
Angela Smith	Netherlands	5	
Aquarius	Italy	1	
Arctic Link	United Kingdom	1	1
Arctic Lynx	Canada	1	
Arctic Shiko	Canada	3	
Atlantic Champagne	France	2	
Atlantic Cinderella	Sweden	1	1
Atlantic Sage	Sweden	1	
Atlantic Service	France	1	
Bartlett	Chile	1	
Batna	Algeria	1	3
Benvorlich	United Kingdom	1	
Berljot	Norway	1	
Besor	Liberia	1	
Bischofstor	Germany	12	
Boujniba	Morocco		2
Breslau 2	Panama	1	
Belocean	United Kingdom		6
Bridgewater	Germany	3	
Brittania	United Kingdom	4	
Brunto	Norway	5	
Calanda	Switzerland	1	
Canadian Explorer	United Kingdom	3	
Canforces Tracker	Canada	2	
CapeCornwall	Japan		3
Cape Lance	Registry Unknown	2	2
Cape Roger	Canada	2	
Cape Syros	Greece	1	
Caribou	Liberia	3	2
Carsten Russ	Panama	4	2
Cast Caribou	Liberia	1	
Cast Husky	United Kingdom	1	
Cast Muskox	United Kingdom	6	
Cast Polar Bear	Liberia	2	15
Cast Salmon	Poland	1	
Century Hope	United Kingdom	1	
Chemspan	Trinidad	1	1
City of Perth	United Kingdom	4	7
Clymene	United Kingdom	8	
Colditz	Germany	5	
CrownPromise	Liberia		3
Cyrena	France	1	

Appendix A (cont'd.)

International Ice Patrol SST and Ice Reports for 1984

Ship's Name	Country of Registry	Ice Reports	SST Reports
Dart Britain	Colombia	1	
Dart Continent	Czechoslovakia	2	
Dart Europe	Belgium	1	
Dart Tiritian	United Kingdom	3	
Dauogulf	Phillipines		1
Dilderdijk	Netherlands Antilles	1	
Dole Vega	Brazil		4
Eastern Harjel	Colombia		3
Eastern Shell	Czechoslovakia	1	
Edough	Algeria		7
Elareg	Canada	1	
Eleusis	Burundi	1	1
Elisabeth	Liberia	3	
Elmina	Greece		1
Erika Bolten	Panama	3	4
Europe	Belguim	1	
GB Falcon	Norway	1	
Falkoen	Sweden	1	
Fanny	United Kingdom	1	
Farnes	Liberia	4	
Federal Danube	Belguim	1	
Federal Maas	Belguim	1	
Federal Ottawa	Belguim	1	
Federal Pioneer	Union of Soviet Socialist Republics	3	
Federal Schelde	Liberia	1	
Federal Thames	Belguim	1	
Finnrose	Finland	1	1
Fivestar	Liberia	5	4
Fogo Isle	Canada	1	
Fort Kipp	Great Britain		1
Fort Ramezay	Canada	1	
Fort Steele	Great Britain		12
Fossnes	Norway		3
Frank Schroder	Germany	1	
Frimaro	Cuba		1
Gaviota	Germany	1	
General Dabrowski	Poland	3	
General Luma	Phillipines	1	
Golarl Petrosun	Liberia	2	2
Gulf Mackenzie	Canada	2	
Halifax	Greece		2
Hampton Lion	Liberia	3	
Helate	Panama	1	1
Helen Schulte	Netherlands	1	3
Heritage	Greece		2
Hohn	Germany	1	
USCGC HORNBEAM	United States of America	7	14
Hudson	Canada	15	8
Hual Traveller	Norway		3
Hunter Bow	Liberia	1	
Husky	Panama	1	
Hydrolock	United Kingdom	1	
Iguazu	Liberia		2
Imperial Quebec	Canada	2	
Ingua Pilot	Panama	1	
Invincible	United Kingdom	4	
Irving Elm	Canada	1	

Appendix A (cont'd.)

International Ice Patrol SST and Ice Reports for 1984

Ship's Name	Country of Registry	Ice Reports	SST Reports
Irish Spruce	Ireland	1	
Irving Forest	United Kingdom	1	
Irving Nordic	Canada	1	
Irving Ours Polaire	Canada	2	
Islander	Malta	2	
Ivan Derbenev	Union of Soviet Socialist Republics	1	
Jena	Germany	4	
John M	Germany	5	1
Joseph Roty	France	1	
Judson	Canada		1
Juventia	Panama	5	
Kemano	United Kingdom	1	
Kansas Getty	Bahamas		10
Kapetan Yannis	Greece		3
Katerina	France	1	
Koeln Express	Germany	1	
Konkar Indo Kitable	Greece	7	
Kurashima Maru	Japan		3
Labrador	Canada	1	
Lady Saunders	Canada	1	
Lake Anne	Norway	2	
Lake Biwa	Chile	3	1
Lakeanina	Norway	1	
Lalberte	Liberia		2
Lantau	Singapore	1	
Leon Et Pierre	Belguim	1	
Lokvihar	India	8	1
Lorena	Spain	1	
Louis L. D.	France	2	15
Louis S. St-Laurent	Canada	1	
Lousdrecht	Netherlands	1	
Ludoluf Oldendorff	Singapore	2	
Lumaaq	Canada	1	
Madeleine	Great Britain	3	
Maersk Triton	Liberia	1	
Mahone Bay	Canada	1	
Malabar	Registry Unknown	1	2
Manchester Challenge	United Kingdom	33	3
Marinz L	Greece	1	
Masovia	Liberia	6	
Mega Bay	Norway	1	
Mela	Indonesia	3	
Meltimi	Greece	6	7
Mesange	Canada	1	
Michalis	Greece	1	2
Mihalis	Greece	2	
MimiM	Greece		2
Minerva	Brazil	1	
Mosbrook	Norway	2	
Moutsqina	Greece	3	
Myuta	Panama	1	
N. M. Engin	Turkey	1	
Nautic Pioneer	Liberia	1	
Navimar 1	Canada	2	
Nihonkaimaru	Japan	1	
Noble Supporter	Liberia		7
Nordstrand	Burundi		1

Appendix A (cont'd.)

International Ice Patrol SST and Ice Reports for 1984

Ship's Name	Country of Registry	Ice Reports	SST Reports
USCGC NORTHWIND	United States of America	69	25
Nyuta	Panama	1	
Olinda	Singapore	1	
Oriental Ruby	Japan		9
Pacific Challenge	United Kingdom	1	
Pacific Courage	United Kingdom	4	
Pacific Freedom	Liberia	1	
Pacific Friendship	Liberia	1	
Pacific Progress	United Kingdom	1	
Palmstar Orchid	Singapore	1	
Pampero	Panama	2	8
Panama	Denmark		9
Parita	Finland		4
Penmen	France	3	9
Perth	United Kingdom	1	
Permnitz	Germany	4	
Pharos	Germany	3	
Philippeld	France	1	
Pokkinen	Finland	1	
Polar Circle	Canada	2	
Polaris	Togolese Republic	5	
Precious	Liberia	2	2
Premwitz	Germany	1	
Princess	Panama	1	
Primorsk	Union of Soviet Socialist Republics	1	
Queen Elizabeth II	United Kingdom	3	
Rannoe	Finland	6	
Rebeka	Romania	3	
Regina	Switzerland	2	
Reynolds	United Kingdom	7	
Rich Alliance	Panama	1	
Rigoletto	Sweden		3
Roman Pazinski	Poland		3
Rubens	United Kingdom	6	
Ryokomaru	Japan	1	
Satu Mar	Singapore	2	
Schnoorturm	Great Britain	1	
Seaforth Atlantic	Canada	1	
Sealand Independence	United States of America	1	
Sealand Leader	United States of America	1	
Sealand Vokager	United States of America	1	
Sealve	Sweden		1
Sekirex	Japan	2	
Shanadith 2	Registry Unknown	1	
Shenandoah	Greece	1	
Shinrei Maru	Japan	1	
Smeliy	Union of Soviet Socialist Republics	1	
USNS SOUTHERN CROSS	United States of America	18	13
Steam Bollard	Liberia	2	
Stefan Batory	Poland	7	
Stefan Starzynski	Poland	3	
Stolt Castle	Liberia	3	1
Stolt Sydness	Liberia	2	2
Stovetrader	Sweden	1	5
String Bridge	Panama		6
Studlasfoss	Iceland		2

Appendix A (cont'd.)

International Ice Patrol SST and Ice Reports for 1984

Ship's Name	Country of Registry	Ice Reports	SST Reports
Takeshimamaru	Japan		1
Temse	Belguim	1	1
Tatucareer	Panama	1	
Terra Nova	Greece	3	
Texaco Massachusetts	United States of America	2	1
Transocean Transport	Phillipines	2	1
Ungava Transport	Canada	1	
United Venture	Singapore	1	
Varjakka	Finland	2	18
Vasiliki	Greece	1	1
Vasya Korokbo	Ukranian Soviet Socialist Republics	1	
Velizh	Union of Soviet Socialist Republics	1	
Vera Maretskaya	Union of Soviet Socialist Republics	1	
Vergo	Canada		8
Victor Bugaey	Union of Soviet Socialist Republics	1	
Vissani	Panama	1	
Vitosha	Bulgaria	1	1
Viva	Norway	1	
Vladimir Timofeyev	Union of Soviet Socialist Republics	1	
Watergeus	Netherlands	3	
Western Viking	Panama	2	
Western Harbour	United States of America	3	
WilfredTempleman	Canada	1	
WorldAgamemnon	Greece		4
WorldDawn	Panama	1	
Willow Peak	Chile	1	
Yevgenit Vaktangov	Union of Soviet Socialist Republics	1	1
Yukona	Liberia	4	1
Yukona	Union of Soviet Socialist Republics	1	
Zagreb	Canada	1	
Ziemia Bilostocka	Poland	3	
Zim Genova	Israel	1	
Zimberia	Israel		1

Appendix B

Oceanographic Conditions on the Grand Banks During the 1984 International Ice Patrol Season

Lieutenant Iain Anderson, USCG

Introduction

For the first time since 1978, International Ice Patrol conducted hydrographic measurements on the Grand Banks (the data report is still to be published). The cruise was divided into two parts; the first dedicated to a hydrographic survey, and the second to iceberg drift and deterioration. Due to an inoperative Ocean Sampling System (OSS), the hydrographic section of the cruise was conducted using Nansen casts.

During the 1984 season, eleven satellite-tracked TIROS Oceanographic Drifters (TOD) were deployed in the IIP operating area. Nine of the TODs were deployed from an HC-130 aircraft during regular ice reconnaisance flights. The remaining two TODs were deployed from the USCGC HORNBEAM, the vessel used to conduct the IIP cruise. The two TODs deployed from HORNBEAM had been recovered after the 1983 season and were reconditioned and then deployed.

TIROS Oceanographic Drifters

Eleven TODs were deployed during the 1984 IIP season (Table B-1). All of the TODs were deployed with window-shade drogues attached to the TOD by a 30m tether. Each TOD was equipped with a sea surface temperature sensor, a drogue tension sensor, and a battery voltage monitor. The position (determined by Doppler shift of the TOD transmitted frequency at the receiver of a polar orbiting satellite) and sensor information from each buoy was obtained through Service ARGOS.

As of 1 October 1984, six of the eleven TODs were still drifting in the IIP region (Figure B-1). One of the TODs (TOD #4513) failed on deployment and another (TOD #4514) failed after nine days. Several of the parachute release mechanisms failed to operate properly at deployment. TOD #4509 and #4531 were observed being dragged across the sea surface by an air-filled parachute during the post-deployment overflight. The apparent source of the problem was insufficient voltage in the gel cells used to supply power to the parachute cutters after the salt-water-activated switch closed. The actual fate of the parachutes is uncertain. We assume that when the drogue fully deployed or when the parachute collapsed, it settled into the water and, at worst, became a near-surface drogue.

Table B-1.
TIROS Oceanographic Drifters Deployed in the 1984 Ice Patrol Season

TOD#	Date Deployed	Position Deployed	Avg Pos/Day	Last date data received*	Deployed
4511	22 MAR(082)	48°17.6'N 50°00.0'W	8.2	1 OCT+	C-130
4509	23 MAR(083)	49°53.4'N 45°50.3'W	6.8	1 OCT	C-130
4510	25 MAR(085)	49°00.0'N 47°58.2'W	8.3	20 SEP	C-130
4512	27 APR(118)	47°51.6'N 47°30.0'W	7.2	14 JUL	C-130
4514	28 APR(119)	48°15.0'N 52°20.0'W	10.4	7 MAY	C-130
4513	10 JUN(162)	47°29.7'N 47°28.8'W	---	------	C-130
4531	13 JUN(165)	48°32.0'N 48°01.0'W	7.9	1 OCT	C-130
2633	06 JUL(188)	48°20.0'N 48°30.0'W	7.8	1 OCT	SHIP
2632	17 JUL(199)	48°37.4'N 46°06.1'W	8.3	1 OCT	SHIP
4528	05 AUG(210)	50°59.4'N 51°01.2'W	9.7	1 OCT	C-130
4530	06 AUG(211)	46°46.8'N 46°54.4'W	9.3	1 OCT	C-130

* Within IIP region

+Picked up by fishermen on 1 AUG 84

There are no significant differences in the velocity distributions for TODs with confirmed parachute releases and those without, suggesting the parachute, if it remained attached did not affect the drift of the TOD (Figure B-2). TOD #2633 and TOD #2632 were deployed from HORNBEAM on 6 July and 17 July, respectively.

The drogue sensors indicated the drogues were never attached to the buoys, although the drogues were attached when deployed and are assumed to have remained attached at least through 1 August. TOD deployment position selection is based on the location of areas of high iceberg concentrations and areas of most unreliable drift prediction. The analysis includes data through 1 October 1984. The drift tracks of the TODs will be discussed below in chronological order according to deployment.

TOD #4511 was deployed on 22 March 1984 (Julian Date 082) near the 200m contour at 48°18'N 50°00'W. This position was about 1/2 mile south of the sea ice edge. Its initial movement was to the east at about 19 cm/s. On 27 March (087), TOD #4511 turned and moved nearly south for five days onto the Grand Banks (averaging 16.5 cm/s). This was not the motion anticipated. We had anticipated the deployment position would have placed TOD #4511 in the Labrador Current, but the TOD motion indicated the deployment position was south of the main current stream. The movement continued generally to the southwest through the Avalon Pass (with anticyclonic motion) at an average velocity of 11 cm/s until 10 July (192) near 46°03'N 54°01'W. TOD #4511 then moved generally north into St. Mary's Bay and was picked up by a fisherman on about 1 August (214). (It was recovered by the Canadian Coast Guard in late October and was returned to the International Ice Patrol.)

TOD #4509 was deployed on 23 March (083) north of Flemish Cap at 49°53'N 45°50'W. It drifted with a slow cyclonic motion at an average velocity of 11 cm/s until 21 April (112). It then began a series of cyclonic and anticyclonic motions centered about 40 km south of its deployed position that lasted until about 2 June (154). TOD #4509 then travelled in a northerly direction at an average velocity of 63 cm/s until 7 June (159). From 8 June to 28 September (160-272), it remained trapped in an anticyclonic eddy. The motion was centered about 52°N 46°W. The radius of the motion ranged from 30 to 120 km at an average velocity of 27 cm/s. Canadian METOC sea surface temperature (SST) charts do not indicate the presence of an eddy near 52°N 46°W for the period TOD #4509 was moving anticyclonically (Figure B-3).

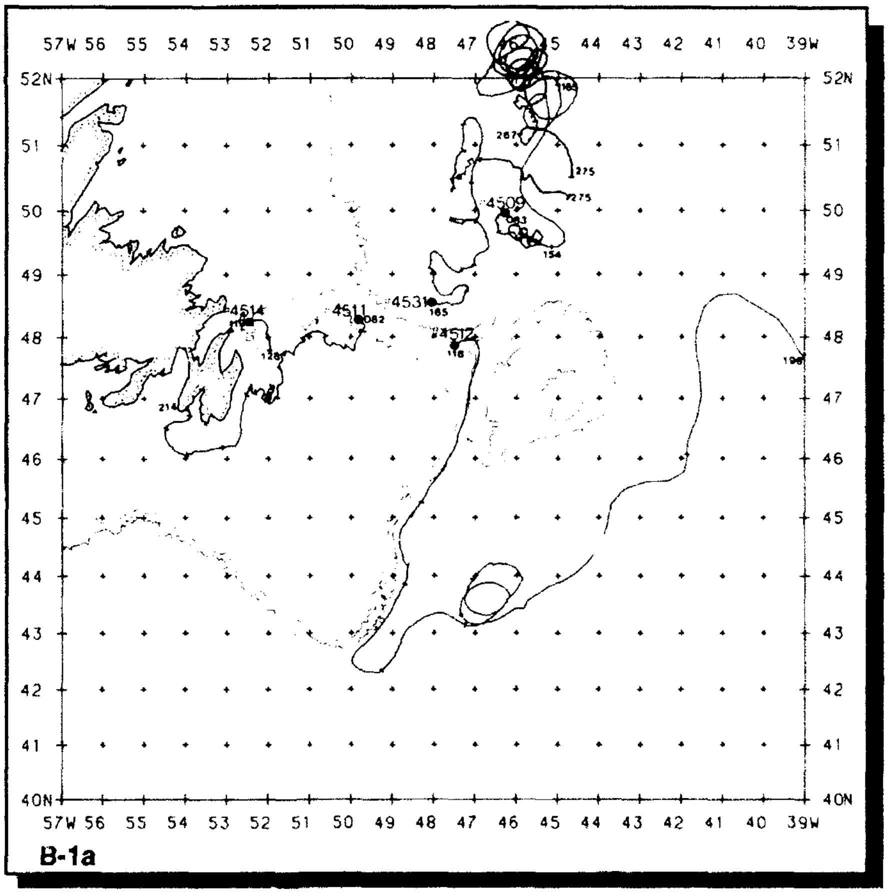
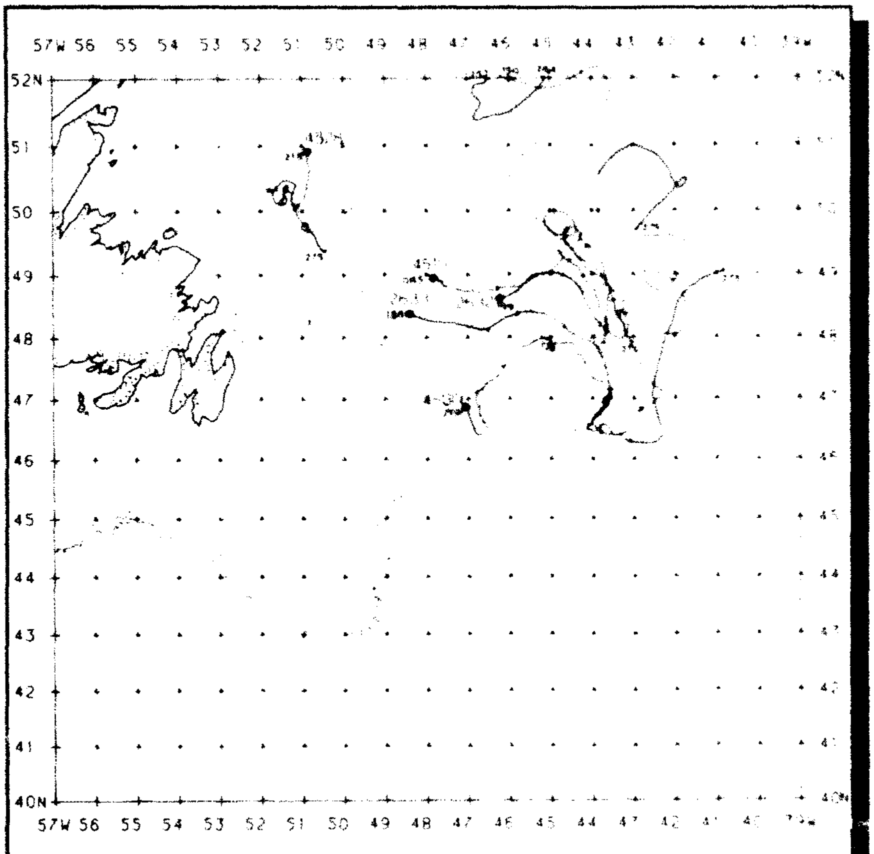


Figure B-1. Drift Tracks for International Ice Patrol's 1984 TODs. The • indicates the deployment position. Tick marks on the drift tracks are 10 days apart. Note the eddies contained in all of the drift tracks and the role of bathymetry in influencing the TOD motion.

TOD #4510 was deployed north of the Flemish Pass on 25 March (085) in position 49°N 47°58.2'W. This deployment position was in about one tenth sea ice cover. It proceeded east around the top of the Flemish Cap and followed the 2000m contour south around the eastern side of Flemish Cap at an average velocity of 17 cm/s until 4 May (125). On 4 May (125), TOD #4510 sharply altered its drift track and began drifting north and then northwest after crossing 49°N at an average velocity of 46 cm/s. Sea surface temperature charts and the drift indicate that TOD #4510 entered the North Atlantic Current on 4 May (125). The SST data from the TOD also confirms that TOD #4510 entered the North Atlantic Current. The drift pattern of TOD #4510 from 4 May (125) until it crossed 52°N on 22 May (143) is similar to those described in previous years (Anderson, 1983a and Summy, 1982). TOD #4510 remained above 52°N until 8 September (252). While above 52°N, TOD #4510 was caught in an anticyclonic eddy that was centered near 53°30'N 48°00'W before heading south on 29 August (241). From 1 September until 20 September (245-264), TOD #4510's motion was anticyclonic, apparently caught in the same eddy as TOD #4509. No signal was received from TOD #4510 after 20 September (264).



B-1b

TOD #4512 was deployed at the northern end of the Flemish Pass on 27 April (118) in position 47°51.6'N 47°30.0'W. TOD #4512 essentially followed the bathymetry south to the Tail of the Bank at an average velocity of 33 cm/s. On 24 May (145), TOD #4512 was caught up in the North Atlantic Current and began moving northeast. It was caught in a cyclonic eddy between 6 June and 27 June (158-179) (average velocity in eddy was 35 cm/s; radius of motion about 90 km). The METOC SST charts indicated the presence of two warm core (anticyclonic) eddies in the area where TOD #4512 exhibited cyclonic motion (Figure B-3). It continued drifting to the northeast at an average velocity of 74 cm/s. TOD #4512 exited the International Ice Patrol region at 46°41'N 39°00'W on 14 July (196).

TOD #4514 was deployed in the northern area of the Avalon Channel on 28 April (119) in position 48°15'N 52°20'W. It drifted slowly to the southwest at an average velocity of 14 cm/s until 7 May (128). No further

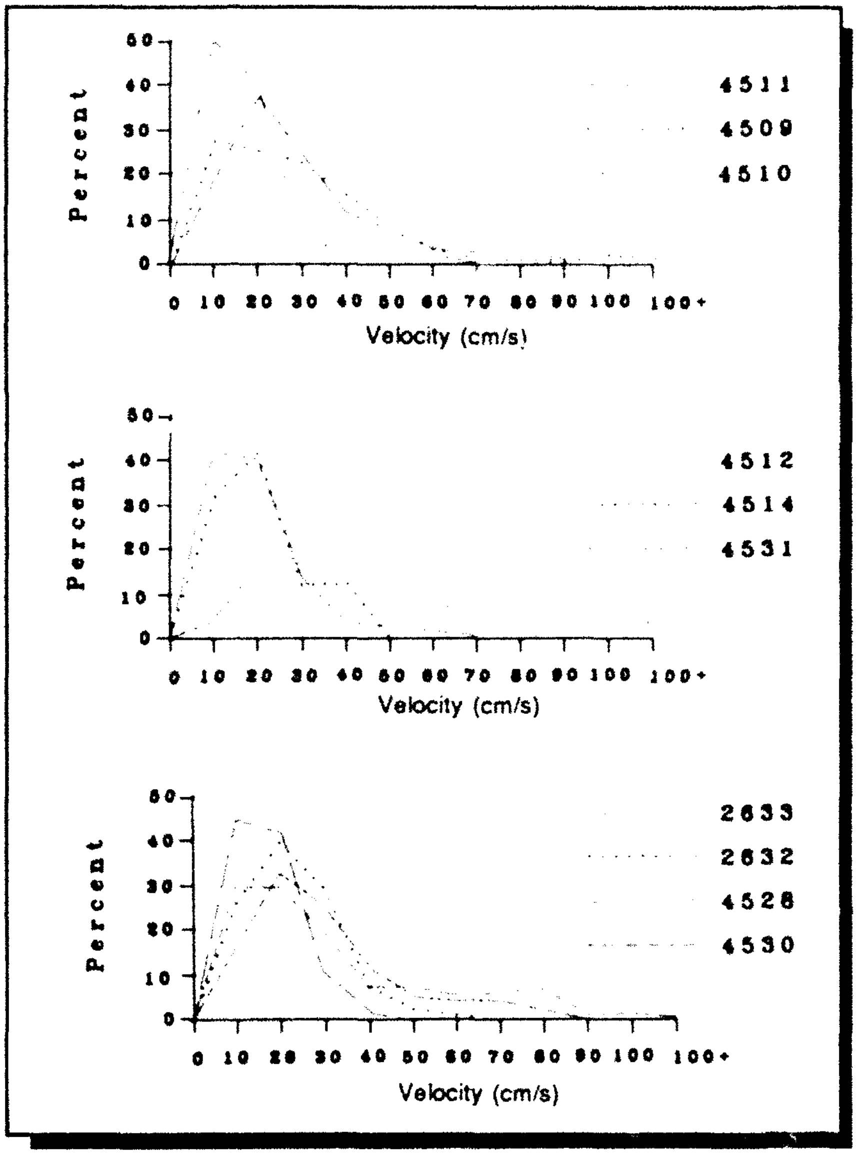


Figure B-2. *Velocity distributions for International Ice Patrol's 1984 TODs. TOD #4512's velocity distribution is significantly different from all others because it remained in the Labrador Current and the North Atlantic Current for the duration of its drift in the International Ice Patrol area.*

signal was received from TOD #4514 after that date, but this short drift illustrated much less than the 49 cm/s average velocity used by the historical current file in this section of the Avalon Channel.

TOD #4531 was deployed about 110 km northwest of the northern end of the Flemish Pass (48°32'N 48°01'W) on 13 June (165). It moved slowly (average velocity 12 cm/s) northward until 30 August (241). It then travelled southward roughly paralleling its northbound leg, about 8 km west of the northbound leg, at 12 cm/s until 18 September (262). After this date, TOD #4531 drifted east, then southeast at 29 cm/s until 1 October (275). The section of the drift after 18 September (262) was nearly perpendicular to the historical current field for that area.

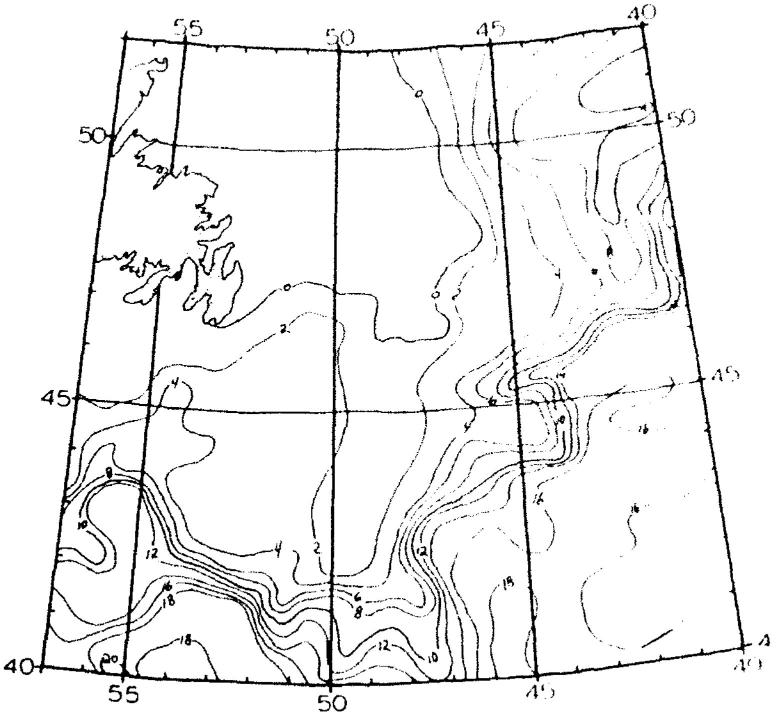
The next two TODs were deployed from USCGC HORNBEAM during the IIP cruise. TOD #2633 was deployed from USCGC HORNBEAM during the IIP cruise. TOD #2633 was deployed on 6 July (188) at hydrographic station #23 in position 48°20'N 48°30'W. It drifted eastward over the top of the Flemish Cap and roughly followed the bathymetry south on the eastern side of the Cap until 28 August (241). It then began drifting northward at an average velocity of 39 cm/s in the North Atlantic Current. As of 1 October (275), TOD #2633 appeared to be caught in the circulation of an anticyclonic (warm core eddy) centered near 50°30'N 43°00'W. TOD #2632 was deployed on 17 July (199) next to the iceberg used in the drift and deterioration experiment described below. TOD #2632 drifted northeast and then southeast roughly following the bathymetry around the top of Flemish Cap until 11 August (224). TOD #2632 then drifted northwest at about 19 cm/s until 5 September (249) and then drifted southeast at 16 cm/s through the same general area it had just traversed. This drift helps illustrate the large temporal variability of the flow field in the Grand Banks region.

TOD #4528 was deployed on 5 August (218) in an area of high iceberg concentration at 50°59.4'N 51°01.2'W. It drifted southward at an average velocity of 15 cm/s until 17 August (230). It then apparently became caught in a weak cyclonic eddy and remained entrapped until 13 September (257). TOD #4528 continued drifting south at 12 cm/s until 1 October (275). The southward velocities indicate that TOD #4528 was not in the Labrador Current, yet the METOC SST charts indicate it should have been on the western edge (Figure B-3). This suggests the METOC SST charts alone cannot always be used to identify the location of the Labrador Current.

Figures 3 (a-g)
Canadian METOC Sea Surface Temperature Charts for the indicated periods. Sea Surface Temperatures (C°)

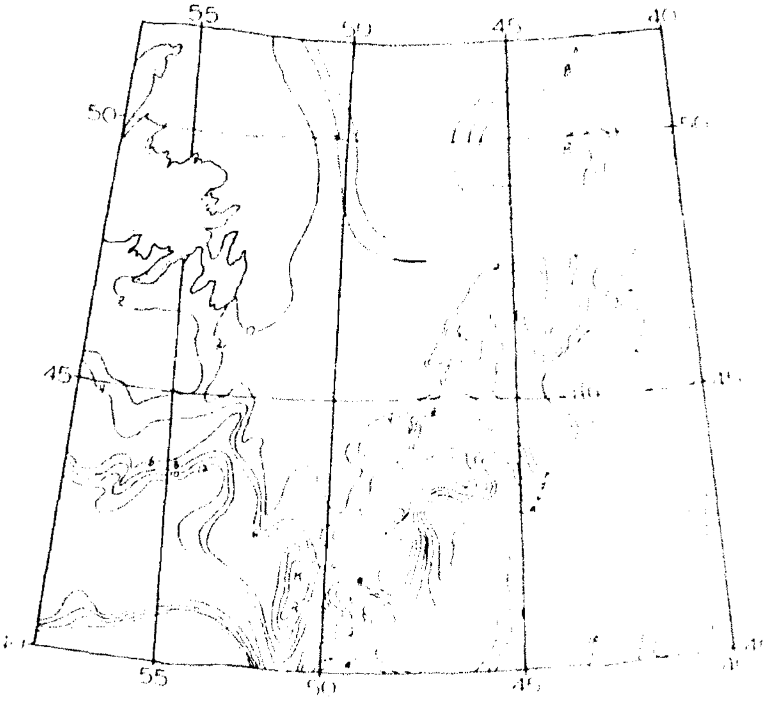
The final TOD of the 1984 season, TOD #4530, was deployed on 6 August (219) in the center of the Flemish Pass in position 46°46.8'N 46°54.4'W. It drifted south at 10 cm/s until 8 August (221). It then drifted north around the top of the Flemish Cap and continued to follow the bathymetry south down the east side of the Cap until 23 September (267). The average velocity around the Cap was 22 cm/s. Kollmeyer (1966) had reported the presence of a north flowing counter current in the Flemish Pass. This drift was similar to that found by Shuhy (1981). After 23 September (267), TOD #4530 began drifting with the North Atlantic Current towards the northeast at an average velocity of 64 cm/s.

The 1984 TOD's clearly demonstrate the variability of the flow field in the vicinity of the Grand Banks. The differences in TOD tracks #4510, #2633, #2632, #4530, and #4531 indicate that the axis of the North Atlantic Current migrates east and west in the area northeast of the Flemish Cap. The velocity distribution of TOD #4512 is significantly different from the remaining distributions (Figure B-2). It was the only TOD that remained in either the Labrador Current or the North Atlantic Current for its duration in the International Ice Patrol operating area. Considering the variability of the flow field, TOD's are essential to International Ice Patrol's ability to successfully predict the movements of icebergs in the Grand Banks area.



15-18 March 1984

Figure 3-a



10-14 April 1984

Figure 3-b

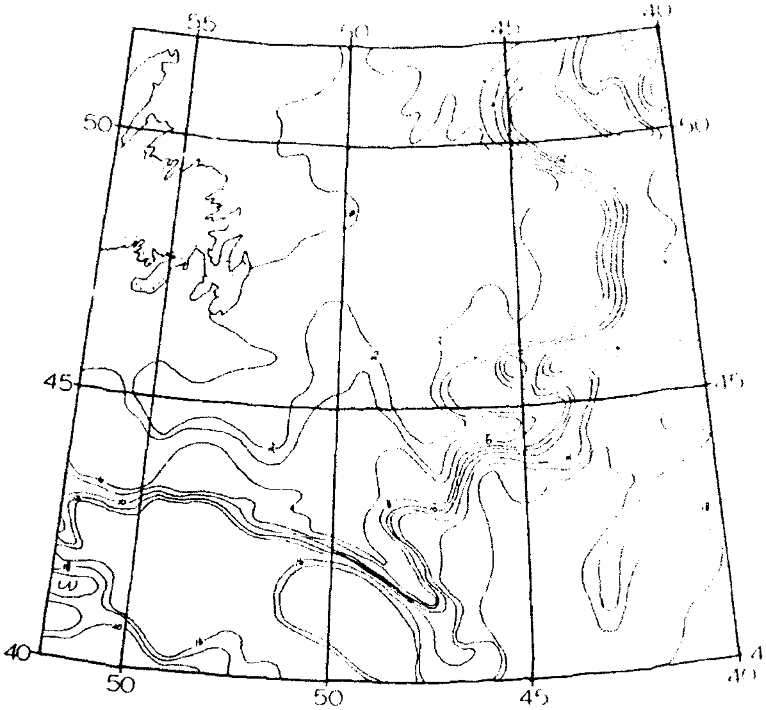
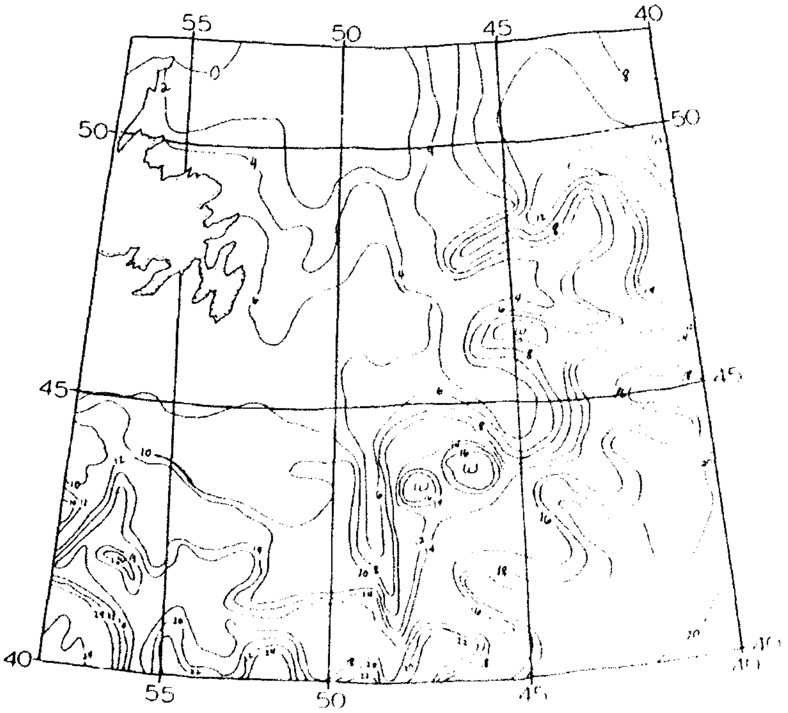
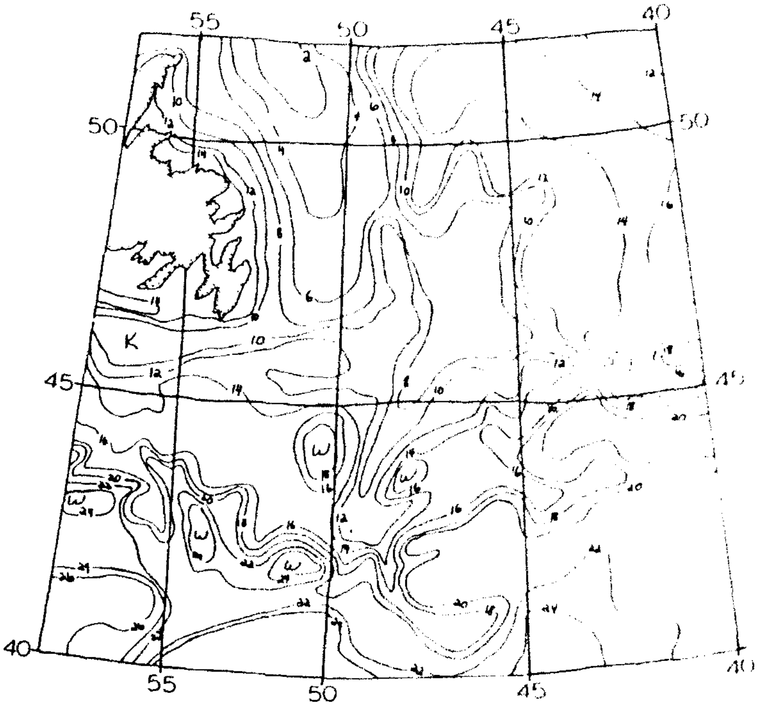


Figure 3-c 10-14 May 1984



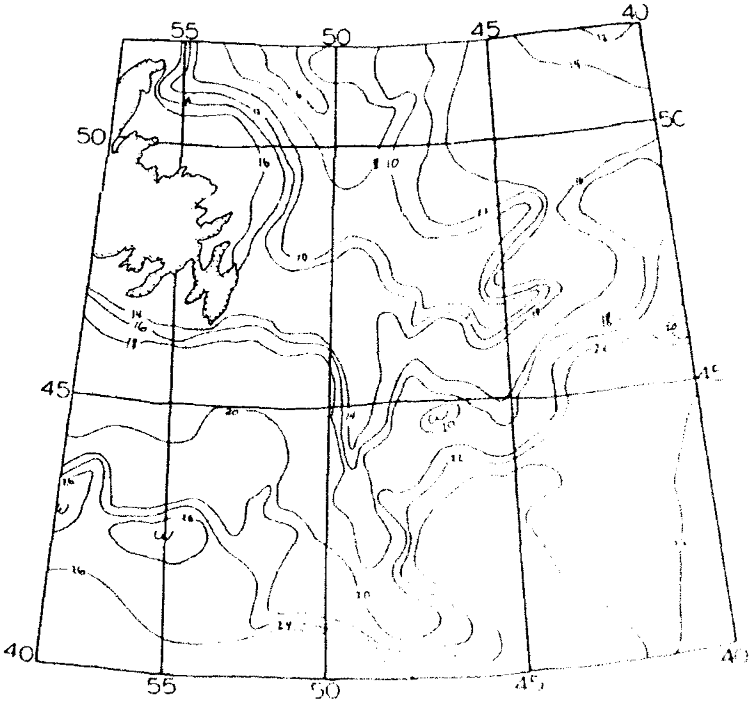
11-14 June 1984

Figure 3-d



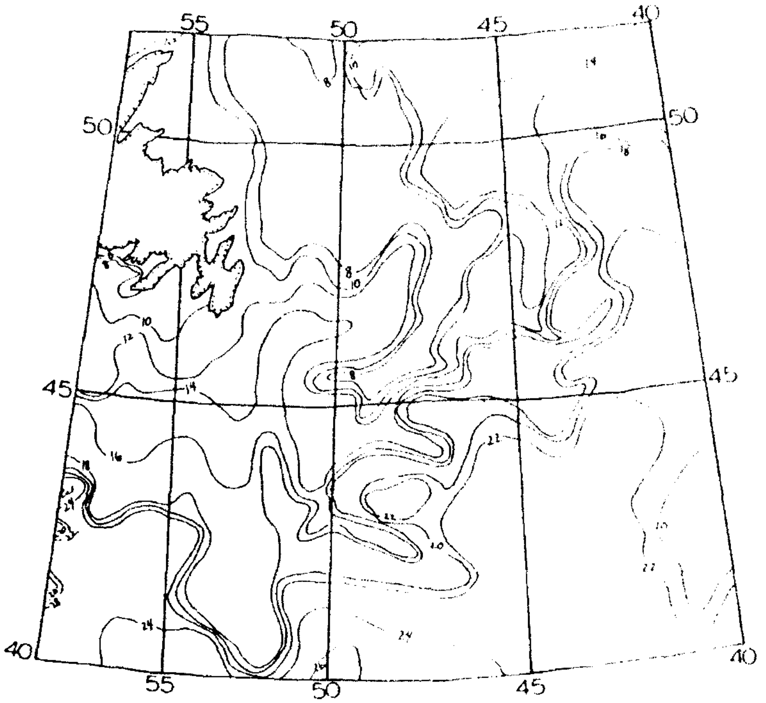
13-16 July 1984

Figure 3-e



10-13 August 1984

Figure 3-f



20-24 September 1984

Figure 3-g

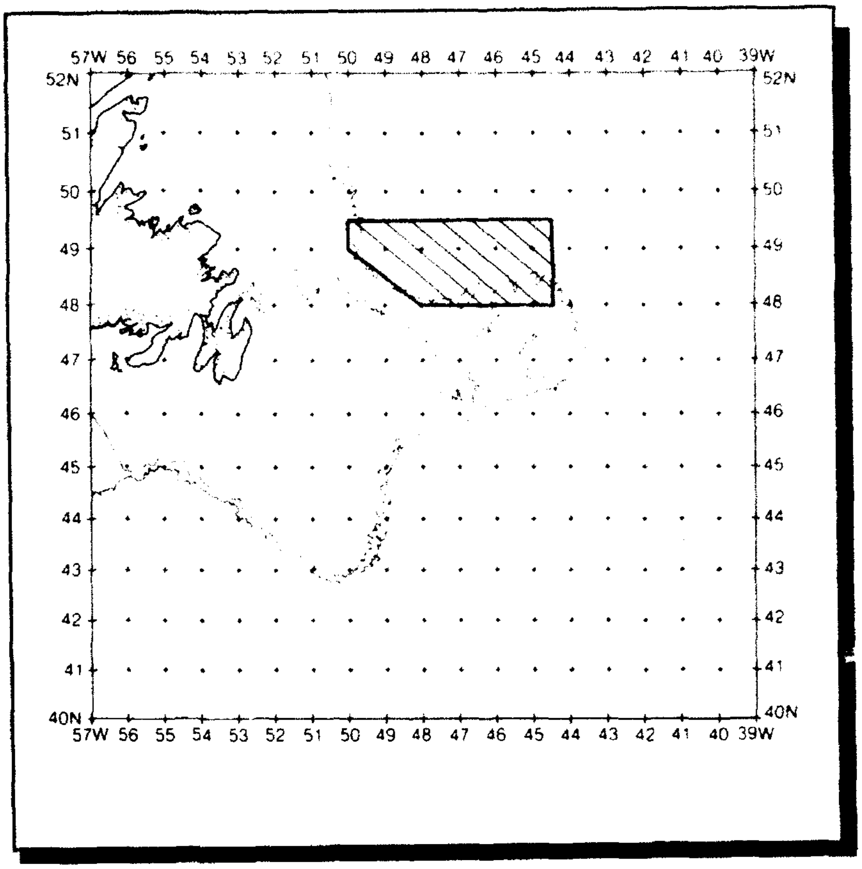
Hydrographic Survey

A two part oceanographic cruise was conducted from USCGC HORNBEAM (WLB-394). The first part was a hydrographic survey conducted between 1 and 11 July 1984 (Figure B-4). One of the objectives of this year's cruise was to compare TOD drift with geostrophic current. The International Ice Patrol has assumed TOD drift tracks can be used to calculate geostrophic currents since first using TODs in 1976. The Ice Patrol uses a computer program to remove wind driven current based on Ekman dynamics from TOD drifts and computes a "quasi-geostrophic" current. This current information is used to modify the time-invariant historical geostrophic current field used to predict iceberg motion. Another objective of the cruise was to determine how accurately Fleet Numerical Oceanography Center (FNOC) environmental products compared with actual conditions. We were interested in the magnitude of the errors in the products we received from FNOC.

Seventy-five of a planned 100 hydrographic stations were occupied during the first phase (Figure B-5). Water samples were collected using Nansen bottles at all standard depths to 500m (Table B-2). Nansen bottles were used because the Coast Guard's Ocean Sampling System (a Conductivity, Temperature, Depth instrument) was inoperative. A minimum of two protected deep sea reversing thermometers were attached to each Nansen bottle sampling above 200m. An unprotected deep sea reversing thermometer was also used on bottles sampling 200m and deeper. The conductivity ratios and corresponding salinities of all water samples were determined at sea, while corrected temperature values were determined after returning to Groton. The dynamic height contours relative to the 500 decibar pressure surface for the survey area are shown in Figure B-6. In previous surveys, dynamic heights were computed from CTD or STD data relative to the 1000 decibar surface and then contoured at 0.02 dynamic meter intervals (Kollmeyer, 1966; Scobie and Schults, 1976). Due to the inherent errors associated with Nansen casts (as compared to CTD data) and the spacing of the station lines, the data from this cruise were contoured at 0.05 dynamic meter intervals. All of the water samples from the 500m bottles had nearly the same temperature and salinity values, indicating the water at 500m was nearly homogeneous for the entire survey area. Historical IIP data shows the geopotential surfaces below 500 decibars are mainly isosteric and contribute only a small fraction to surface dynamic height variations, making relative measurements to 500 decibars valid for examining circulation in this area.

TOD #2633 was deployed immediately after occupying station #23 (48°20'N 48°30'W) on 6 July (188). The anticipated drift was through the survey area. For the first three to four days, TOD #2633, for the most part, followed the observed geostrophic flow (Figure B-6). The geostrophic current in this section of the hydrographic survey was well-defined. For the

Figure B-4. *The location of the hydrographic survey conducted by International Ice Patrol from the USCGC HORNBEAM, 1-11 July 1984*



period of 6 -10 July (188-192) (when the buoy followed the geostrophic flow), the thermocline depth was about 20m for the area through which the buoy drifted. For this period, the drogue was below the middle of the thermocline.

East of 46°30'W, the observed geostrophic current field became less distinct. By the time TOD #2633 crossed 46°W on 20 July (202), the hydrographic data was 10 days old. The observed currents east of 46°W were weak. The current field of that particular area has a high degree of variability (Soule, 1964; Scobie and Schultz, 1976). For the period of 24 July - 1 August (206-214), TOD #2633 more closely followed the wind current (Figure B-7). The thermocline depth varied between 35m and 40m, indicating the drogue was above the middle of the thermocline, and thus, in the surface mixed layer. To illustrate this effect, the buoy motion is compared with a calculated wind driven current based on McNally (1981). He used 1.5% of the wind speed *directed 30° to the right of* downwind. Measured winds from HORNBEAM were used to calculate the wind driven current when available. Otherwise, FNOC winds were used.

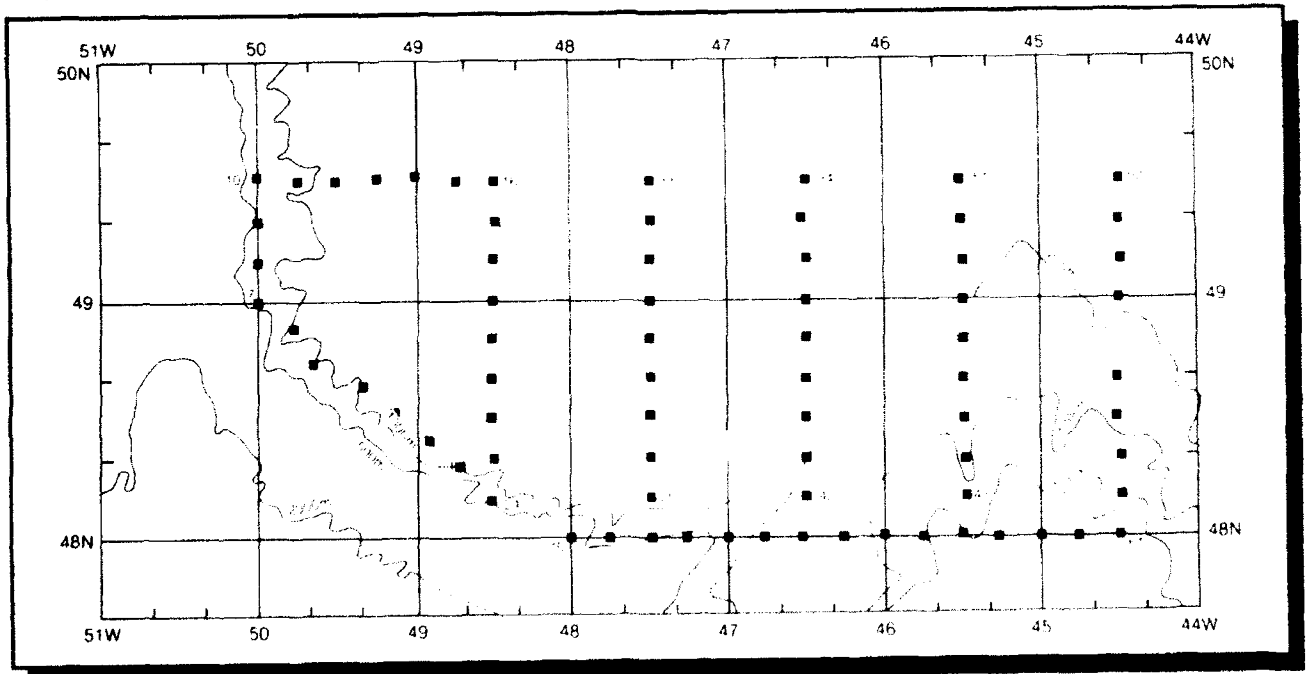


Figure B-5. *Hydrographic cast stations taken from USCGC Hornbeam 1-11 July 1984*

Table B-3. Measured vs FNOC Winds

Date	Direction+ Difference	Speed+ Difference	Speed Difference/ Measured Wind Speed*	Speed Difference/ FNOC Wind Speed*
7 JUL	40°	-6.5 M/S	162%	-62%
8 JUL	82°	-0.5 M/S	10%	-9%
10 JUL	-10°	-2.0 M/S	29%	-22%
11 JUL	0°	-2.5 M/S	28%	-22%
15 JUL	-32°	-2.0 M/S	22%	-18%
16 JUL	-43°	-5.5 M/S	110%	-52%
16 JUL	4°	0.0 M/S	0%	0%
17 JUL	-96°	-2.0 M/S	36%	-27%
18 JUL	30°	-3.0 M/S	40%	-29%
18 JUL	-20°	-2.5 M/S	50%	-33%
20 JUL	-23°	-6.0 M/S	120%	-55%
21 JUL	-11°	-1.0 M/S	22%	-18%
22 JUL	-27°	0.5 M/S	-7%	+7%
AVG	-8.2°	-2.5 M/S	48%	-26%
STD**	43°	2.2 M/S	51%	21%

+ Observed - FNOC; * Times 100; ** Standard Deviation

Table B-2

Standard Depths Sampled

0m	75m	300m
10m	100m	400m
30m	150m	500m
50m	200m	

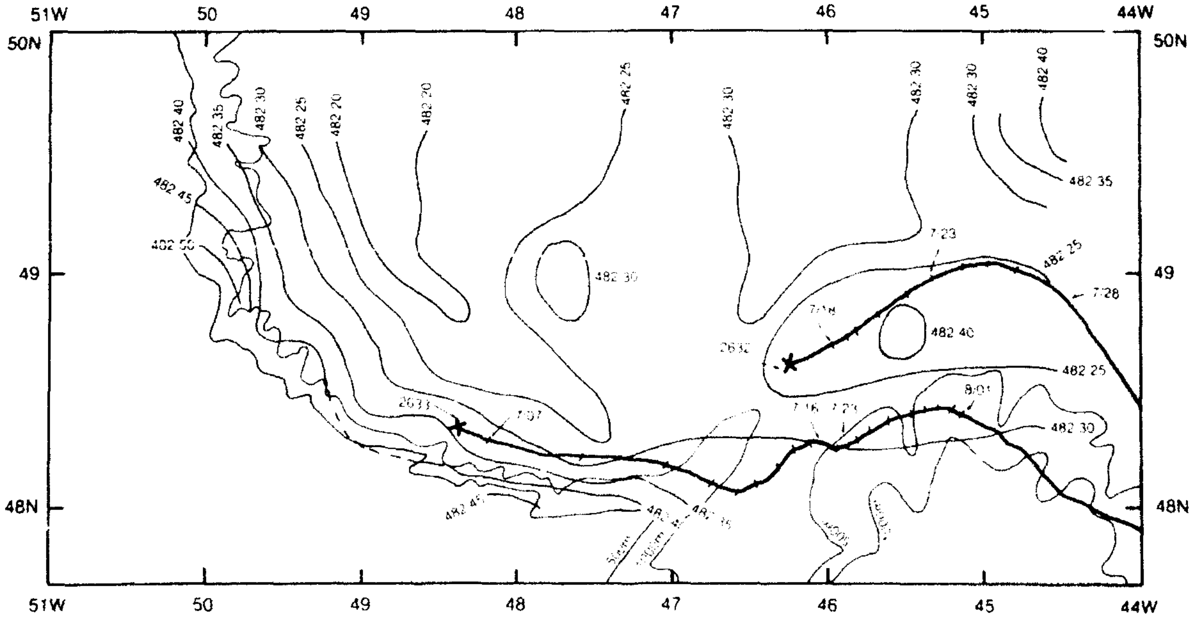
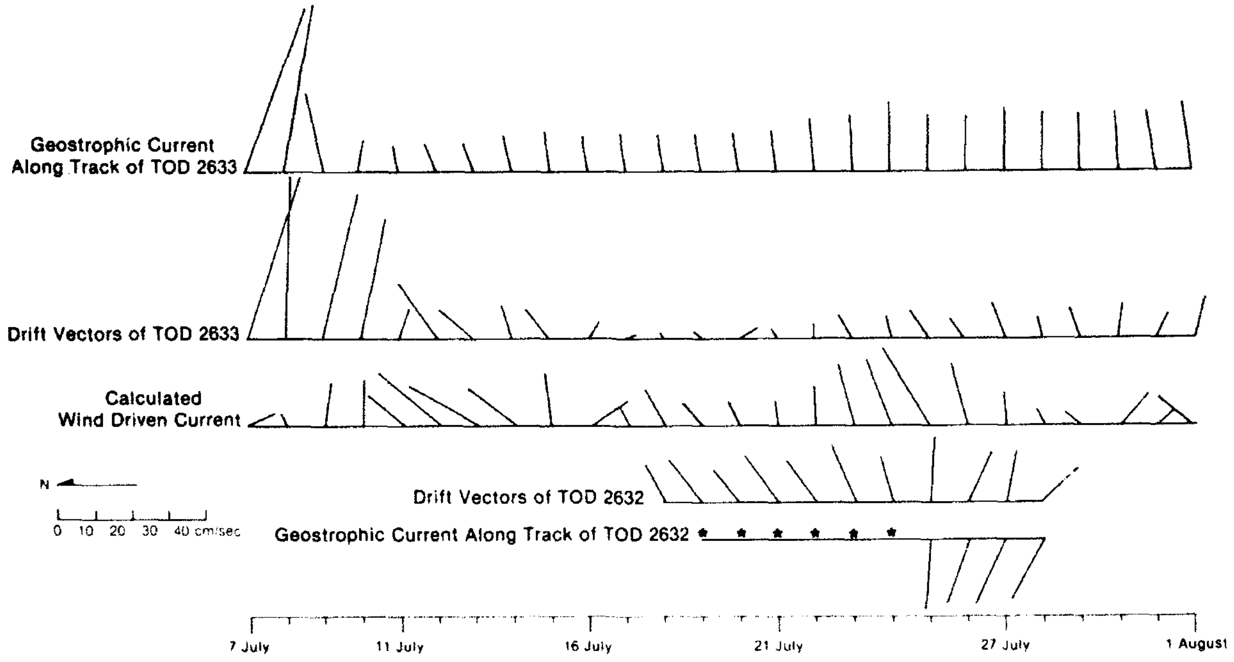


Figure B-6. *Dynamic heights calculated from the hydrographic survey of 1-11 July 1984 relative to the 500 decibar surface. The contouring interval is 0.05 dynamic meters. The 500m and 1000m depth contours are plotted. The heavy dark lines are the drift tracks of TODs #2633 and 2632 with the* **X** *indicating deployment positions.*

TOD #2632 was deployed as part of an iceberg drift and deterioration study and it remained in the survey area until 28 July (210). The drogue of TOD #2632 remained above the middle of the thermocline (35-40m) for the period of 17-28 July (199-210). The drift of TOD #2632 within the survey area can be almost totally explained by the wind driven current.

During both phases of the cruise, wind speed and direction measurements were taken aboard HORNBEAM every hour. The anemometer was approximately 15m above the water. The FNOC Marine Layer Wind product used by IIP represents winds 19.5m above the sea surface. Twelve hour average measurements for 0000Z and 1200Z (+/- 6 hours) were determined and compared to the analysis wind products received from FNOC. It should be noted that a comparison is being made between point source winds (HORNBEAM) and spatially averaged winds (FNOC). The data show that wind velocity computed by FNOC was consistently higher than that measured (Table B-3). The FNOC winds are used in the



TOD Drift, Measured Geostrophic Current, and Calculated Wind Driven Current

Figure B-7. *The geostrophic current shown for each TOD track was calculated from data obtained1-11 July 1984. The TOD drift vectors are a 24-hour average centered around 1200 GMT of each day. The wind driven current was calculated based on McNally (1981) and used 1.5% of the wind speed directed 30° to the right of downwind. Observed winds from the HORNBEAM were used in the calculations when available (7-11 and 16-21 July). FNOC winds were used for the remaining calculations. The * indicates an area where accurate geostrophic currents could not be calculated.*

process described above to create a "quasi-geostrophic" current from the TOD drift data. This apparent over-estimate of the wind velocity would adversely affect the calculation of the Ekman wind current subtracted from the TOD motion. This study of the FNOC winds was not meant to be exhaustive but was an effort to identify possible sources of error in our calculations of the Ekman wind driven current.

Iceberg Drift and Deterioration

The second part of the cruise was an iceberg drift and deterioration study conducted between 16 and 22 July 1984. The primary objective of the second phase was to evaluate the iceberg deterioration model being used by IIP. The iceberg deterioration model was used operationally during both the 1983 and 1984 seasons. The model is described in detail in Anderson (1983b). We hoped to locate a group of icebergs of various sizes and follow them and observe their deterioration. By following the melting icebergs, obtaining drift data was only a matter of recording the iceberg position periodically.

A medium iceberg approximately 120m long by 115m wide by 37m high was located on the afternoon of 16 July in position 48°41.9'N 46°20.4'W (Figure B-8). We were able to follow this iceberg until the morning of 22 July before we had to depart the area. At our departure, the iceberg was about 40m long, 28m wide, and 12m high (Figure B-8). The dimensions given here and discussed below will be maximum dimensions in each phase regardless of shape. Unfortunately, we were not able to locate a group of icebergs to observe.

Most of the size measurements of the iceberg were determined using a reticulated laser range finder. Due to extremely poor visibility (less than 200m) during

Table B-4 Actual vs Modelled Iceberg Deterioration

			Predicted Deterioration Due to			
Date/Time July/Zulu	Actual Length	Predicted Length	Insolation	Buoyant Convection	Wind-Forced Convection	Wave Erosion
16/1400	120m	120.0m	----	----	----	----
16/1800	137m	117.7m	.01m	.03m	.20m	2.08m
17/0600	114m	110.3m	.01m	.10m	.63m	6.54m
17/1800	102m	105.1m	.01m	.10m	.66m	4.46m
18/0600	87m	99.2m	.01m	.10m	.66m	5.09m
18/1800	90m	92.3m	.01m	.11m	.68m	6.06m
19/0600	91m	85.5m	.01m	.11m	.68m	5.95m
19/1800	87m	79.6m	.01m	.11m	.72m	5.08m
20/0600	67m	73.8m	.01m	.11m	.72m	4.98m
20/1800	----	69.0m	.01m	.11m	.72m	3.99m
21/0600	60m	64.7m	.01m	.12m	.79m	3.41m
21/1800	53m	60.4m	.01m	.12m	.79m	3.41m
22/0600	40m	54.9m	.01m	.13m	.84m	4.49m

the last two days of the study, measurement estimates of the dimensions of the iceberg were made by bringing HORNBEAM alongside the iceberg. The estimates were made using the frame numbers on the HORNBEAM. Photographs of the iceberg were taken and the range to the iceberg and the focal length of the lens recorded so measurement estimates could later be made from the pictures. The position of the iceberg, wave height and period, and wind force and direction were recorded hourly. SST was recorded several times per day.

The observed environmental information was used as inputs into IIP's deterioration model (Table B-4). An assumed relative motion of 25 cm/s was used in calculating wind force convective melting. Calculated remaining length was plotted against the maximum observed length (Figure B-9). The results show the model gives fairly good predictions for this one case.

There were several major calving events observed. The IIP model does not include calving. El-Tahan, et al. (1984) used a time integrated scheme at the iceberg waterline wave-cut notch to model calving. (The loss due to calving is estimated to be of the same order as wind driven convection.) The iceberg we observed showed some weakness in the above scheme. El-Tahan, et al. (1984) assume the iceberg remains in a constant

Figure B-8. *Photographs of the iceberg observed during the drift and deterioration portion of the 1984 International Ice Patrol cruise.*
Top: *1426Z 16 July 1984, 115-120m across base, maximum height 37m.*
Bottom: *1400Z 21 July 1984, 45-50m across base maximum height 13m.*

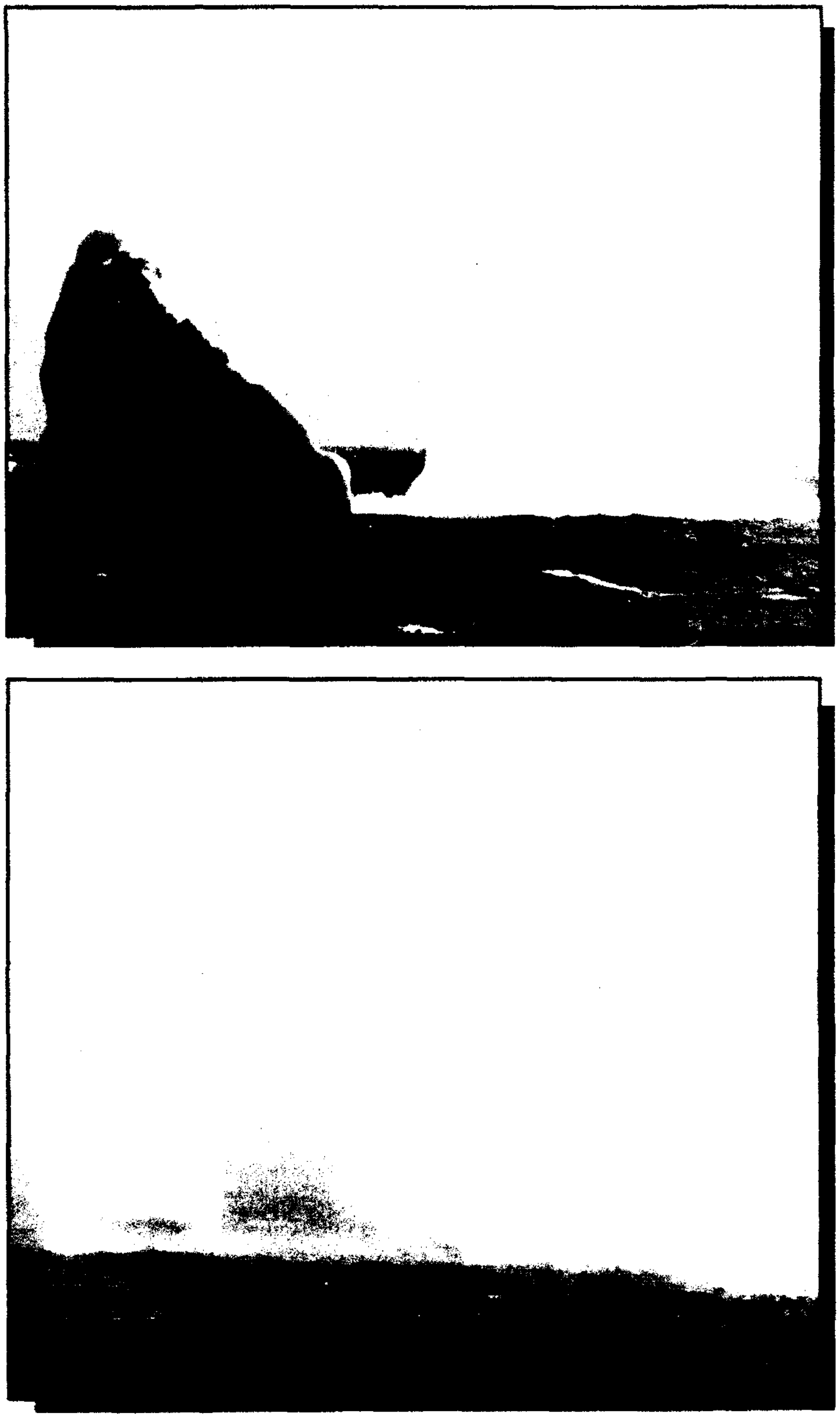
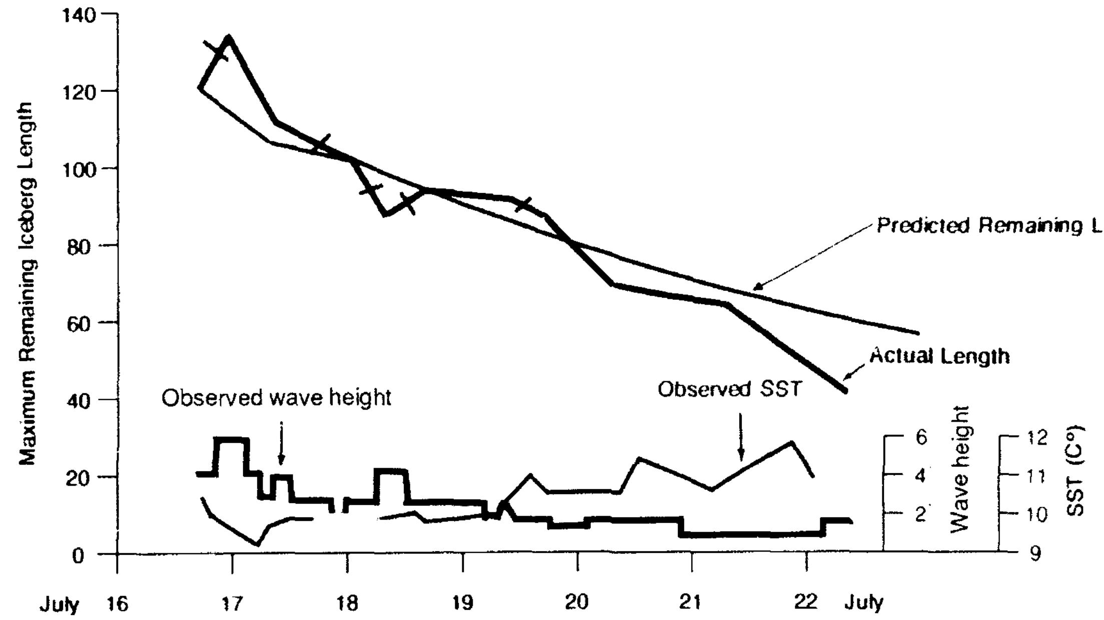


Figure B-9. *Observed vs remaining length predicted by International Ice Patrol's deterioration model. The observed wave height and sea surface temperature (SST) were used as the model inputs. The tick marks on the observed length indicate observed instances of iceberg rollover.*



attitude to the wave field. The iceberg we observed rolled at least seven times in five days. Each time it rolled, a different section of the iceberg was exposed to wave erosion, therefore requiring their integration scheme to start over. Since iceberg rollover cannot be modelled, calving will not be included in our model until an acceptable scheme is available. This will allow the predictions from our model to remain on the conservative side.

Radar ranges and bearings to the iceberg and HORNBEAM's position as determined by LORAN-C were recorded every hour. The geographical position of the iceberg was then determined.

On 17 July, TOD #2632 was deployed within 400m of the iceberg in position 48°37.4'N 46°06.1'W. The TOD drifted to the northeast at a speed slower than the iceberg. After five days, the TOD was located 16.5 nm away and bearing 252°T from the iceberg (Figure B-10). This is approximately upwind (using the average wind for the period) of the iceberg, indicating the difference between the iceberg and the TOD may be due to the different leeway of the iceberg and the drift buoy.

The initial sighting position of the iceberg was entered into IIP's iceberg drift model and allowed to drift until 0000Z 22 July. FNOC winds and unmodified historical currents were used as the environmental inputs to the model. The maximum difference between the actual and predicted position of the iceberg was 7.2 nm and occurred 30 hours after the sighting. The error after five days was only 4.3 nm (Figure B-11). This preliminary analysis of the drift data is encouraging because the accumulated error was so small. Further analysis of this and other iceberg drift data still needs to be done.

Conclusions

The cruise has answered part of the question posed concerning the TOD's ability to follow the geostrophic flow. The data indicates that a TOD will follow the geostrophic flow as long as the drogue is below the thermocline. For next season, IIP intends to lengthen the drogue tethers on the buoys to 50m to place the drogues consistently below the surface layer and the thermocline in the area north of 43°N (Scobie and Schultz, 1976). This plan would eliminate the step of removing wind-driven current from the TOD motion to calculate geostrophic current.

The comparisons of FNOC winds conducted in both 1983 and

Figure B-10. *Actual iceberg and TOD drift from 17-22 July.. The predicted iceberg motion is from the International Ice Patrol drift model. The model drift was begun on 16 July and all predicted motion is from this initial sighting. Tick marks are at 0000Z each day.*

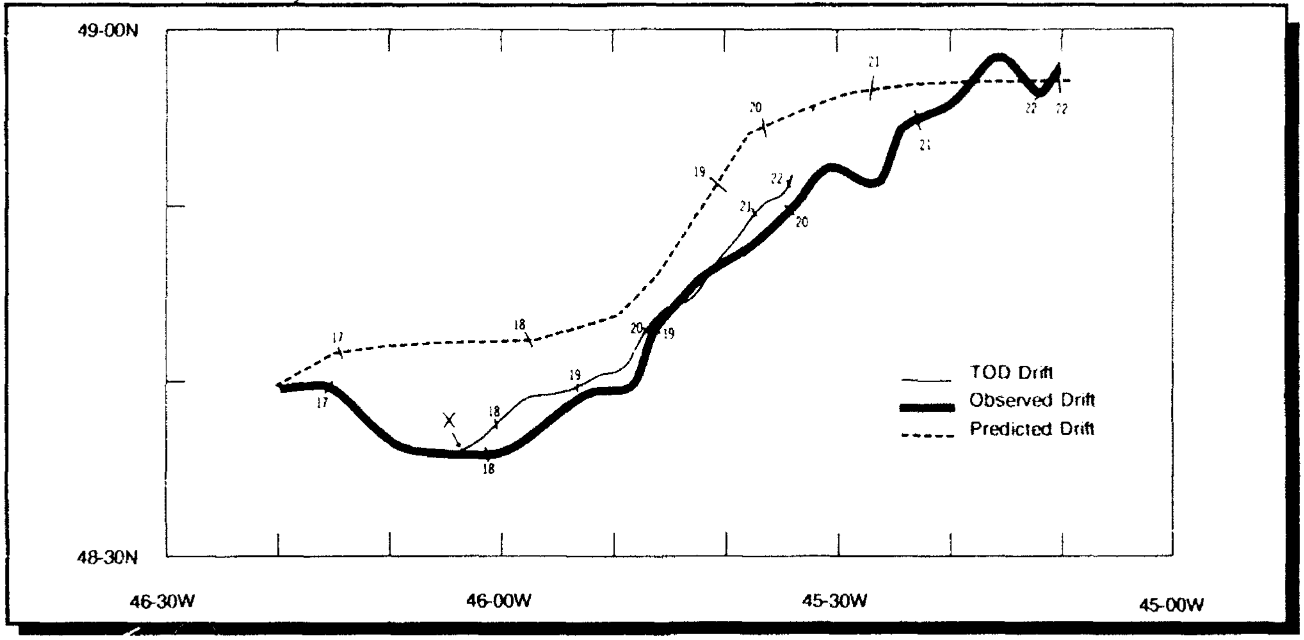
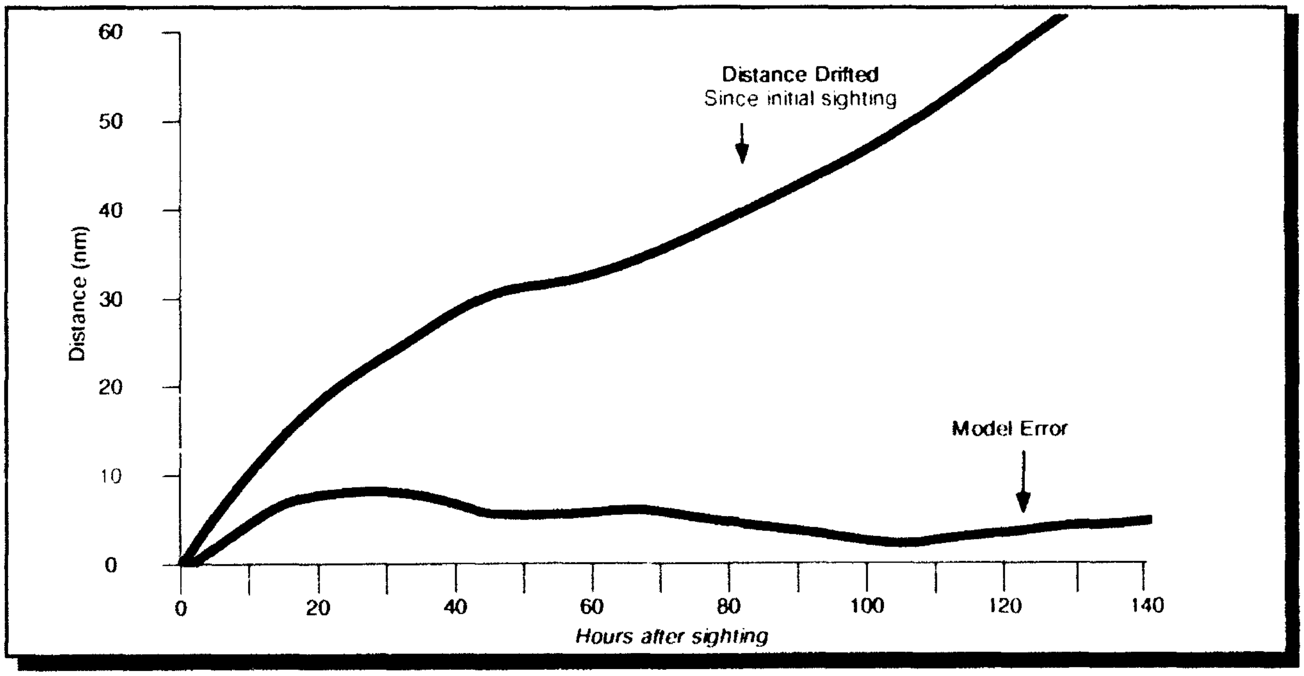


Figure B-11. *The iceberg Drift model error plotted vs total distance the iceberg drifted. The iceberg was drifted continuously by the model from its initial sighting position on 16 July 1984.*



1984 have indicated that the FNOC velocities are consistently too large. This was an added error source in computing geostrophic current motion using the existing method. By using a 50m tether and eliminating the step of removing the wind driven current, the new TOD motion should more closely measure the geostrophic current in our operating area.

IIP intends to continue using TODs to modify the historical current field on a real-time basis. The experiment of a TOD following the geostrophic current will be repeated on future hydrographic cruises using a CTD system rather than Nansen bottles to measure the water column characteristics.
The results from the iceberg deterioration study are very encouraging, but our data set of one is not large enough to draw any conclusions. The deterioration model will be used in its present form, and a total deterioration percentage of 175% of the original length will be used as the point where deletion from the active iceberg list will be considered.

IIP does not plan to make further changes to our iceberg drift model before next season. IIP plans to evaluate the drift model using the drift data obtained from HORNBEAM, data from TIROS Arctic Drifters aboard icebergs during the 1983 season, and other sources. This analysis should allow IIP to evaluate the estimates of the model's error.

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Appendix C

Effects of Side Looking Airborne Radar (SLAR) on Iceberg Detection During the 1983 and 1984 International Ice Patrol Seasons

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Introduction

The AN/APS-135 Side-Looking Airborne Radar (SLAR) was introduced to International Ice Patrol (IIP) reconnaissance flights at the beginning of the 1983 IIP season, the first continuous operational use of SLAR by IIP. The AN/APS-135 is a replacement for the AN/APS-94D SLAR which was occasionally used by IIP on an experimental basis starting in 1976. With this more powerful AN/APS-135 SLAR, visual reconnaissance was replaced by SLAR as the main search method, and reconnaissance coverage of the IIP region was significantly increased. Since the IIP region is an area of frequent heavy fog and bad weather, the all-weather capability offered by SLAR increased both the number of days that IIP could conduct reconnaissance flights and the amount of reconnaissance coverage of search areas under conditions of intermittent visibility. In addition, longer flights became possible with SLAR, and regular reconnaissance of the eastern part of the region began. This increased capability is evident in that prior to the 1983 season, it was necessary to maintain an Ice Reconnaissance Detachment (ICERECDET) in Newfoundland continuously during the IIP season, while in 1983 and 1984, ICERECDETs were deployed every other week with the same number of flight hours as in previous years.

The introduction of SLAR constitutes a major change in the IIP iceberg detection techniques. An important question arises from this change. What effect does SLAR have on the number of icebergs south of 48°N, the traditional indicator of the severity of an iceberg season? This question is addressed in Part b. of the following section using the IIP data base for the years 1960 through 1984, data contained in the IIP historical data file. Part a. is a brief discussion of the effect on the number of icebergs estimated south of 48°N due to the introduction of the iceberg drift prediction model (IBERG) to International Ice Patrol operations in 1979.

Discussion

In 1900, the U.S. Naval Hydrographic Office began estimating the number of icebergs passing south of 48°N as a measure of the severity of each iceberg year. The International Ice Patrol, with its beginning in 1914, continued to keep records of this number. Prior to 1983, the mean annual number of icebergs south of 48°N was 364, with a range from 0 in 1966 to a record of 1584 in 1972. The number of icebergs south of 48°N was 1348 in 1983 representing the fourth highest number on record, and 2202 in 1984, the new record. Given the increased iceberg detection capability offered by SLAR, it seems possible that these elevated figures for 1983 and 1984 are primarily the result of SLAR reconnaissance. As a result, comparing the 1983 and 1984 numbers of icebergs south of 48°N directly with those of previous years might provide a misleading indication of the severity of these two seasons.

a. Iceberg Drift Prediction Model

In investigating the effect of SLAR, it was first necessary to assess the possible impact of the IBERG drift and deterioration model on the number of icebergs estimated south of 48°N, with its introduction to IIP operations in 1979. Any significant effect on the number of icebergs estimated south of 48°N would necessitate treating the IBERG and pre-IBERG data separately in the SLAR analysis. The IBERG impact was analyzed by comparing the number of icebergs south of 48°N with the number of sightings south of 48°N. Table C-1 shows the number of non-growler sightings south of 48°N from the International Ice Patrol historical data file for 1960 through 1984. Since the number of icebergs estimated south of 48°N does not include growlers, growler sightings were removed from the data. The ratio of non-growler sightings south of 48°N to icebergs estimated south of 48°N has three groups of values with significantly different ranges: prior to 1965 (9.9 to 16.4), 1965 through 1978 (0 to 39.8), and after 1978 (90.5 to 800). The change in this value in 1965 is not explicable through any change in methods mentioned in International Ice Patrol records. After 1979, the change in this ratio was due to the introduction of the iceberg drift prediction model (IBERG) to International Ice Patrol operations. It is important to note that the ratio increased dramatically in 1979, and that in 1980, the "sense" of the ratio changed; that is, the number of icebergs south of 48°N became greater than the number of sightings received. With the introduction of this model, the number of icebergs south of 48°N became an estimate based on both sighting reports received south of 48°N and icebergs drifted south of 48°N by the model. The model also made it possible to more accurately determine if a report was a resight of an iceberg or an original sighting. Since some resighting was done before IBERG, the net effect of introducing the model should be to increase the number of icebergs south of 48°N, due to the icebergs drifted across 48°N by the model. Examination of Table C-2 ,however, shows no significant change in the relationship between icebergs south of 48°N and the iceberg sighting ratio, a measure of iceberg season severity discussed in Part b. Therefore, IBERG and pre-IBERG data will be combined in the following analysis of the effect of SLAR on IIP iceberg detection.

b. Icebergs South of 48°N

In this section we seek to evaluate the impact of SLAR on the 1983 and 1984 seasons by establishing an alternate indicator of the severity of an iceberg season.

Over the years, ships transitting the IIP region have furnished regular sea surface temperature (SST) reports and sighting reports for any icebergs encountered. These ship reports provide a sample of iceberg population data which is independent of IIP detection techniques. Since the number of iceberg reports received is dependent on both iceberg density in the shipping lanes and the amount of maritime traffic, the number of reports alone cannot be used to indicate the severity of an iceberg year. Ships making SST reports, assumed to be the most consistent iceberg reporters, make their SST reports in numbers independent of iceberg density and provide a measure of the annual traffic. Therefore, by dividing the number of ship iceberg reports by the number of ship sea surface temperature reports, a term representing iceberg density, independent of traffic, is obtained. (Regression analysis of SST reports versus icebergs estimated south of 48°N for 1970-82 yield an F value of .004, clearly demonstrating independence, assuming normal distribution.) We will call this term the iceberg sighting ratio.

Although the iceberg sighting ratio is independent of the

Table C-1 Icebergs South of 48°N: Estimated vs Sightings

	South of 48° N		Ratio		South of 48°N		Ratio
Year	Icebergs Est.	Sightings, All Sources	(Est / Sighting X100)	Year	Icebergs Est.	Sightings, All Sources	(Est / Sighting X100)
1960	253	1538	16.4	1972	1548	3978	39.8
1961	117	1286	9.1	1973	850	2980	28.5
1962	120	1072	11.2	1974	682	3355	20.3
1963	25	163	15.3	1975	101	331	30.5
1964	369	3712	9.9	1976	151	454	33.3
1965	76	277	27.4	1977	22	84	26.2
1966	0	13	0.0	1978	75	341	22.0
1967	441	1448	30.5	1979	152	168	90.5
1968	226	719	31.4	1980	24	3	800.0
1969	57	171	33.3	1981	63	26	242.3
1970	85	324	26.2	1982	188	70	268.6
1971	73	222	32.9	1983	1348	620	217.4
				1984	2202	1106	198.3

amount of traffic, it is sensitive to the marine traffic patterns in the IIP region. Throughout the iceberg season, typically March through June, ship traffic passes through the area south of the Grand Banks between latitudes 48°N and 44°N. Late in the season, when the Straits of Belle Isle become ice-free, a large amount of traffic transits the northern part of the International Ice Patrol area, north of 50°N. This paper assumes that this traffic pattern does not vary widely from year to year and gives a consistent annual sample of the iceberg population in the IIP area. The number of icebergs encountered by ships in the southern traffic lanes is assumed to have a direct relationship to the number of icebergs south of 48°N that year, dependent on the amount of traffic. It is further assumed that the number of icebergs sighted and reported by ships in the northern traffic lanes is related to the number of icebergs passing south of 48°N and that this relationship does not vary widely from year to year. These assumptions regarding the relationship of iceberg sightings to the number of icebergs south of 48°N have two weaknesses. First, during especially light or heavy iceberg years, the normal traffic pattern is disturbed. Presumably, even though shipping tracks may be displaced to the north or south during these years, the relationship between iceberg density and the probability of iceberg sighting by individual ships should not be greatly affected, since ships will tend to travel through waters of "normal" (i.e., low) iceberg density even in abnormal years. Second, as icebergs drift south from the northern lanes, they are subject to varying environmental conditions (sea surface temperatures, wave heights, winds and currents) that affect iceberg deterioration and transport. The fraction of the icebergs sighted in the northern lanes that eventually reach 48°N varies with these changing environmental conditions. However, since these environmental conditions usually follow predictable seasonal patterns and long-term variations from seasonal norms (e.g., 1972 and 1966) are rare, it is reasonable to assume that the relationship between the number of sightings in the northern lanes and the number of icebergs south of 48°N does not vary widely.

Table C-2 contains totals of ship iceberg and SST reports, numbers of sightings south of 48°N from the International Ice Patrol historical data file (which contains information for 1960 through 1984), and the computed iceberg sighting ratio for each year. It is important to point out that ships often report more than one iceberg sighting on a single report. The term "ship iceberg reports" in Table C-2 represents the total number of ship iceberg reports received by International Ice Patrol throughout the IIP area for any given year, while "sightings south of 48°N" is the total number of sightings south of 48°N from all sources recorded as individual icebergs at IIP. Icebergs estimated south of 48°N are the total number determined by the International Ice Patrol to have actually passed south of 48°N during the season and reported in the annual Ice Bulletin.

There is an abrupt change in the iceberg sighting ratio in 1970, which could be attributed to the disestablishment of Coast Guard Radio Station Argentia in 1969. Since 1970, the International Ice Patrol has broadcast daily ice bulletins and facsimile charts to ships from Coast Guard Communications Station Boston, but has no direct communications with vessels transitting the Grand Banks. This lack of direct contact is believed to be the cause of the significant decrease in the number of SST reports received by the International Ice Patrol. Sea surface temperature reports decreased by a factor of 14 in the mean annual number between the two periods. Therefore, these two periods will be treated independently in this analysis.

Table C-2 also shows that the previous record year of 1972 still holds the record as the most severe iceberg year on record if the iceberg sighting ratio is used as the evaluating criterion. Using this criterion, 1984 is unquestionably a severe iceberg year, but not as severe as 1972.

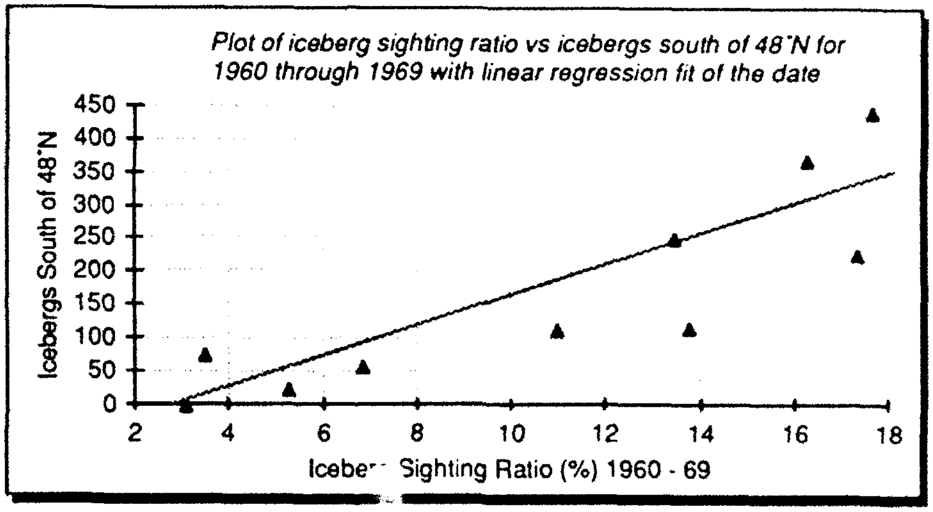
Table C-2 Icebergs South of 48° N vs. Iceberg Sighting Ratio

	South of 48 °N				Iceberg
Year	Icebergs Estimated	Sightings, All Sources	Ship Iceberg Reports	SST Reports	Sighting Ratio % (Berg RPT/SST)
1960	253	1538	1008	7436	13.6
1961	117	1286	928	8342	11.1
1962	120	1072	1077	7916	13.6
1963	25	163	251	4633	5.4
1964	369	3712	1362	9147	14.9
1965	76	277	227	6347	3.6
1966	0	13	51	1592	3.2
1967	441	1448	524	3194	16.4
1968	226	719	384	2271	16.9
1969	57	171	139	1985	7.0
1970	85	324	439	1014	43.3
1971	73	222	162	159	101.9
1972	1584	3978	1151	432	614.0
1973	850	2980	842	381	191.4
1974	682	3355	540	215	179.5
1975	101	331	197	260	77.9
1976	151	454	312	297	59.3
1977	22	84	316	257	117.1
1978	75	341	399	478	68.4
1979	152	168	183	397	46.6
1980	24	3	40	215	34.8
1981	63	26	39	302	17.4
1982	188	70	92	434	21.2
1983	1348	620	148	334	44.3
1984	2202	1106	586	353	166.0

Although the 1983 number of 1348 icebergs south of 48°N makes it appear as a very severe year, the iceberg sighting ratio suggests that it is a light year. Comparison to 1975, the median year with respect to icebergs south of 48°N, indicates that 1983 would have fewer icebergs south of 48°N than that year and that 1984 would have more.

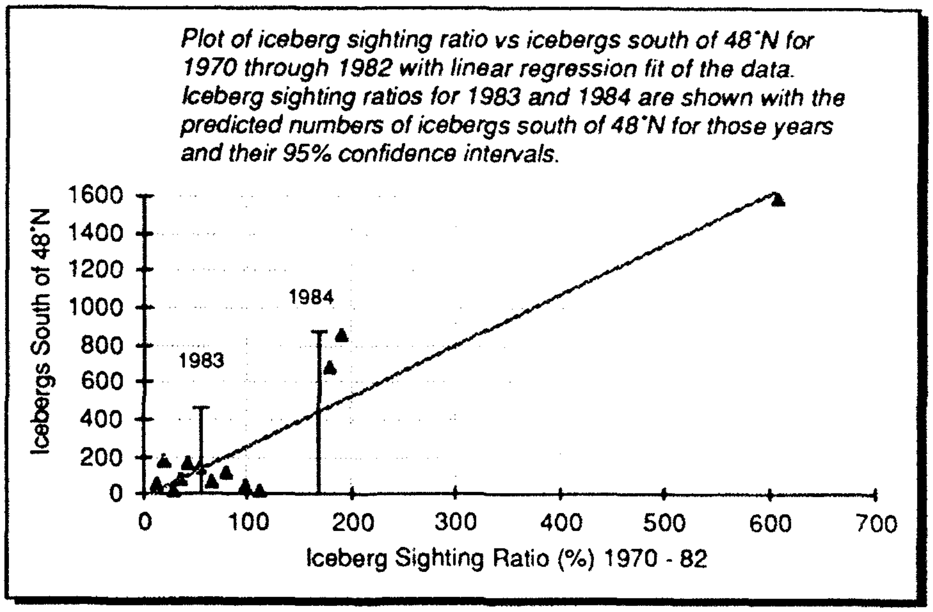
Figures C-1 and C-2 show plots of the iceberg sighting ratio versus icebergs south of 48°N for the periods 1960 through 1969 and 1970 through 1982 and the linear regression fits of those data. In Figure C-2, the iceberg sighting ratio has been adjusted by removing iceberg sighting and SST reports received from Coast Guard vessels from the data. Coast Guard vessels, when deployed in the IIP area, typically contribute a significant number of iceberg and SST reports to IIP. They do not operate within the normal traffic pattern described above, often actively search for icebergs and have operational requirements to submit regular SST reports, all of which might bias the Coast Guard component of the iceberg sighting ratio. The number of reports contributed by individual vessels, including Coast Guard vessels, was not recorded in the International Ice Patrol Bulletin prior to 1972 so this adjustment could not be made to earlier data. Using the regression fit shown and the

Figure C-1



Plot of iceberg sighting ratio vs icebergs south of 48°N for 1960 through 1969 with linear regression fit of the date

Figure C-2



Plot of iceberg sighting ratio vs icebergs south of 48°N for 1970 through 1982 with linear regression fit of the data. Iceberg sighting ratios for 1983 and 1984 are shown with the predicted numbers of icebergs south of 48°N for those years and their 95% confidence intervals.

iceberg sighting ratios for 1983 and 1984, the solved-for values are 102 (+/- 483 at the 95% confidence level) and 430 (+/- 417 at the 95% confidence level), respectively. The data clearly shows the existence of a SLAR effect for both years, since the number of icebergs estimated south of 48°N each year far exceeds the values predicted by the iceberg sighting ratio, even at the upper limits of the 95% confidemce interval (Figure C-2). Given the small number of observations (n=13) used in performing this analysis and the large confidence intervals (due in part to the scatter of the data), this estimate only demonstrates that the effect of SLAR on iceberg reconnaisance exists and should not be used to compare the SLAR and pre-SLAR data numerically.

In addition to improved iceberg detection with SLAR, the increase may also be partly caused by misidentification of non-iceberg targets as icebergs, due both to unfamiliarity with the new technology and the inherent ambiguities of SLAR imagery.

It is important to note that data presented throughout this appendix was collected and analyzed over the years by a constantly changing International Ice Patrol staff, using techniques that undoubtedly varied somewhat with the turnover in personnel. Therefore, this data should be examined with that caution in mind.

Conclusion

The effect of introducing the iceberg drift prediction model (IBERG) to International Ice Patrol operations on 1979 was analyzed by examining the relationship of icebergs estimated south of 48°N to iceberg sighting reports south of 48°N for 1960 through 1984. These values had a close linear relationship for the years 1965 through 1978 and their ratio showed a marked increase with the introduction of the model. But since the relationship of the number of icebergs estimated south of 48°N due to the iceberg sighting ratio appeared to be unchanged after 1979, we assume that the effects of the side-looking airborne radar (SLAR) on the number of icebergs estimated south of 48°N are much greater than those of the IBERG model.

The introduction of SLAR to IIP in 1983 significantly changed the nature of IIP iceberg reconnaissance. Reconnaissance no longer depended on visibility, complete coverage of search areas was possible under conditions of intermittent visibility, and longer flights made it possible to search the outlying areas of the IIP region.

These improvements, together with possible misidentification of non-iceberg SLAR targets due to inexperience and the limitations of SLAR imagery resulted in elevated estimates of icebergs south of 48°N in 1983 and 1984. This conclusion is supported by relating pre-SLAR numbers of icebergs south of 48°N with the corresponding values for 1983 and 1984. These values were compared using the ratio of the ship iceberg reports and the ship SST reports, an iceberg density function called the iceberg sighting ratio. The apparent increase in iceberg detection due to SLAR is by an order of magnitude in 1983 and by half that in 1984, with large confidence intervals at the 95% confidence level.

The analysis of the effect of SLAR reconnaissance presented here provides only a preliminary investigation of the issue. In no way can an evaluation of two years of SLAR data identify the long-term effect of SLAR on IIP operations. Neither can it adequately place the 1983 and 1984 iceberg seasons in the context of the previous years of IIP history. It is clear that SLAR has increased the number of icebergs detected by IIP and that with several more years of SLAR data, and with the research currently being conducted on iceberg detection and identification by SLAR, we should be able to address this issue with more confidence.

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