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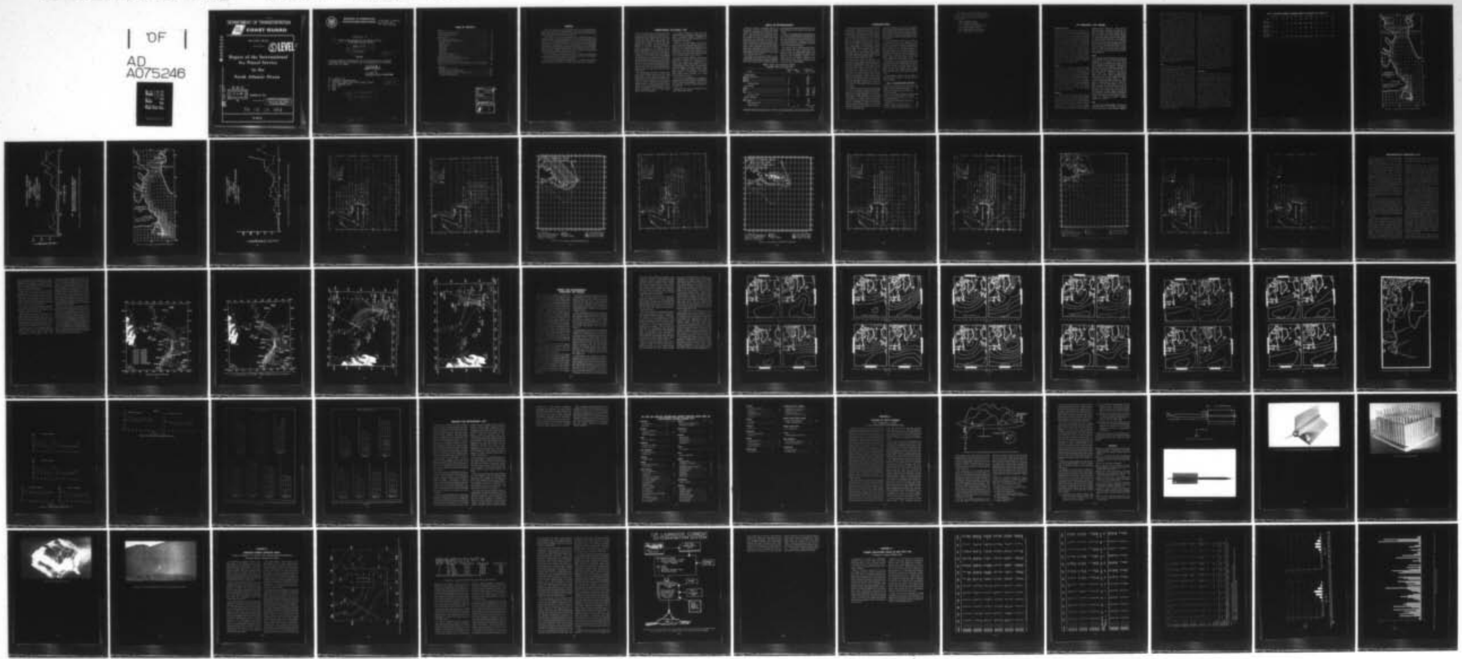

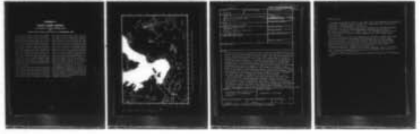

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DEPARTMENT OF TRANSPORTATION

COAST GUARD

BULLETIN NO. 63

Report of the International Ice Patrol Service in the North Atlantic Ocean

SEASON OF 1977

CG-188-32

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

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(6) REPORT OF THE INTERNATIONAL ICE PATROL SERVICES IN THE NORTH ATLANTIC OCEAN,

Season of 1977

(14) USCG-BULL-63,
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(11) 1977

FOREWORD

Forwarded herewith is Bulletin No. 63 of the International Ice Patrol describing the Patrol's services, and ice observations and conditions during the 1977 season.

C. C. HOBDY, Jr.
Acting Chief, Office of Operations

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Appendicies:

PREFACE

This is the 63rd in a series of annual reports on the International Ice Patrol Service in the North Atlantic Ocean. It contains information on Ice Patrol organization, communications and operations, and on ice and environmental conditions and their relationships in 1977.

The authors of this report, Lieutenants K. N. KNUTSON and T. J. NEILL, USCG, acknowledge applicable ice, weather and oceanographic data provided by the Canadian Department of the Environment, U.S. National Weather Service, U.S. Naval Weather Service and U.S. Coast Guard Oceanographic Unit. Recognition is given to Chief Marine Science Technician N. O. TIBAYAN, Marine Science Technician First Class C. W. JENNINGS, Marine Science Technician Third Class J. D. STEELMAN and Yeoman Second Class T. L. GEST, all USCG, for their assistance in the preparation of this manuscript and illustrations for this report.

The U.S. National Aeronautical and Space Administration contribution to the continuing effort to devise an all-weather method of detecting and identifying icebergs is gratefully acknowledged.

The continued cooperation and generosity by Canadian Coast Guard Radio Station St. John's/VON is worthy of particular note and gratitude.

INTERNATIONAL ICE PATROL, 1977

The 1977 International Ice Patrol Service in the North Atlantic Ocean was conducted by the United States Coast Guard under the provisions of Title 46, United States Code, Sections 738, 738a through 738d, and the International Convention for the Safety of Life at Sea, 1960, Regulations 5 through 8. The International Ice Patrol is a service for observing and disseminating information on ice conditions in the Grand Banks Region of the Northwest Atlantic Ocean. During the ice season, the southeastern, southern and southwestern limits of the regions of icebergs in the vicinity of the Grand Banks of Newfoundland are guarded for the purpose of informing passing ships of the extent of this dangerous region. The International Ice Patrol also studies ice conditions in general with emphasis on the formation, drift and deterioration of icebergs, and assists ships and personnel requiring aid within the limits of operation of the Ice Patrol forces.

The International Ice Patrol is directed from the Ice Patrol Office located at the U.S. Coast Guard Base, Governors Island, New York. The Office gathers ice and environmental data from a variety of sources, maintains an ice plot, forecasts ice conditions, prepares the twice-daily Ice Bulletin, replies to requests for special ice information, and executes operational control of the Aerial Ice Reconnaissance Detachment, the Ice Patrol oceanographic cutter, and the Surface Patrol cutter when assigned.

Vice Admiral William F. REA III, U.S. Coast Guard, was Commander, International Ice Patrol. Commander Albert D. SUPER, U.S. Coast Guard, was directly responsible for the management of the Patrol.

Preseason Ice Patrol flights were made in January and late February-early March 1977. The Aerial Ice Reconnaissance Detachment was deployed to St. John's, Newfoundland, on 15 March 1977. The Detachment returned to the United States on 22 June 1977, after completion of a Post Season flight on 21 June 1977.

The 1977 Ice Season officially commenced at 0000 GMT, 13 March 1977, when the first Ice Bulletin was broadcast by International Ice Patrol Radio Station Boston/NIK; U.S. Navy LCMP Broadcast Radio Stations Norfolk/NAM; Canadian Maritime Command Radio Station Mill Cove/CFH; and Canadian Coast Guard Radio Station St. John's/VON. Ice Patrol Radio Station Boston broadcast an ice radio facsimile chart once a day.

The USCGC EVERGREEN, commanded by Lieutenant Commander Joseph H. DISCENZA, USCG, conducted oceanographic cruises for the Ice Patrol from 1 April to 1 May and 23 May to 28 June 1977.

During the 1977 season, an estimated 22 icebergs drifted south of 48°N.

AERIAL ICE RECONNAISSANCE

During the period 1 September 1976 to 31 August 1977, a total of 72 ice observation flights were flown; 13 preseason, 58 seasonal, and 1 post season. The objective of the preseason survey was to study the iceberg distribution patterns in the Labrador Sea and to evaluate the iceberg potential of the developing ice season. The season flight objectives were to locate the southwestern, southern, and southeastern limits of icebergs, to evaluate the short-term iceberg potential of the waters immediately north of the Grand Banks, and occasionally to determine the iceberg distributions along the Labrador coast. One post season flight was made to conduct a final census of the icebergs south of 50°N.

The flight statistics shown in Table 1 do not include flight time required to make the passages between U.S. Coast Guard Air Stations Elizabeth City, North Carolina and St. Petersburg, Florida and the Ice Patrol operating airfield at St. John's, Newfoundland for crew relief or aircraft maintenance.

Aerial ice reconnaissance was accomplished by U.S. Coast Guard HC-130B (Lockheed Hercules) four-engine aircraft from Coast Guard Air Stations at Elizabeth City, North Carolina and St. Petersburg, Florida. During the ice season, the aircraft operated out of Torbay Airport, St. John's, Newfoundland, Canada.

On 15 March, the Ice Reconnaissance Detachment deployed to St. John's. This location continues to be the most operationally effective and efficient location for staging Grand Banks reconnaissance. The Detachment remained at St. John's through the season, returning to the United States on 22 June upon completion of the single post season reconnaissance.

TABLE 1—Aerial Ice Reconnaissance Statistics

1 September 1976 to 31 August 1977

Month	*Number of Flights* *Visual*	*SLAR*	*Flight Hours* *Visual*	*SLAR*
PRESEASON				
September-December	1*		13.9*	
January	4		20.1	
February	5		31.5	
March	3		18.7	
Preseason Total	13		84.2	
IN SEASON				
March	8	0	37.1	0.0
April	17	0	91.4	0.0
May	19	3	99.3	14.2
June	4	7	16.8	33.9
In-Season Total	48	10	244.6	48.1
POST SEASON				
June	1		6.0	
July-August	0		0.0	
Post Season Total	1		6.0	
Season Totals	62	10	334.8	48.1
	72		382.9	

* USCG Ice Observer participation in a USN ice reconnaissance flight on 10 and 11 November 1976.

COMMUNICATIONS

Ice Patrol communications included ice reports, environmental conditions, Ice Bulletins, special ice advisories, a daily Facsimile Chart, and the administrative and operational traffic necessary to the conduct of the Patrol. The Ice Bulletin was transmitted by teletype from the Ice Patrol office in New York twice each day to over 30 addressees, including those radio stations which broadcast the Bulletin. These stations were the U.S. Coast Guard Communications Station Boston/NIK/NMF, U.S. Naval Radio Station Norfolk/NAM, U.S. Naval Radio Station Londonderry/NST, U.S. Naval Radio Station Thurso/GXH, U.S. Naval Radio Station Keflavik/NRK, Canadian Coast Guard Radio Station St. John's/VON, and Canadian Maritime Command Radio Station Mill Cove/CFH.

International Ice Patrol Ice Bulletins were broadcast by Coast Guard Communications Station Boston/NMF/NIK by CW at 0018 GMT on 5320 and 8502 kHz and at 1218 GMT on 8502 and 12750 kHz. After a two-minute series of test signals, the transmissions were made at twenty-five (25) words per minute and then repeated at sixteen (16) words per minute. Coast Guard Communications Station Boston/NIK/NMF also transmitted a daily radio facsimile broadcast depicting the locations of icebergs and sea ice at 1600 GMT simultaneously on 8502 and 12750 kHz at a drum speed of 120 revolutions per minute.

Ice Bulletins were also broadcast twice daily by U.S. Naval Radio Stations Norfolk/NAM, Londonderry/NST, Thurso/GXH, and Keflavik/NRK on the LCMP Broadcasts between 0500–0600 GMT and 1700–1800 GMT on a wide range of frequencies. Canadian Coast Guard Radio Station St. John's/VON made CW broadcasts at 0000 and 1330 GMT on 478 kHz, and Canadian Maritime Radio Station Mill Cove/CFH also broadcast at 0130 and 1330 GMT on a wide range of low to high frequencies.

Special broadcasts were made by Canadian Coast Guard Radio Station St. John's/VON as required when icebergs were sighted outside the limits of all known ice between regularly scheduled broadcasts. These transmissions were preceded by the International Safety Signal (TTT) on 500 kHz.

Sea ice information services for the Gulf of St. Lawrence, as well as the approaches, from 58°00′W to 66°30′W longitudes including the Strait of Belle Isle to west of Belle Isle itself, were provided by the Canadian Ministry of Transport during the period from December to approximately late June. Ships obtained ice information by contacting the Ice Operations Officer, Dartmouth, Nova Scotia via any east coast Canadian Coast Guard Radio Station.

Supplementary ice conditions and navigational warnings for the Strait of Belle Isle, the coast of Newfoundland, and the Grand Banks were obtained by contacting Canadian Coast Guard Radio Stations: St. Anthony/VCM, Comfort Cove/VOO, St. John's/VON, and St. Lawrence/VCP.

Communications statistics for the period 1 September 1976 through 31 August 1977 are shown in Table 2.

TABLE 2—COMMUNICATIONS STATISTICS

Number of ice reports received from ships	316
Number of ships furnishing ice reports	52
Number of ice reports received from commercial aircraft	1
Number of sea surface temperature reports	1,150
Number of ships furnishing sea surface temperature reports	44
Number of ships requesting special ice information	18
Number of NIK Ice Bulletins issued	195
Number of NIK facsimile broadcasts	97

Of the number of ships furnishing Ice Patrol with ice reports and special sea surface temperature observations, the six most outstanding contributors were:

- HMCS HURON/CGXY
- M/V BAKKAFOS/TFXQ
- M/V STADT WOLFSBURG/DCWE
- M/V MONT ROYAL/SFHN
- M/V DELCHIM ALSACE/FNRC
- M/V ATLANTIC SPAN/SLPN

ICE CONDITIONS, 1977 SEASON

September-December

Due to large departures from the norms, including above average temperatures and prevailing onshore winds along the Labrador coast, sea ice formation and iceberg movement were greatly inhibited. By the end of October, only the northwestern portion of Baffin Bay and the near shore along Baffin Island down to Cumberland Sound were frozen. Throughout November, advancement continued nearshore, where new ice covered the Labrador coast to about 30 miles offshore from Goose Bay north. December closed with the ice just reaching the northern tip of Newfoundland. The northern Strait of Belle Isle was frozen over and sea ice extended 100 to 150 miles offshore along the Labrador coast. Only three icebergs were reported during this period, all by ships approaching the Strait of Belle Isle, and all north of 53°N.

January

The sea ice continued its advance, though slowly due to the continued deviation from normal conditions. By the end of January, new sea ice had formed all the way to Cape Bonavista, Newfoundland, but not extending eastward beyond 54°W. A limited January preseason survey found indications of a very light season (Figure 1). Iceberg distribution along the Labrador coast was well below average, shown graphically by latitude (Figure 2). A total of 34 icebergs were located between 55 and 60°N. No icebergs were sighted south of 55°N. No ship reports were received in January.

February

As meteorological conditions began to normalize in late February with an increased southerly and southeasterly flow, icebergs and sea ice approached the Grand Banks. By mid-February the sea ice had reached Pt. St. Francis and icebergs began to exit from the ice pack. A nearly complete census was obtained during the period 22 February through 6 March on the February preseason survey (Figure 3). About half the normal number of icebergs were sighted with only 145 medium and large icebergs south of 63°N. The relative scarcity of icebergs confirmed that the overall season would be light (Figure 4). The first iceberg south of 48°N was reported in position 47°23′N, 50°55′W on 28 February. By the end of the month, new sea ice extended almost to Cape Race, Newfoundland and as far east as 49°W. The easternmost pack ice (6 to 8 octas of young and first year light) reached 47°30′N, 50°W and extended north northwestward. Only three icebergs drifted south of 48°N during February.

March

The southern and southeasterly flow continued through March with above average temperatures inhibiting sea ice growth. As storm fronts passed through the Grand Banks region, the sea ice was broken up and spread out. Although the leading edge of the consolidated pack began its retreat, the resulting brash and small floes of first year light ice remained in the northern Grand Banks area. Preseason reconnaissance flights on 3, 4 and 5 March encompassing the limits of all known ice south of Belle Isle, located 8 icebergs and 6 growlers (Figure 5). Eight regular reconnaissance flights were made subsequent to commencement of the 1977 season on March 13. Ice observation flights on 18 and 20 March (Figure 6) surveyed the limits of all known ice from 44°N to 48°N. Only 4 icebergs, 2 growlers and 1 radar contact were observed. The easternmost and 1977 season's southernmost extent of sea ice, 47°30′N, 47°30′W and 46°20′N, 51°25′W respectively, occurred about 29 March (Figure 7). During this month, 7 icebergs drifted south of 48°N.

April

By mid-April, conditions began to revert to the abnormals observed in December and January. Predominant onshore winds along the Labrador coast and southwesterly winds off the coast of Newfoundland accelerated sea ice pack retreat and dispersed the icebergs eastward along 48°N. Ice observation flights on 3, 5, 7 and 10 April surveying the limits of known ice from 45°30′N, to 49°N, (Figure 8), illustrate this phenomenon. Only 3 of the 30 plus icebergs were south of 48°N. The southernmost iceberg of the season was predicted to have reached 45°00′N, 48°40′W on 9 April before melting. The easternmost iceberg of the season was predicted to have reached 47°00′N, 45°40′W on 17 April. As the pack ice continued its retreat, only isolated patches of brash ice remained south of 50°N (Figure 9). The easternmost extent of sea ice observed during the season reached 46°50′N, 46°30′W approximately 15 April. Ice observation surveys on 20, 21 and 22 April found the sea ice limit had retreated significantly with only 6 bergs south of 49°N (Figure 10). By the end of April the sea ice retreated to a very open pack configuration nearshore to 50°W along the Newfoundland and Labrador coasts to Goose Bay. North of Goose Bay 6 to 8 octas of first year light and medium ranged to 120 miles offshore along the coast to Cape Dyer. During the month of April, 12 icebergs drifted south of 48°N.

May

Southwesterly winds off the coast of Newfoundland and predominant onshore winds along the coast of Labrador prevented further ice formation and greatly retarded iceberg movement to the south. Ice observation flights on 30 April, 1 and 2 May confirmed that there were no icebergs south of 48°N and only three icebergs south of 49°N, all grounded (Figure 11). By mid-May the sea ice still extended south of the Strait of Belle Isle primarily in the form of isolated belts and strips. The iceberg distribution continued to remain nearshore with concentrations centered around 49°N, 52°W (Figure 12). Warming temperatures combined with upstream wind-driven currents resulted in a rapid retreat of sea ice to the vicinity of the Strait of Belle Isle by late May, some two to three weeks ahead of normal. These general conditions persisted well into June. Ice reconnaissance flights on 29 and 30 May showed the southernmost iceberg to be at 48°45′N, 51°45′W (Figure 13). All icebergs drifting south of 49°N melted prior to crossing 48°N during May.

June

Early June surveys disclosed a fairly constant number of icebergs located between 50°N and 52°N. As new bergs moved south, some bergs drifted below 49°N and melted. Regular attrition into the Strait of Belle Isle occurred. Sea ice along the Labrador coast consisted of 6 to 8 octas of first year light and medium extending to 100 miles offshore with patches and strings up to 4 octas concentration along the perimeter. One tongue of patches and strings extended out to 53°W along latitude 55°N. By 16 June, there were predicted to be only two icebergs south of 49°N. Ice observation flights on 9 and 17 June surveyed the southern ice limits and the ice conditions near the Strait of Belle Isle (Figure 14). Due to the unusually warm sea surface temperatures during this period, the southern bergs were predicted to melt within two days and those north of 49°N were predicted to melt before crossing 48°N. There had been no confirmed reports of ice south of 48°N since 24 April or south of 49°N since 1 June. Thus, there appeared to be no further threat to the primary shipping lanes for the remainder of the year. The maritime community was notified accordingly and Ice Patrol terminated its services for the 1977 season on 17 June. No icebergs drifted south of 48°N during the month.

July-August

Sea ice deterioration continued at a fairly rapid rate. In mid-July, there was no ice south of Goose Bay, Labrador, and by the end of the month Hudson Strait and Frobisher Bay were ice free. By the end of August, only the area along Baffin Island from Cape Mercy to Lancaster Sound to about 60 miles offshore was not ice free. Although the Ice Patrol services had officially terminated, the Ice Season terminates on 31 August for statistical purposes with the new season beginning 1 September. During July and August many iceberg reports were received from ships on approach to, and traversing the Strait of Belle Isle, the southernmost of which reached 48°50′N, 50°00′W before melting. In all, the 1977 season proved to be very light with a statistical total of 22 icebergs drifting south of 48°N.

Table 3—ESTIMATED NUMBER OF ICEBERGS SOUTH OF LATITUDE 48°N, SEASON 1977

	Sept	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Total*
1977	0	0	0	0	2	8	34	92	91	55	15	3	300
TOTAL 1946–1977	10	2	4	11	64	265	1075	2951	2897	1751	483	100	9,613
AVERAGE 1946–1977	0	0	1	1	2	9	41	100	128	68	22	6	383
TOTAL 1900–1977	256	109	0	0	0	3	7	12	0	0	0	0	22
AVERAGE 1900–1977	3	1	110	91	184	716	3177	7796	9980	5269	1679	489	29,856

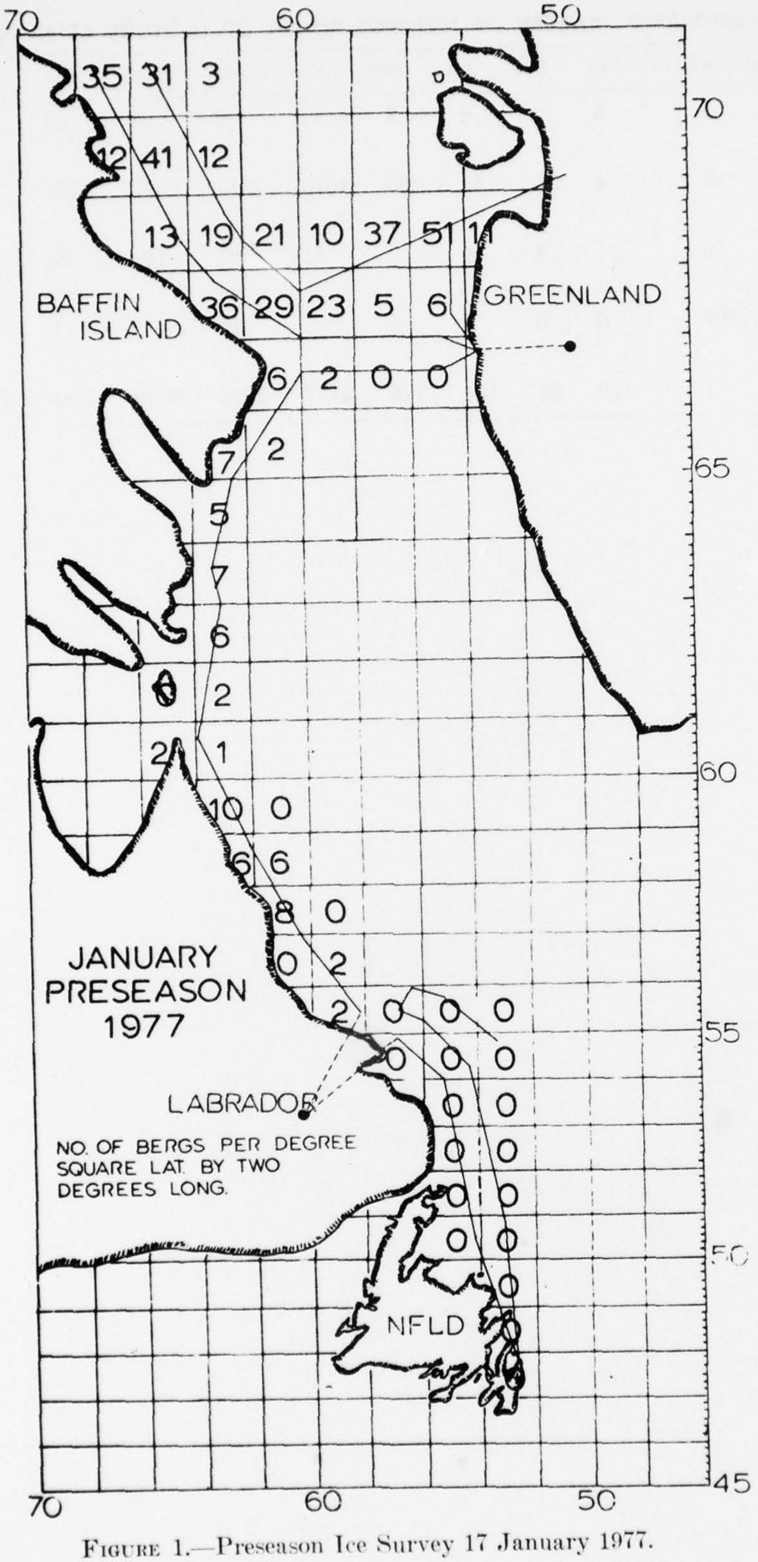
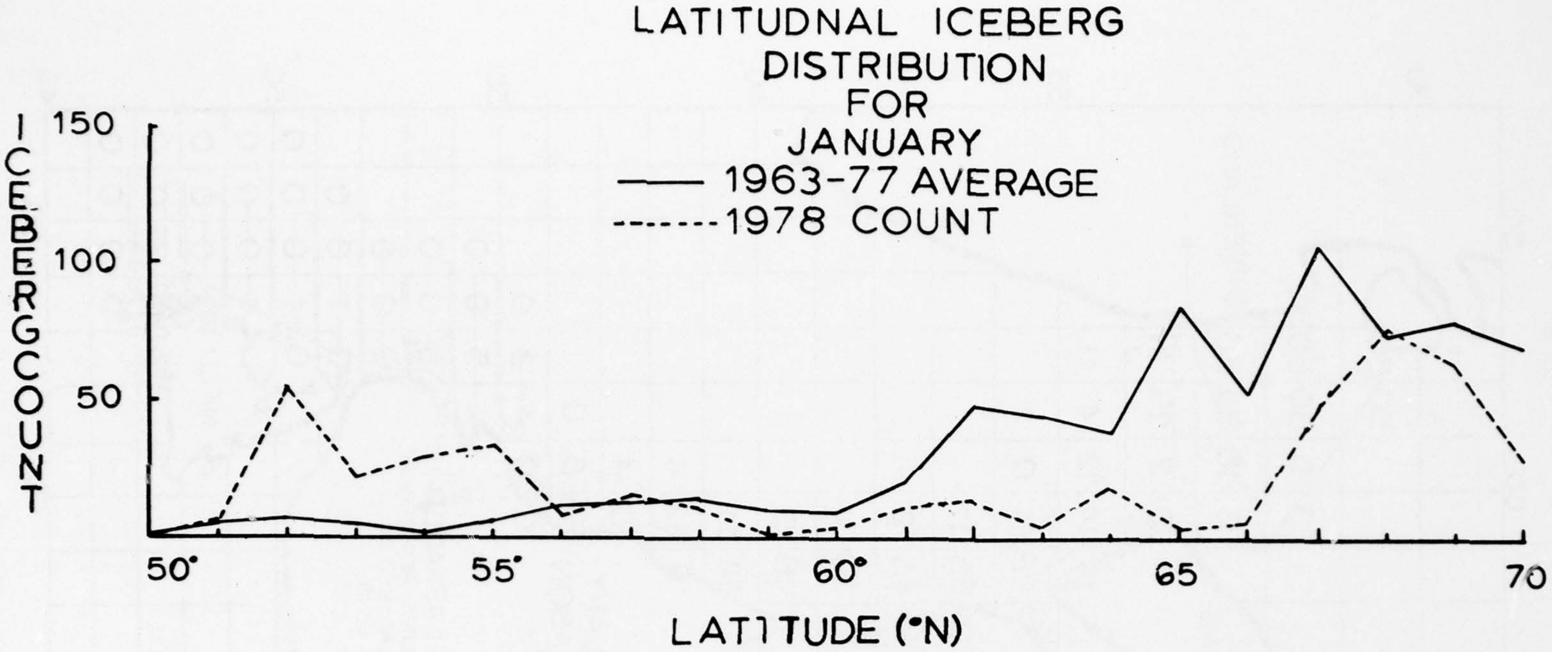


Figure 1.—Preseason Ice Survey 17 January 1977.



NOTE: DUE TO LACK OF HISTORICAL DATA THE COUNTS FOR THE AREA NORTH OF 68 N AND EAST OF 60 W WERE NOT INCLUDED IN THE DATA PRESENTED ON THIS CHART.

FIGURE 2.—Latitudinal Iceberg Distribution, JANUARY PRESEASON FLIGHTS.

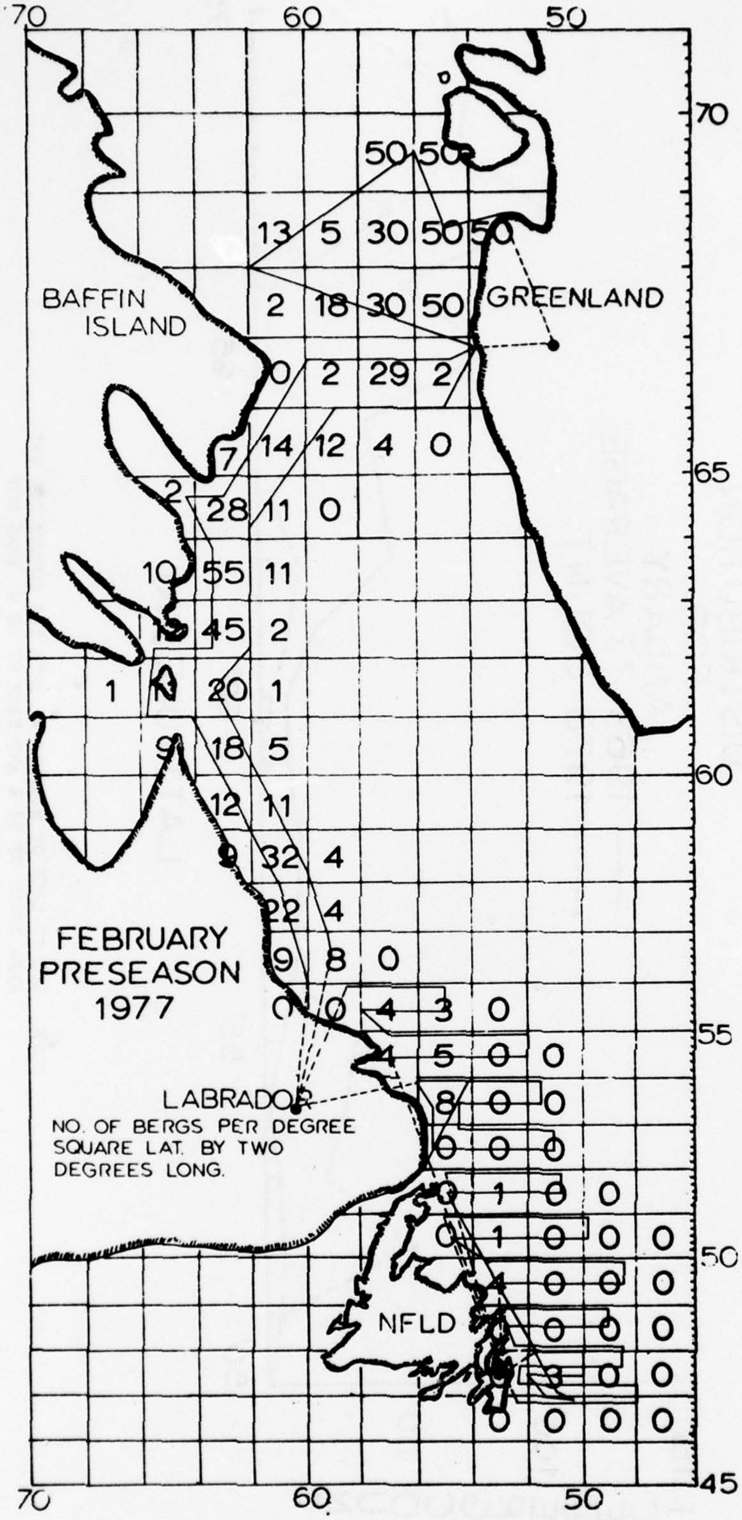


FIGURE 3.—Preseason Ice Survey 22 Feb-6 Mar 1977.

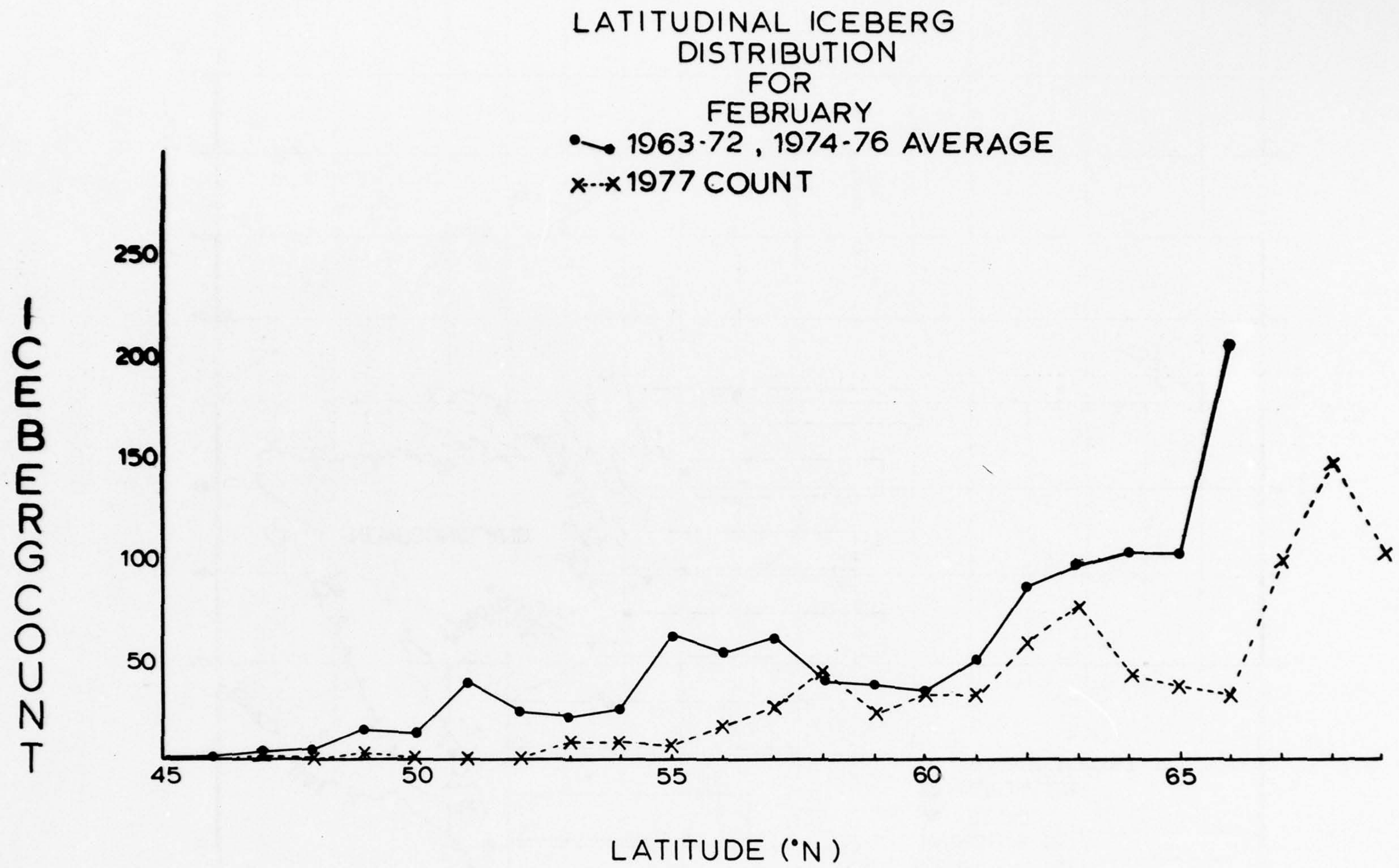


FIGURE 4.—Latitudinal Iceberg Distribution, FEBRUARY PRESEASON FLIGHTS.

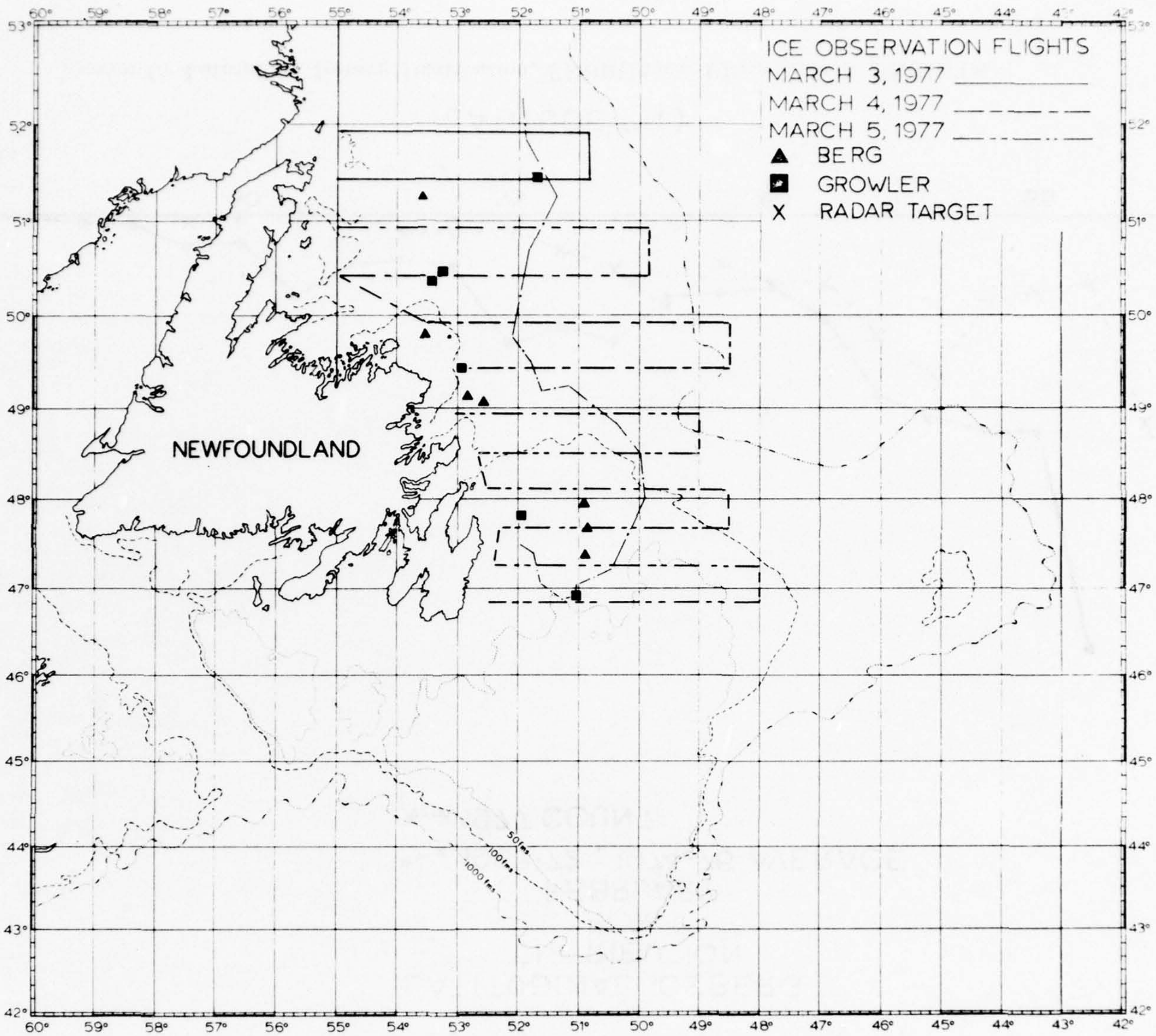


FIGURE 5.—Ice Observation Flights 3, 4 and 5 March 1977.

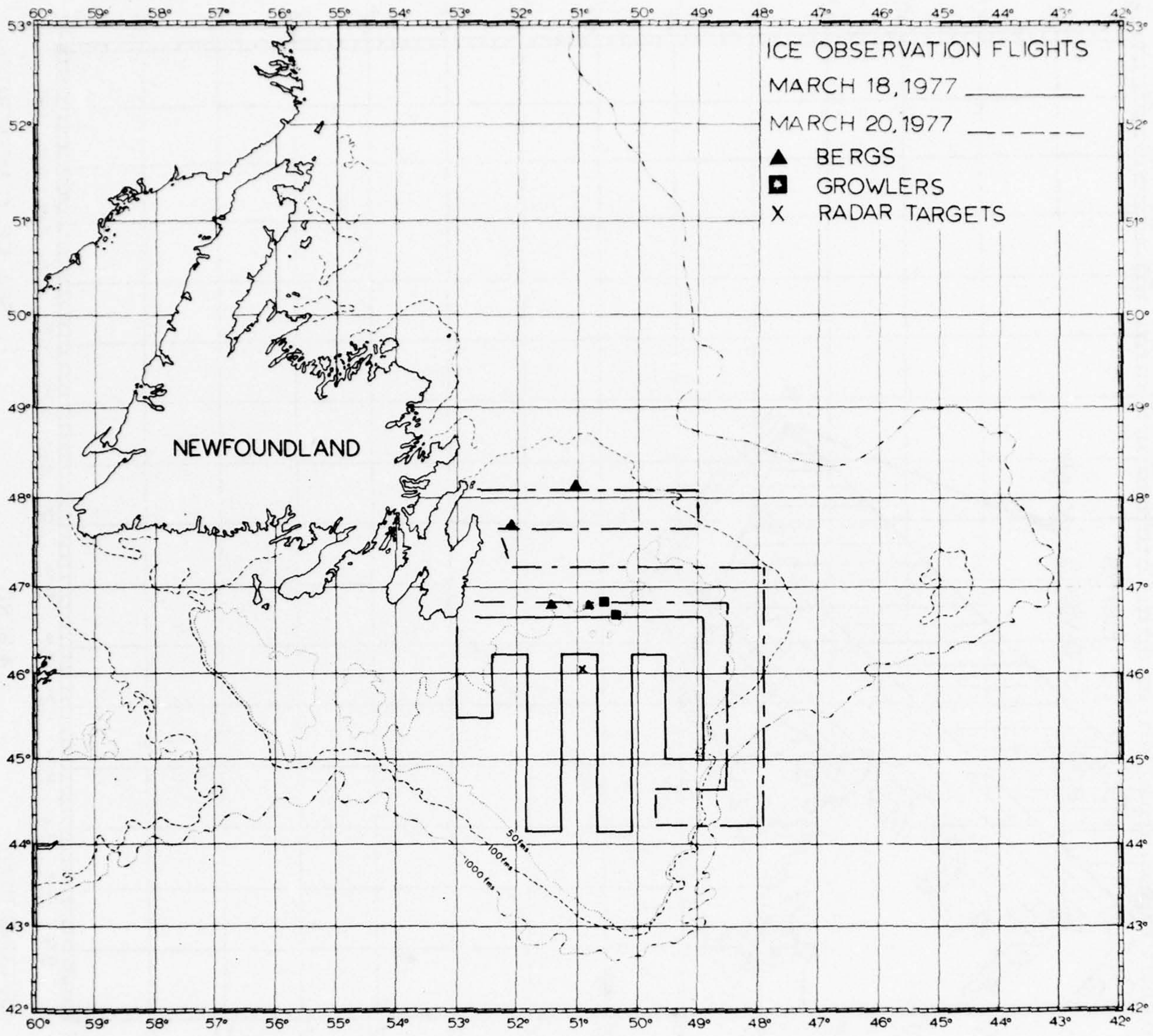


FIGURE 6.—Ice Observation Flights 18 and 20 March 1977.

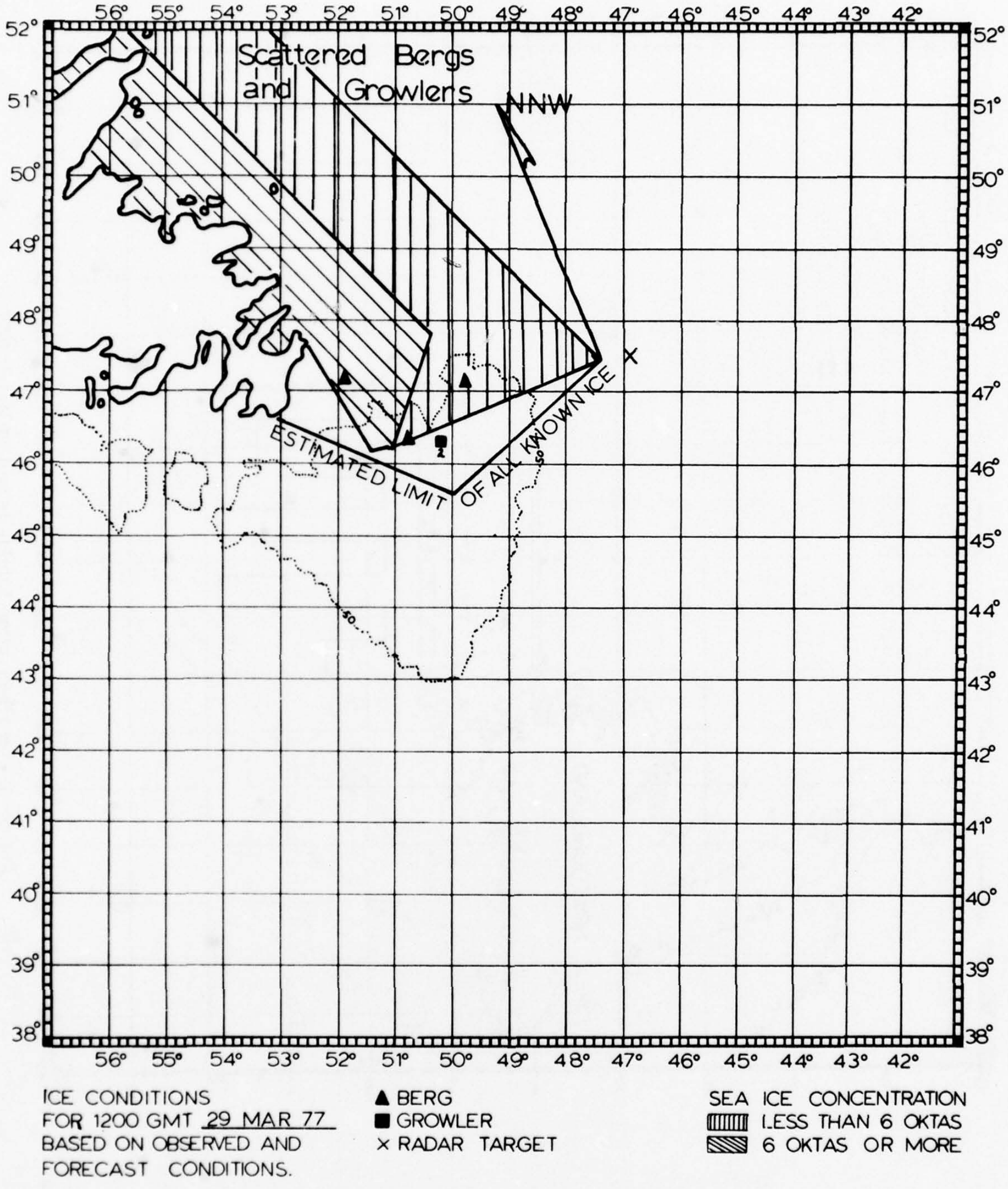


FIGURE 7.—Ice Conditions, 1200 GMT 29 March 1977.

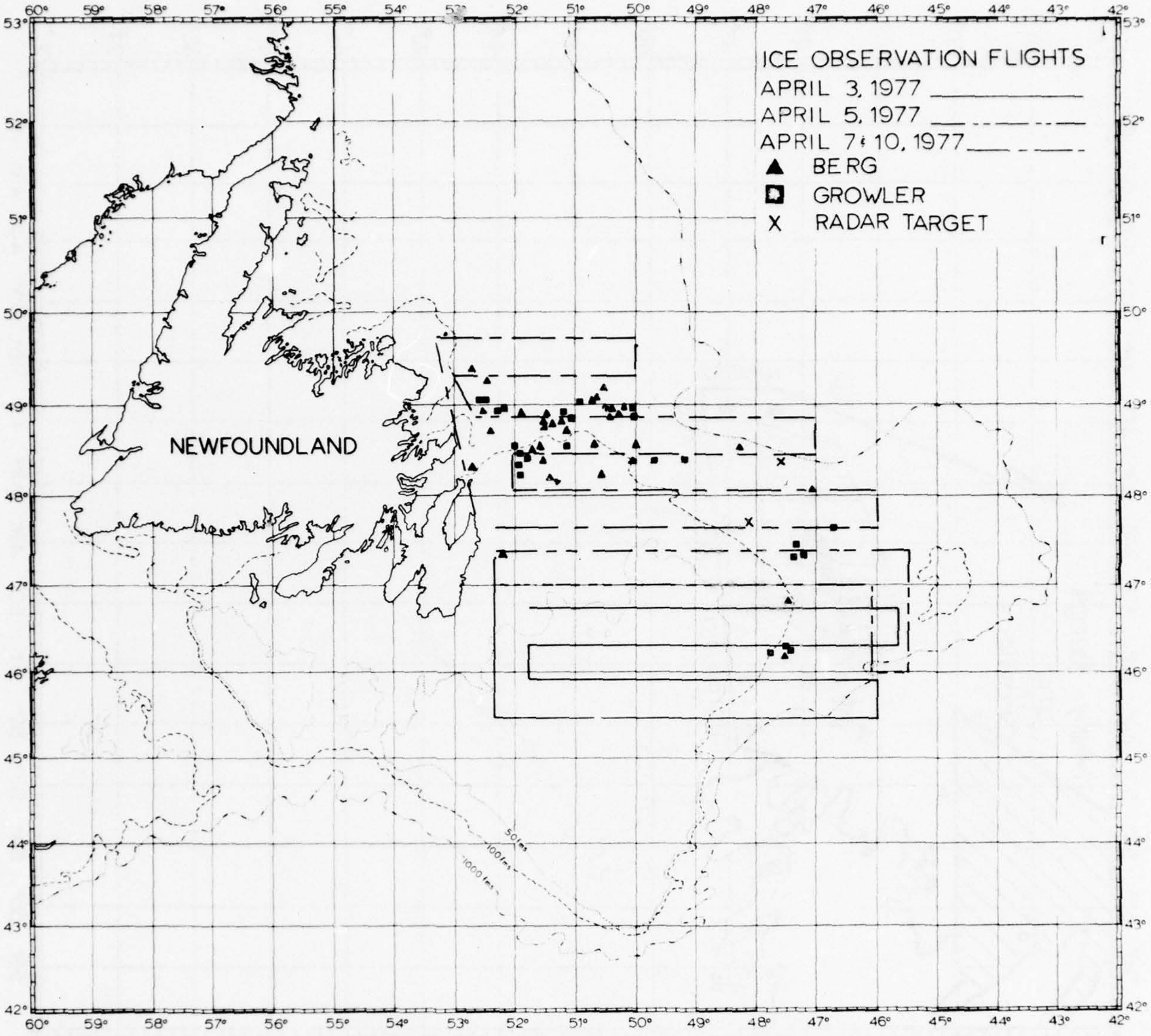


FIGURE 8.—Ice Observation Flights 3, 5, 7 and 10 April 1977.

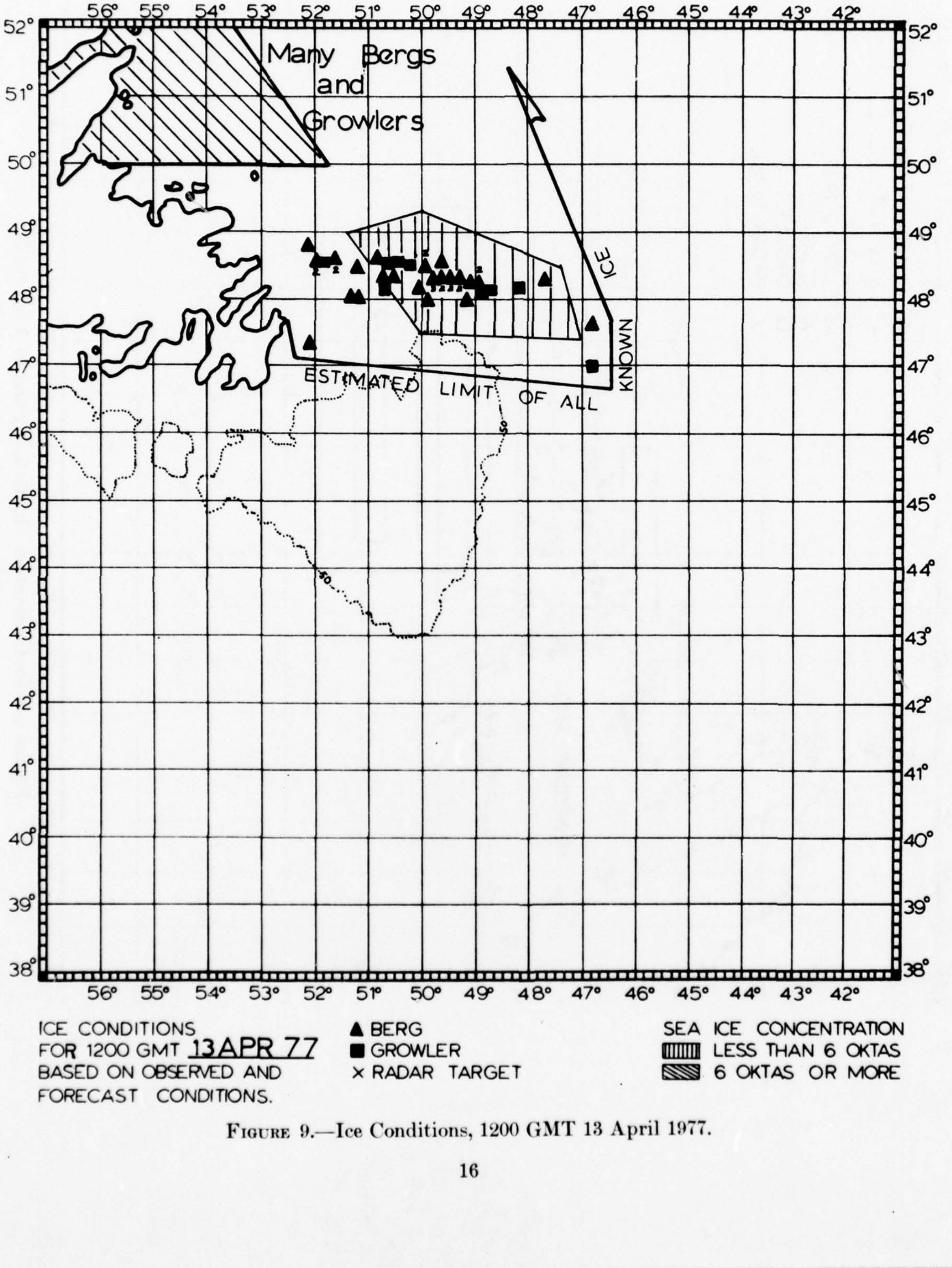


FIGURE 9.—Ice Conditions, 1200 GMT 13 April 1977.

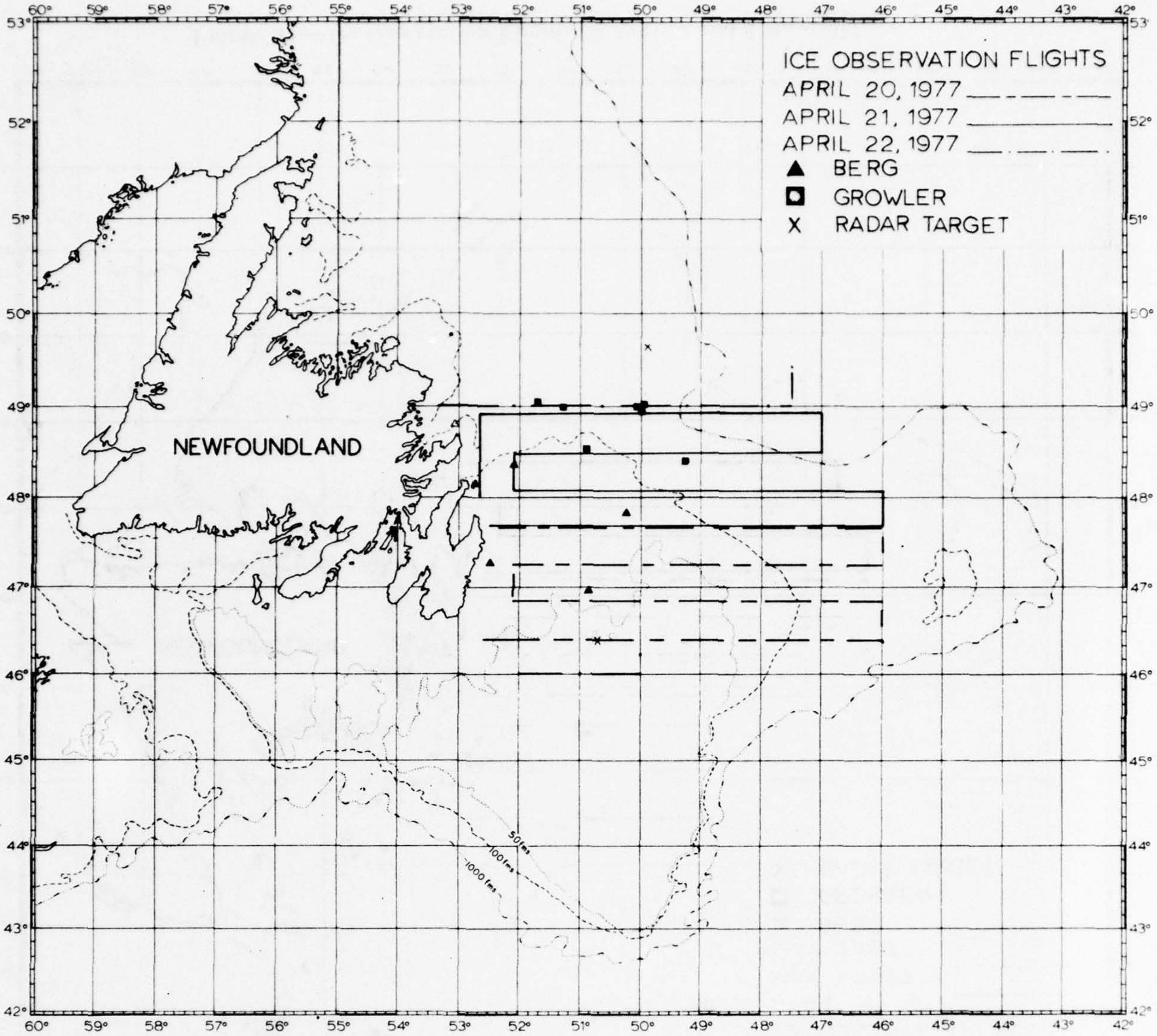


Figure 10.—Ice Observation Flights 20, 21 and 22 April 1977.

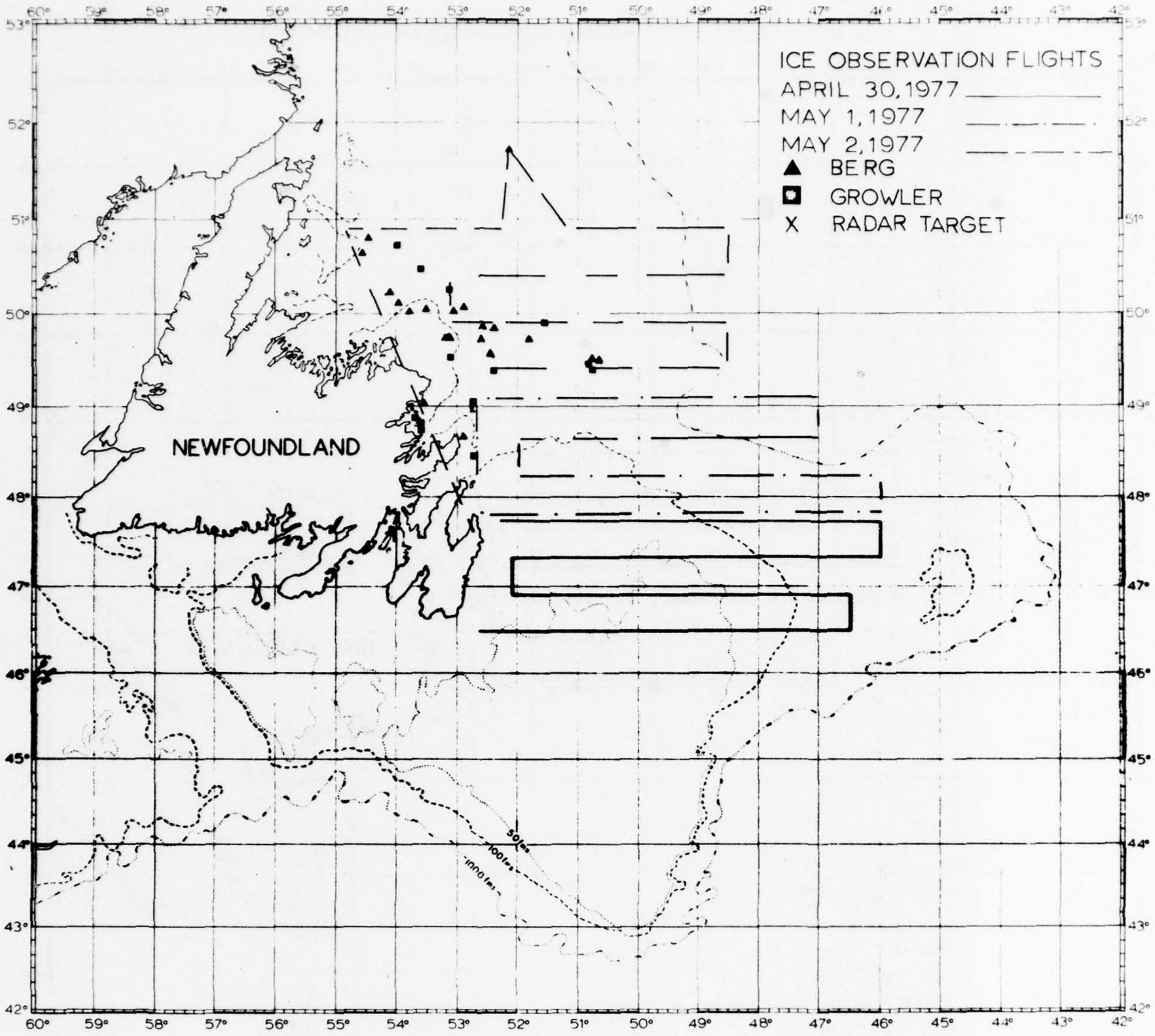


FIGURE 11.—Ice Observation Flights 30 April, 1 and 2 May 1977.

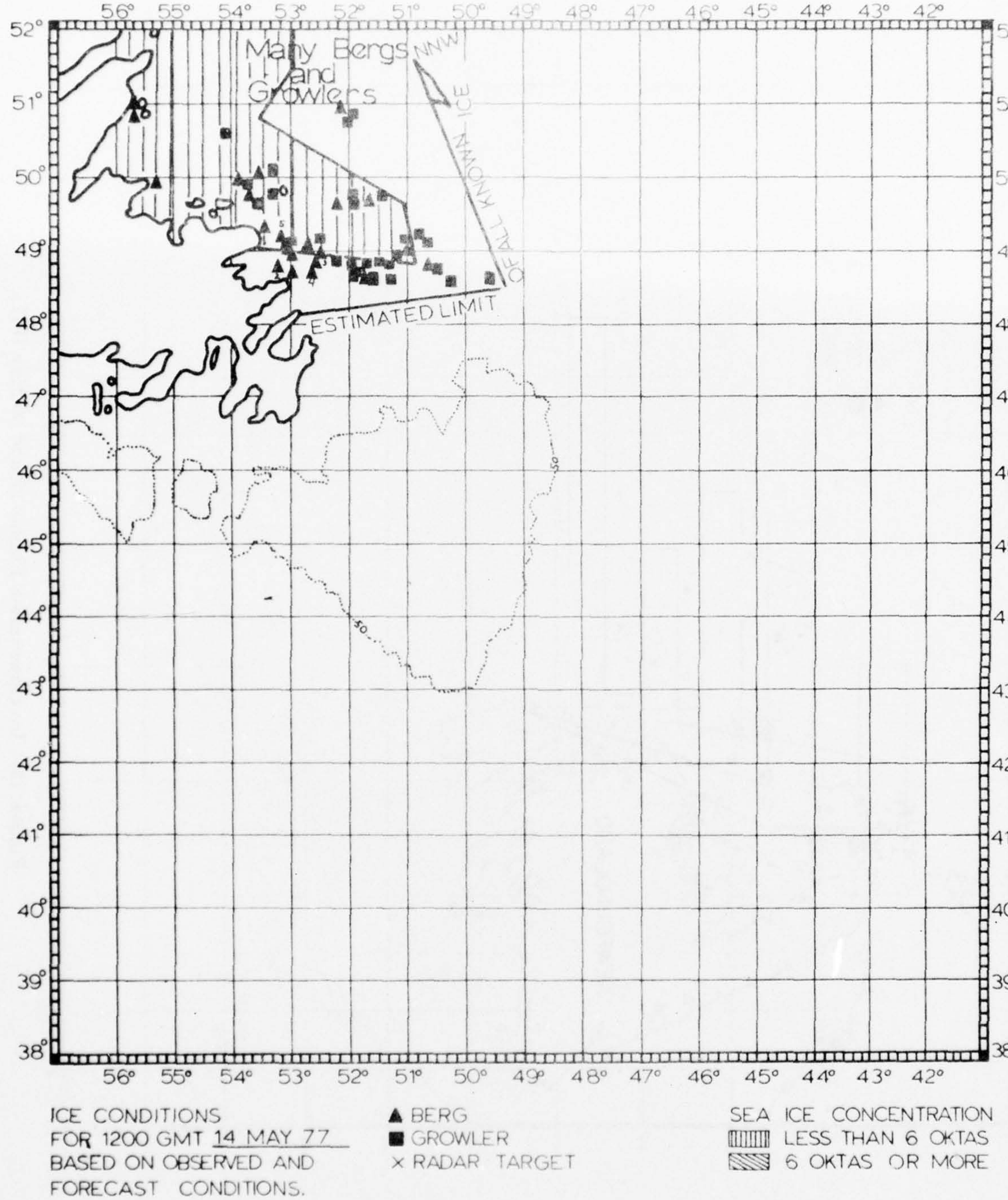


Figure 12.—Ice Conditions, 1200 GMT 14 May 1977.

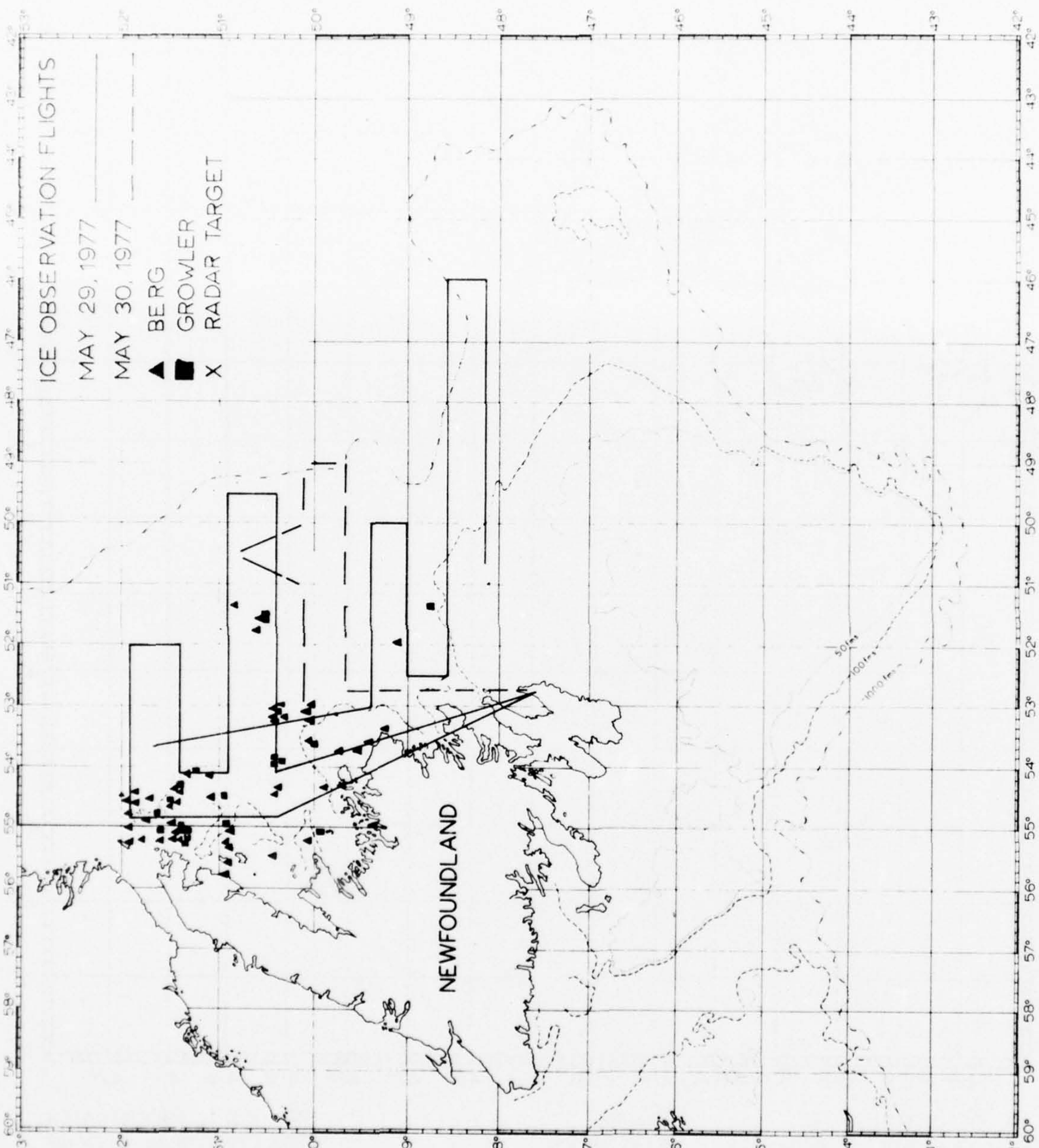


FIGURE 13.—Ice Observation Flights 29 and 30 May 1977.

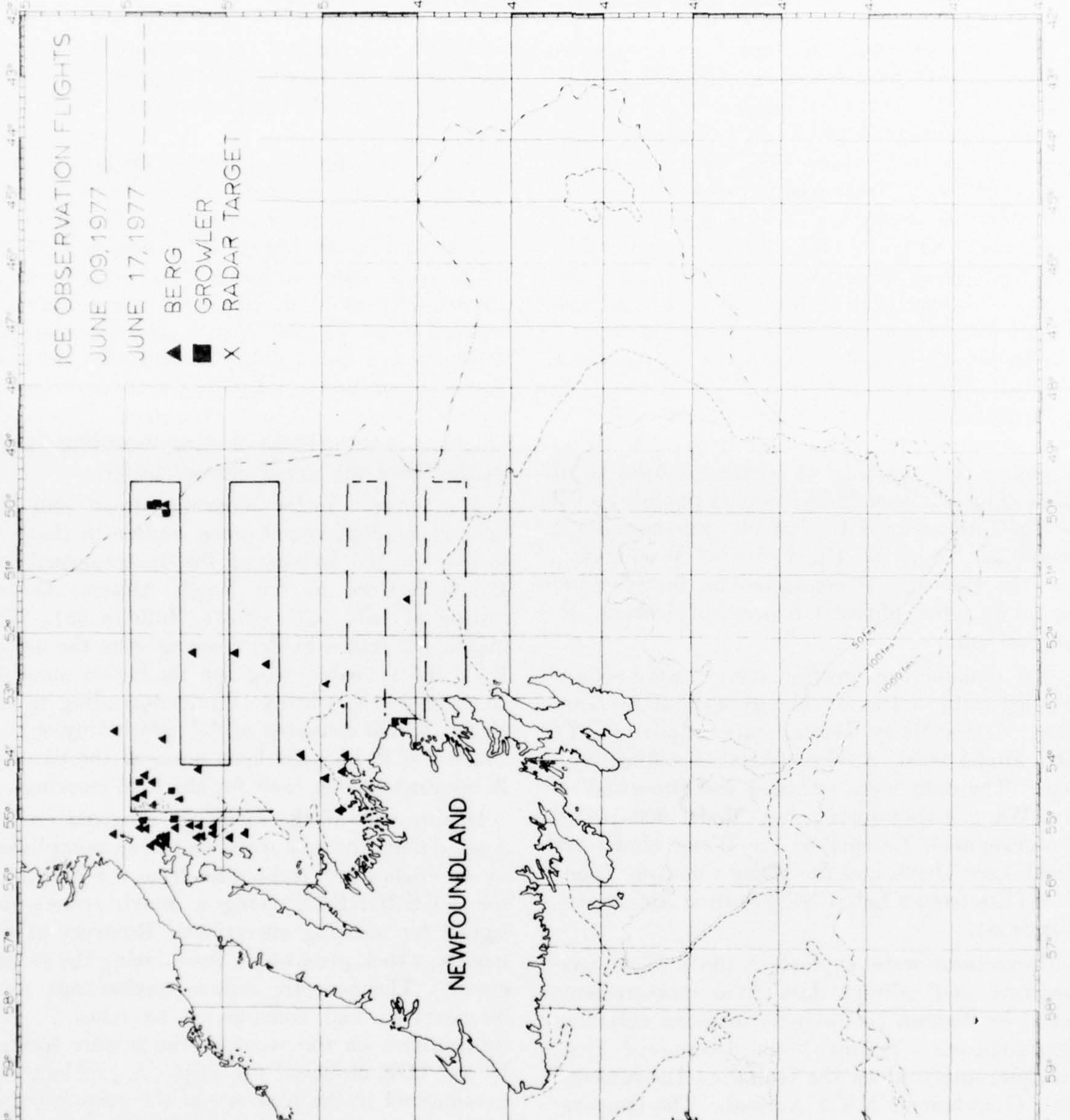


FIGURE 14.—Ice Observation Flights 9 and 17 June 1977.

OCEANOGRAPHIC CONDITIONS—1977

The International Ice Patrol oceanographic mission in 1977 consisted of two USCGC EVERGREEN (WAGO 295) cruises to the Grand Banks of Newfoundland from 1 April to 1 May and 23 May to 28 June 1977. These provided sea current data from hydrographic surveys for the computer prediction of iceberg drift. Satellite-tracked drogued buoys (BTT's) were used for the second consecutive year to verify and improve operational iceberg drift by making Lagrangian measurements of sea current to compare with estimates obtained by the hydrographic method. As an additional mission of the IIP–2–77 cruise, iceberg and drogued buoy drift data were collected aboard the EVERGREEN for an on-going research project with the objective of improving the iceberg drift model presently used by the International Ice Patrol. Furthermore, a researcher from the University of Washington, Seattle, Washington conducted an investigation examining the physical aspects of iceberg deterioration.

The dynamic topography surveys were accomplished using a Plessey Environmental Systems, Inc., Conductivity/Temperature/Depth (C/T/D), Model 9040, Environmental Profiling System. The data were recorded and processed on the Wang Laboratories, Inc. Model 600–14–TP Programmable Calculator, the Wang Model 629 Dual Tape Drive, and the Wang Counting Interface (Electronics Lab, USCG Station Alexandria, Virginia).

Corrections were applied to the C/T/D temperature and salinity data from measurements made by Nansen bottles with deep-sea reversing thermometers. Salinity was determined from Samples analyzed on the Guildline Instruments, Inc. (Larchmont, N.Y.) Autosal. The temperature quality control values were applied as a constant correction with depth from an average difference between C/T/D System and Nansen bottle for each oceanographic section. The salinity quality control differences were computed for the surface and the bottom, averaged for each oceanographic section. Temperature quality control corrections ranged from +.02°C to +.03°C and salinity corrections ranged from $-.07^{\circ}/_{oo}$ to $+.05^{\circ}/_{oo}$.

Operations during the 1977 season included deployment and recovery of two current meter moorings in the Ice Patrol area. One mooring was located in the Labrador Current at 43°47′N, 49°00′W in 493m of water. The second was at 43°20′N, 47°46′W in 3560m of water near the western edge of the North Atlantic Current. The moorings were of 3/16″ coated wire and each included two vector averaging current meters at approximately 100m and 400m depth. The deep mooring also included a film recording depth gauge above the upper current meter.

The current meter mooring design and the method of deployment were similar to that described in the Report of the International Ice Patrol Service in the North Atlantic Ocean, Season of 1976 (CG–188–31, Bulletin 62). The major differences in the mooring were the use of 3/16″ plastic-coated wire for the entire mooring line except the bottom 60 meters leading to the singer, which consisted of 5/8″ plaited nylon. A single 500 lb buoyant float replaced the two 300 lb buoyant spheres used for the 1976 moorings.

Deployment of the moorings occurred on 7–8 April during the first cruise and was accomplished by an anchor last techniques from the fantail of the EVERGREEN using a winch system designed for mooring operations. Recovery of the moorings took place on 24 June during the second cruise. The acoustic release mechanisms were interrogated and commanded to release. The transmitters on the recovery floats were located by an ADF on-board the ship. A problem was encountered in the recovery of the deep mooring where the acoustic release failed to respond to repeated interrogation, although it ultimately did release successfully.

The current meters on the shallow mooring provided good records for the entire deployment period, yielding 77 days of data from each meter.

The current meter at 100m depth on the deep mooring yielded 30 days of data before a partial flooding of the instrument occurred, while the lower meter malfunctioned and yielded no usable data. The depth gauge on the deep mooring flooded and no data were obtained.

Initial analysis of the data reveals average velocities in the Labrador Current that are parallel to the bottom contours with magnitudes of 46 cm/sec at 120m depth and 18 cm/sec at 385m depth. Spectral analysis indicates that the major variations of the current occur at a time scale of 12 to 16 days and that these variations are coherent with the local wind field.

Two BTTs (Buoy Transmitting Terminal) were used in 1977, platform identifications 0647 and 0671. These were of the same type as those used during IIP–76 (CG–188–31).

Buoy 0647 was deployed on 13 April 1977 at 2100Z in position 47°02′N, 47°15′W. It was allowed to drift until 1815Z 22 April when it was recovered in position 45°27′N, 47°26′W (figure 15), a Handar Inc. automatic direction finder, Model 602A was used to locate the buoy and to test the electronic package before deployment.

This buoy provided two important inputs to CIIP. The first was the speed of the Labrador Current. This current was measured using hydrographic survey techniques. This survey measured a maximum velocity of 44 cm/sec. The buoy showed that the speeds were closer to 60 cm/sec, an important difference when drifting icebergs. The second important input was obtained from the direction of the buoy's drift. The hydrographic survey showed a section of the Labrador Current was changed from its normal southerly direction and was flowing in a northeasterly direction. It was not known for certain that this was an accurate picture of the current. When the buoy entered this area it also swung back towards the northeast and followed the direction indicated by the survey very closely. This information allowed CIIP to have a much higher confidence in their product.

Buoy 0671 was deployed on 20 April 1977 at 2351Z, but stopped transmitting the next day. Buoy 0647 was redeployed on 31 May 1977 at 1242Z but stopped transmitting on 2 June. At the time of the apparent failure, both buoys were indicating good battery voltages and for several days the cause of the failure was unknown. However, when the EVERGREEN returned to St. John's, Newfoundland, personnel from the fishing vessel Cape Wrath II returned Buoy 0647. It had become entangled in the ship's fishing nets. The use of BTT buoys in areas where fishing is extensive will have to be used with the understanding that the mortality rate will be higher than in remote regions of the ocean.

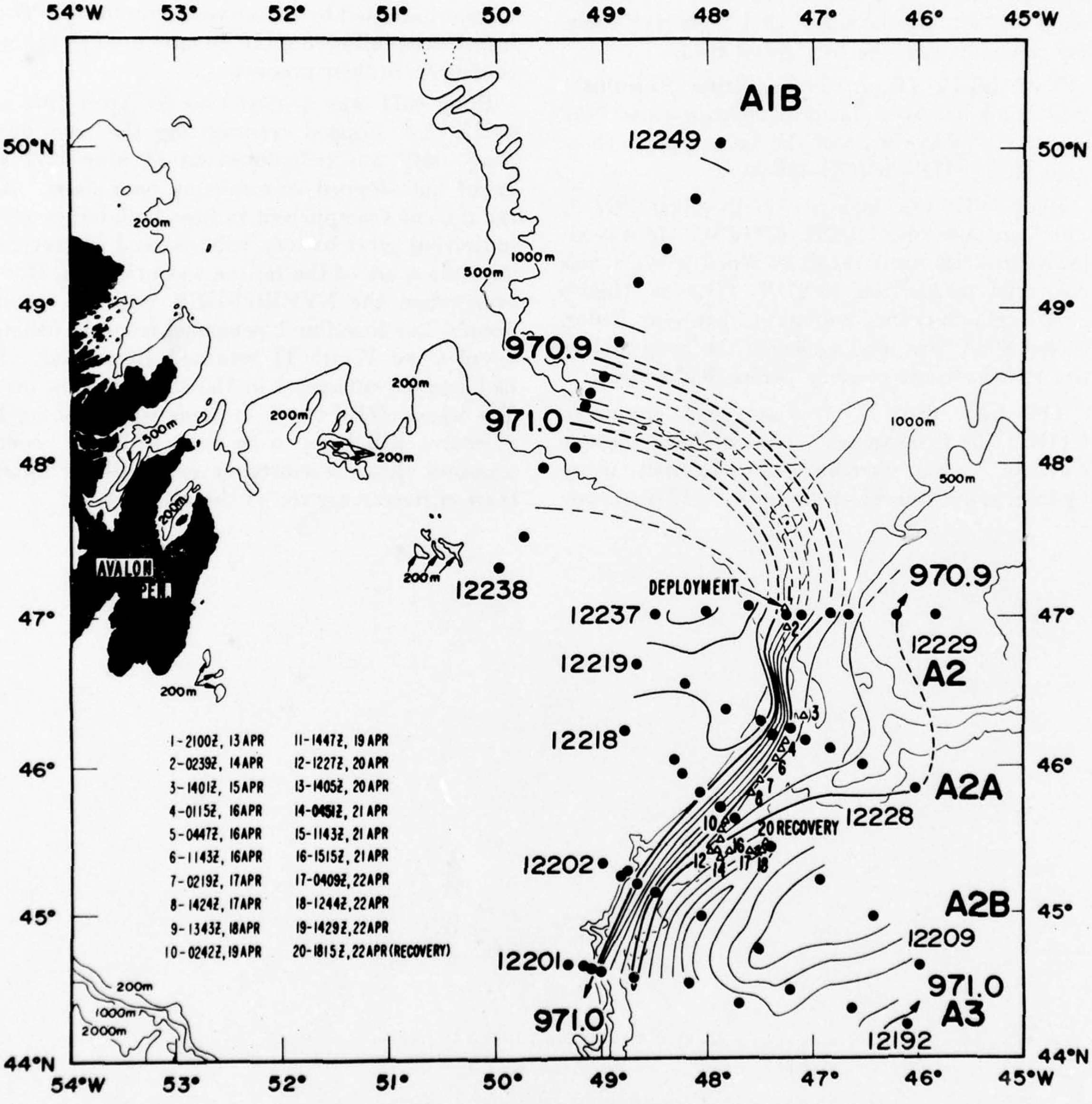


FIGURE 15.—Plot of BTT 0647.

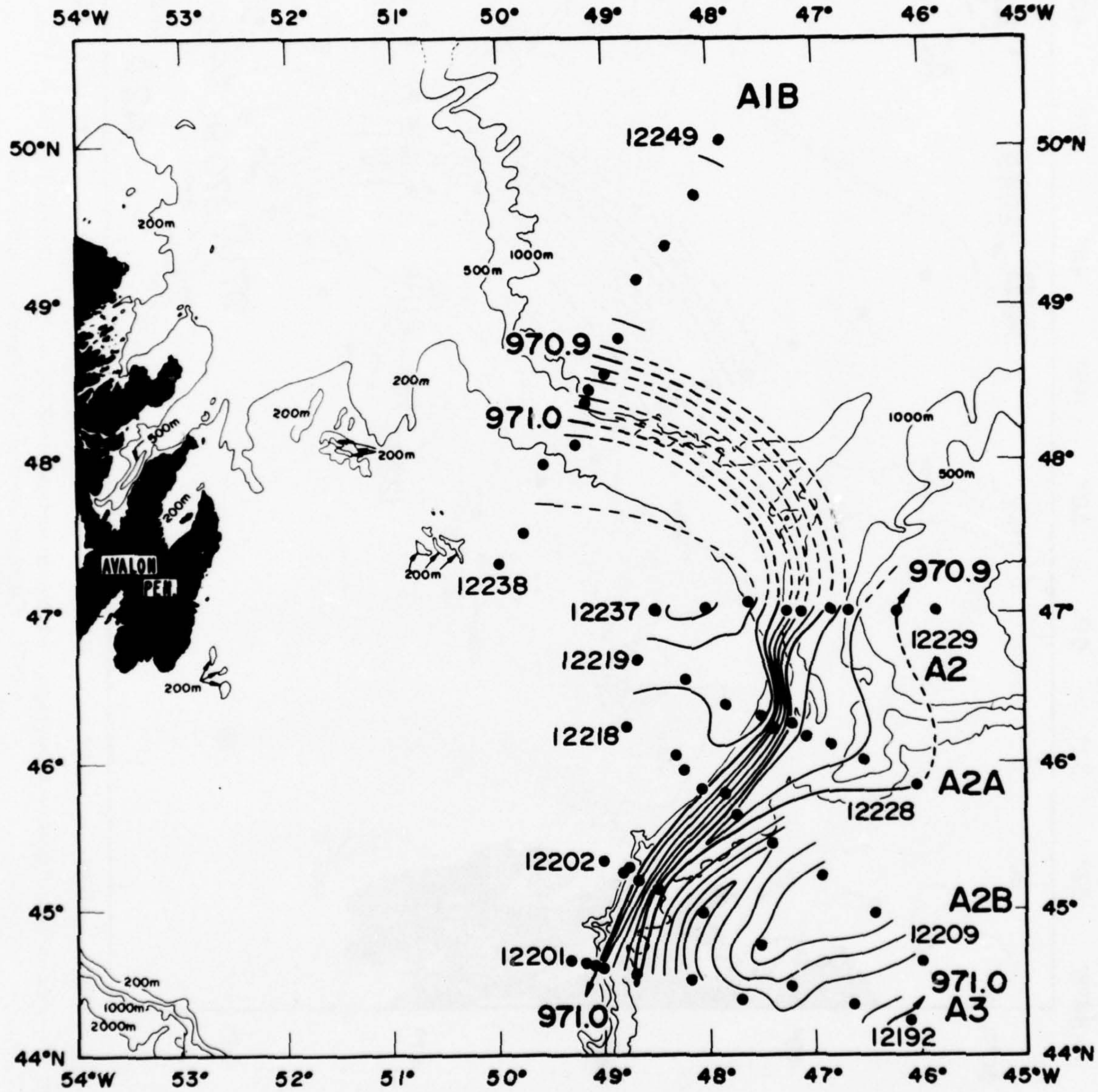


FIGURE 16.—Sea surface dynamic topography (dynamic meters) relative to the 1,000 decibar level, CGC EVERGREEN 8–14 April 1977. Contour interval is 2 dynamic centimeters.

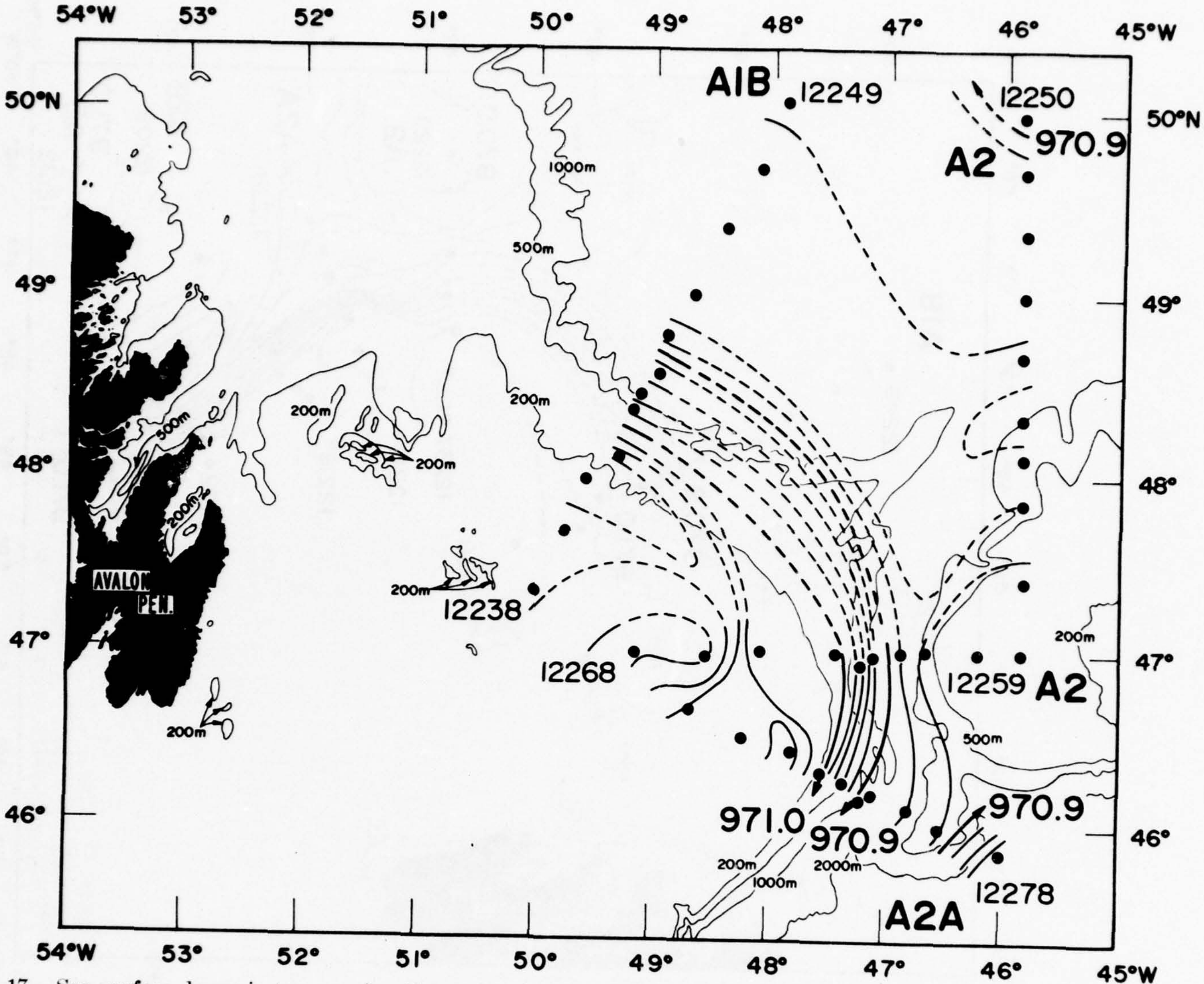


FIGURE 17.—Sea surface dynamic topography (dynamic meters) relative to the 1,000 decibar level, CGC EVERGREEN 17–22 April 1977. Contour interval is 2 dynamic centimeters.

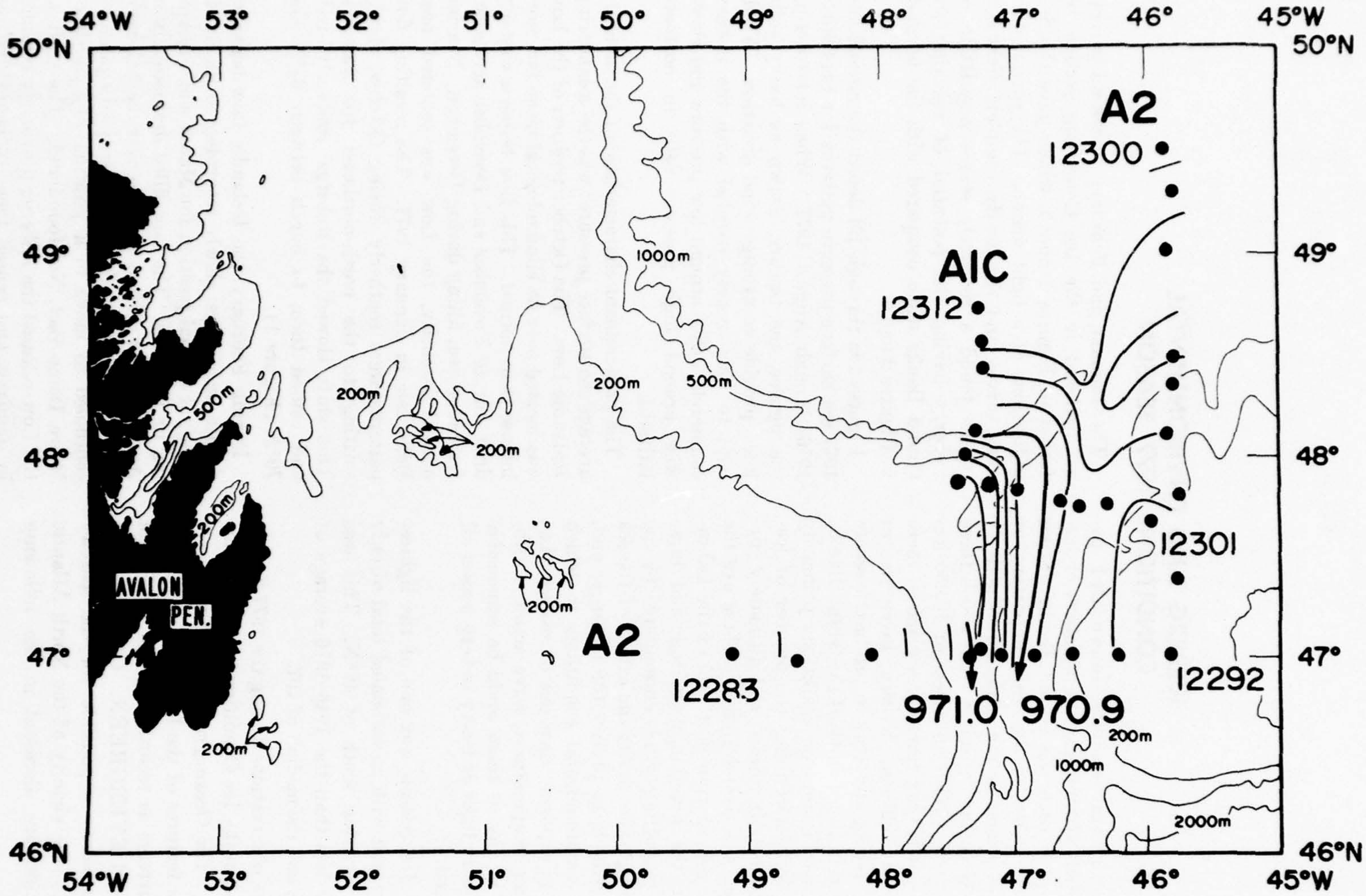


FIGURE 18.—Sea surface dynamic topography (dynamic meters) relative to the 1,000 decibar level, CGC EVERGREEN 27–31 May 1977. Contour interval is 2 dynamic centimeters.

ICEBERG AND ENVIRONMENTAL CONDITIONS 1977 SEASON

There are several complex interrelated parameters which account for the numbers of icebergs that will reach the Grand Banks during an ice season. One of the least important of these is fluctuations in the annual productivity of the west Greenland glaciers from which these bergs originated. With an excess of 10,000 icebergs calved each year from these glaciers, there is certainly a sufficient iceberg inventory in Baffin Bay during any year to produce a severe iceberg season in the vicinity of the Grand Banks. There are four factors or conditions primarily responsible for determining the number of icebergs that will drift toward and ultimately survive to reach the Grand Banks. These are the intensity or volume transport rate of the Labrador Current; the direction, magnitude and duration of the prevailing winds encountered by the icebergs during their drift; the extent of the sea ice cover available to protect the icebergs; and, finally, the environmental conditions to which the iceberg is exposed when out of sea ice (i.e., air and water temperatures, wave action). Abnormalities in any of these could be responsible for either a very light or heavy iceberg season off Newfoundland.

The 1977 Ice Season was one of the lightest seasons on record with an estimated total of only 22 icebergs drifting south of 48°N. This was significantly less than the 1946–1976 average of 300 icebergs and the median of 107.

The sea ice observations during the 1977 Season are discussed in the Ice Conditions section of this publication. The Oceanographic Conditions section reviews features of the Labrador and North Atlantic Currents as recorded by the Ice Patrol research vessel EVERGREEN. Other environmental parameters responsible for the scarcity of icebergs in the vicinity of the North Atlantic shipping lanes are discussed in the following paragraphs.

The January and February preseason surveys as discussed in the Ice Conditions section referred to Figures 1 and 3, which gave the first indications of a light season. The partial January survey and the nearly complete February census found a relatively scarce population of icebergs having the potential of reaching the Grand Banks when compared with the normals in Figures 2 and 4.

Figures 19a through 19l depict the normal and 1977 sea surface pressure patterns for September 1976 through August 1977. When interpreting the figures, the isobars, drawn as heavy solid lines, provide an average wind direction. Winds tend to blow nearly parallel with the isobars, counterclockwise around low pressure and clockwise around high pressure cells in northern latitudes.

The predominant characteristic of the monthly average sea surface pressures was the meandering Icelandic Low. The October position of the Low was located near its climatological mean but more intense than normal. This Low began a westerly drift during November and December across the Labrador Sea, filling during December. Nearing normal intensity, the Low was centered near Belle Isle in January 1977. The resulting flow patterns were southerly during October, slowly shifting to the north-northeast for January. This shift slowed the icebergs' southerly drift and caused them to bunch between 65°N and 70°N (Figure 1).

During February, the Icelandic Low began to deepen once more, slowly returning to its climatological normal position for March while retaining its intensity. The Low filled dramatically in April and had drifted again to over the Labrador Sea. During May, the Low intensified again and continued to move to a position just north of Notre Dame Bay, Newfoundland. The shift of the Low released the icebergs previously retained in January, and caused them to begin drifting south again during February and March. The position of the Low in April caused onshore winds and resulted in a large number of iceberg groundings along the Labrador Coast. During May, the winds along 48°N were from the southwest causing a pool of icebergs to form above 48°N, impeding more southerly drift. Here unprotected by the retreating sea ice and subjected by warming spring temperatures, the iceberg population began to thin rapidly.

The Icelandic Low continued to move westward and fragmented in June. Continued southwesterly flow over the entire Newfoundland and Labrador coastlines caused northerly and easterly drifts for those few surviving icebergs. These icebergs melted rapidly in the open water and with warm air temperature prevailing as summer approached.

The 1977 surface pressure gradients are graphically shown in Figure 20, with a comparison to their 1946–1976 normals provided. Surface pressure gradients are the differences in surface pressures between two geographical points. The steeper the gradient or the more rapid a change in pressure, the higher the wind velocity will be; the opposite is true for shallower gradients or milder pressure changes. The Ice Patrol has established six such gradients from the Davis Strait off the Labrador and Newfoundland coasts in an attempt to better understand the wind magnitudes and primary wind directions flowing along the main iceberg drift routes heading toward the Grand Banks region. These gradients are depicted in Figure 21 and 22.

The most obvious and significant feature of the gradients in Figure 21 is the low valley that occurred in gradients 1, 2 and 3 during December 1976 and January 1977. These valleys indicate the strong northwesterly flow incurred by the Icelandic Low moving toward Newfoundland and explain the impeded southerly drift of the early season icebergs. The large peak in February and March shows the return of strong southwesterly wind flow encouraging drift to the south. Once again, flow is reversed in April and continues for the remainder of the season as shown by the shallow valleys. Hence the decreased influx of icebergs. The southerly winds across gradient 3 during this period brought warm air into the region accounting for the retreat of sea ice and melting of the trapped icebergs above 48°N. The very slight easterly winds from late May through the end of the season, as shown in gradient 4, did not encourage much easterly iceberg drift and thus, most icebergs remained close to shore.

Air temperatures over Labrador and east Newfoundland show various departures from climatological averages throughout the ice season, all stemming from the abnormal positioning of the Icelandic Low. Generally, the winter temperatures were at or slightly above normal in the northerly regions, cooler than normal in the south. For the spring and early summer months, temperatures were generally cooler than average to the north, and near normal in the south. The graphs in Figures 23 and 24 represent the cumulative frost-degree-days and melting-degree-days, respectively. Locations of the seven preselected shore stations are shown in Figure 20. A frost-degree-day is defined as one day mean of one degree Fahrenheit below 32°F, and a melting-degree-day is defined as one day mean of one degree Fahrenheit above 32°F. That is, a daily averaged temperature of 12°F equals twenty frost-degree-days, and a daily averaged temperature of 42°F equals ten melting-degree-days.

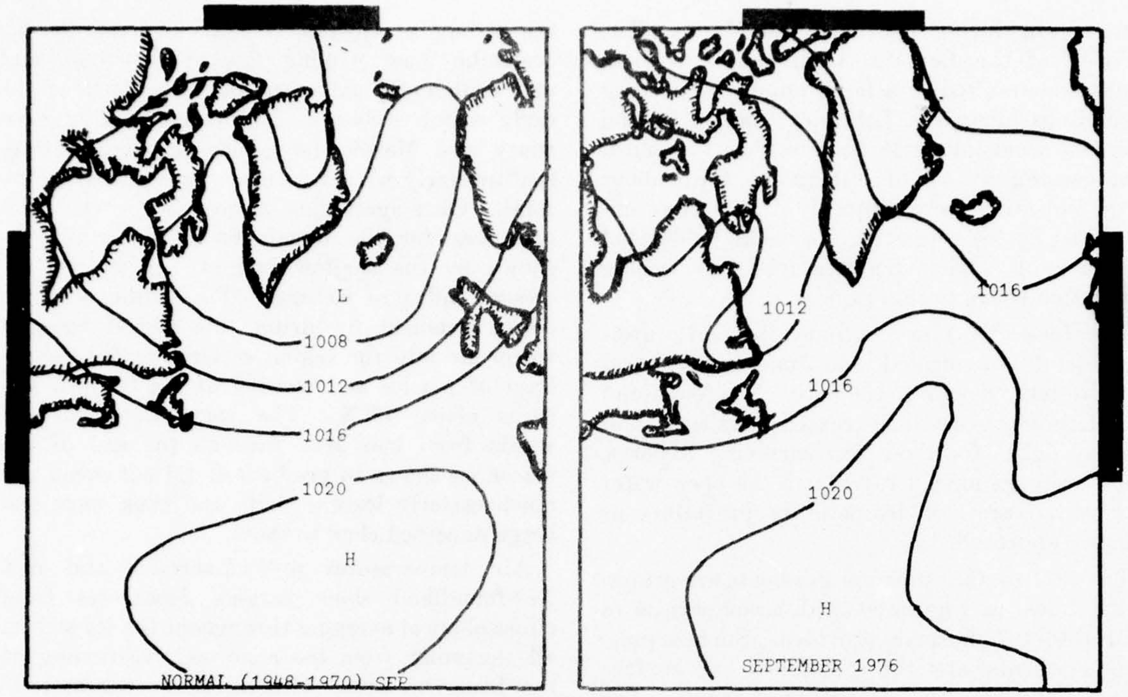


FIGURE 19a.—September 1976 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

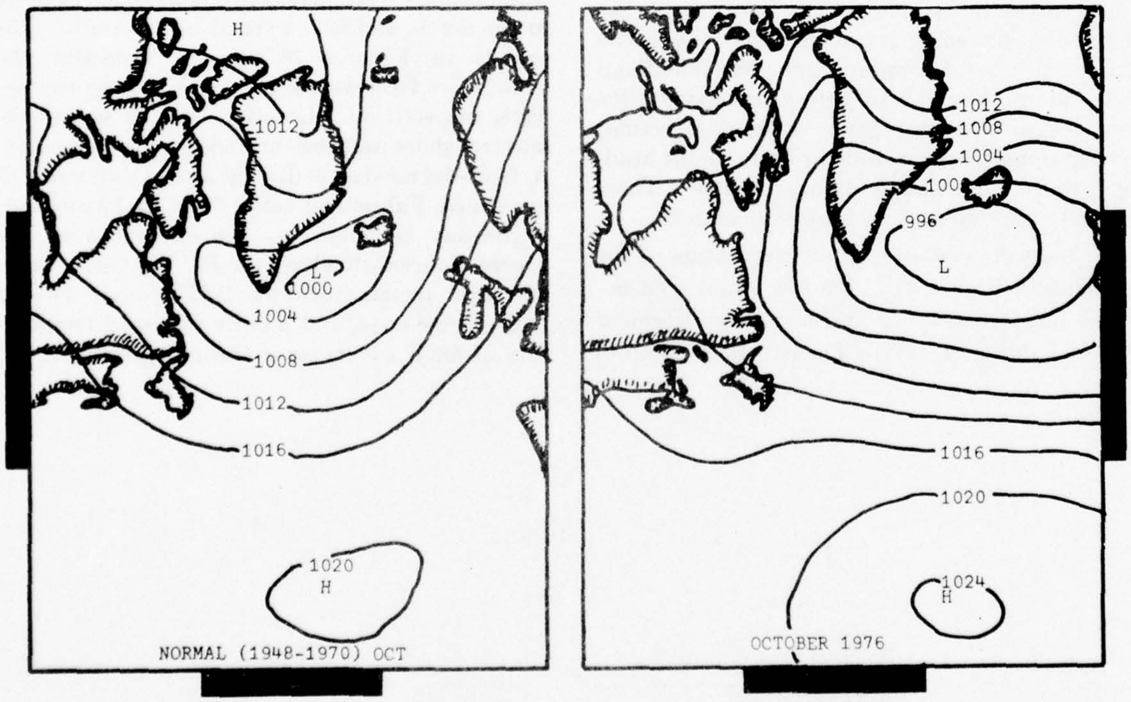


FIGURE 19b.—October 1976 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

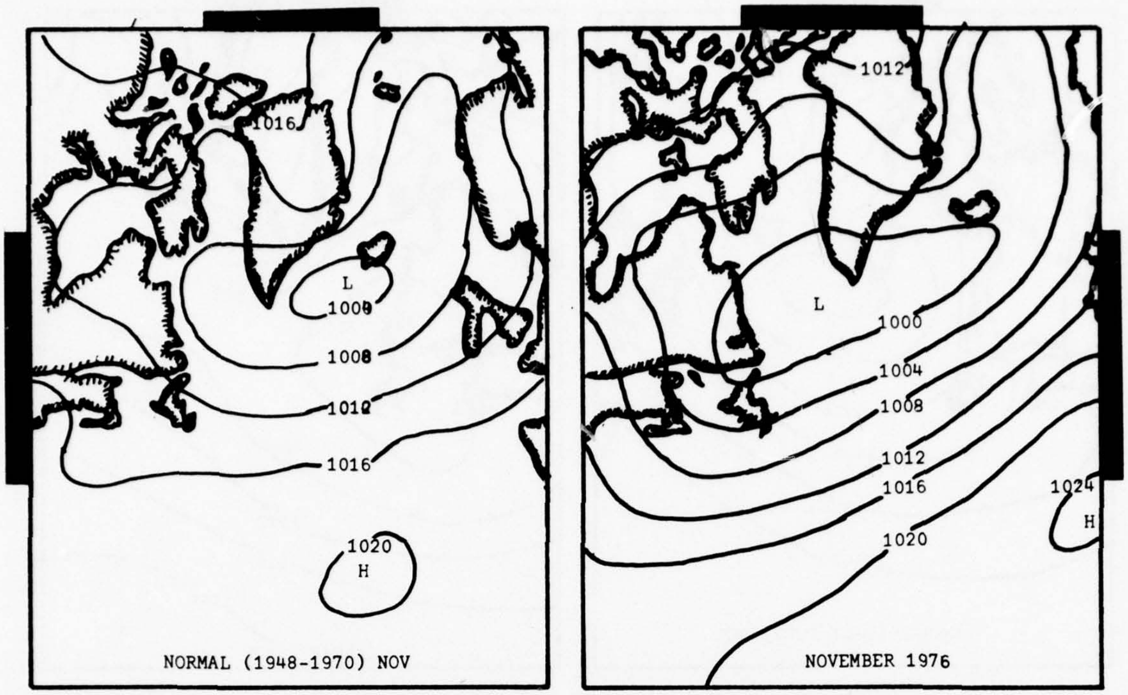


FIGURE 19c.—November 1976 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

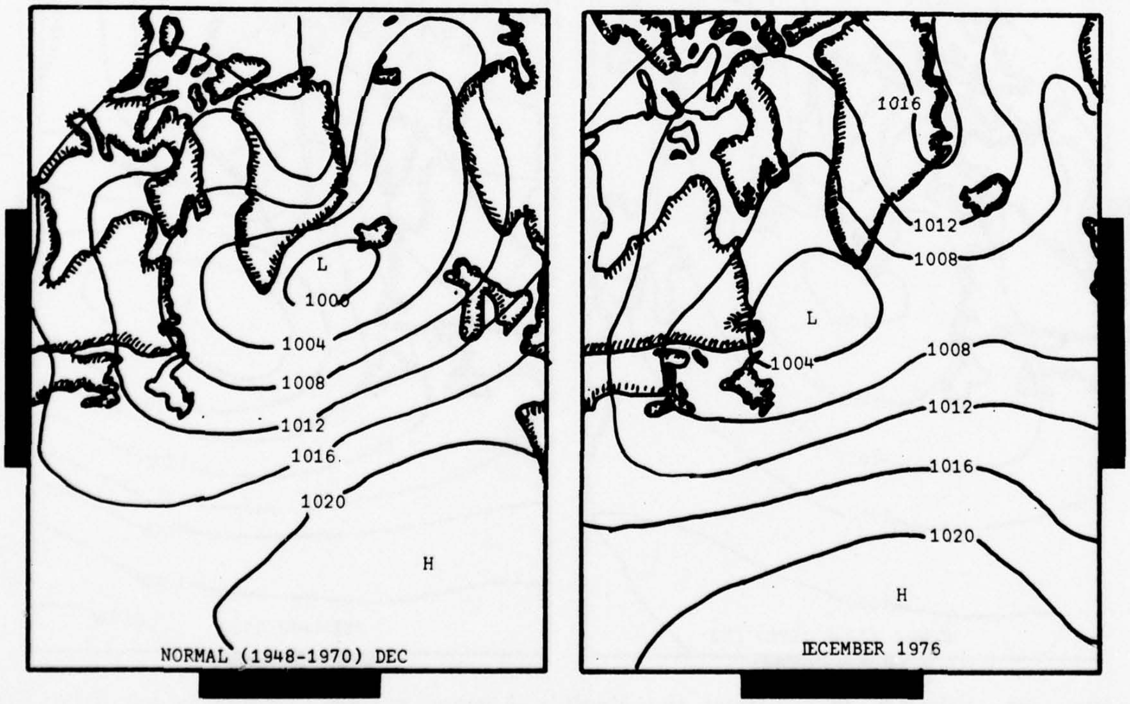


FIGURE 19d.—December 1976 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

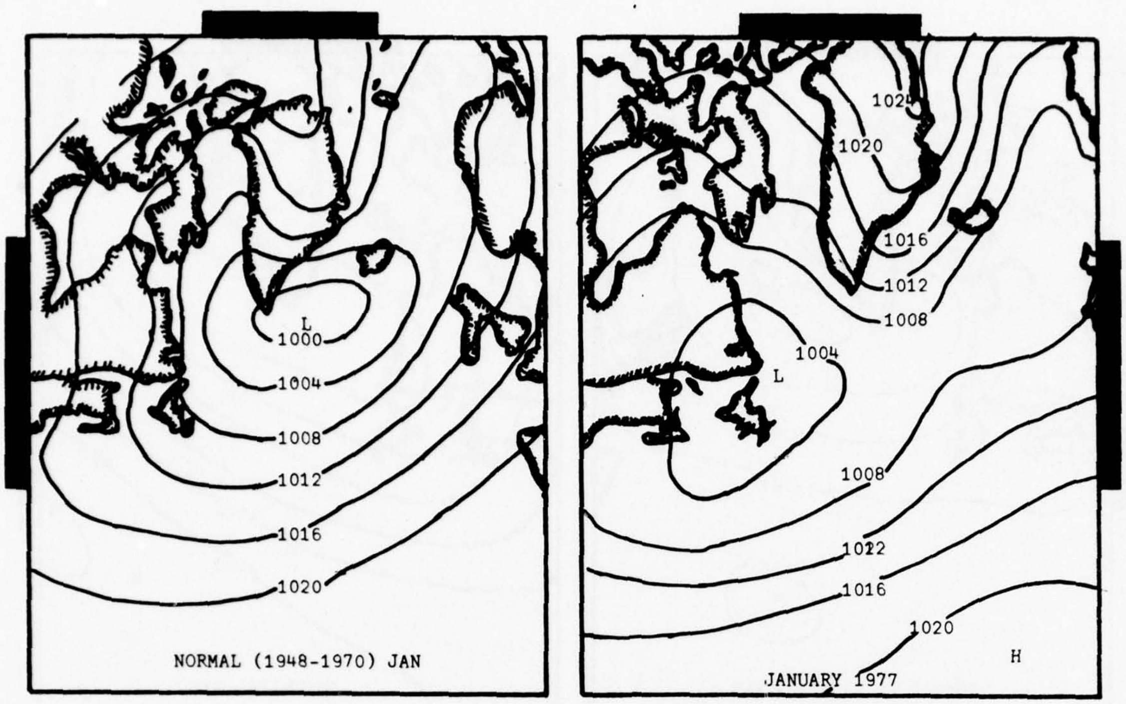


FIGURE 19e.—January 1977 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

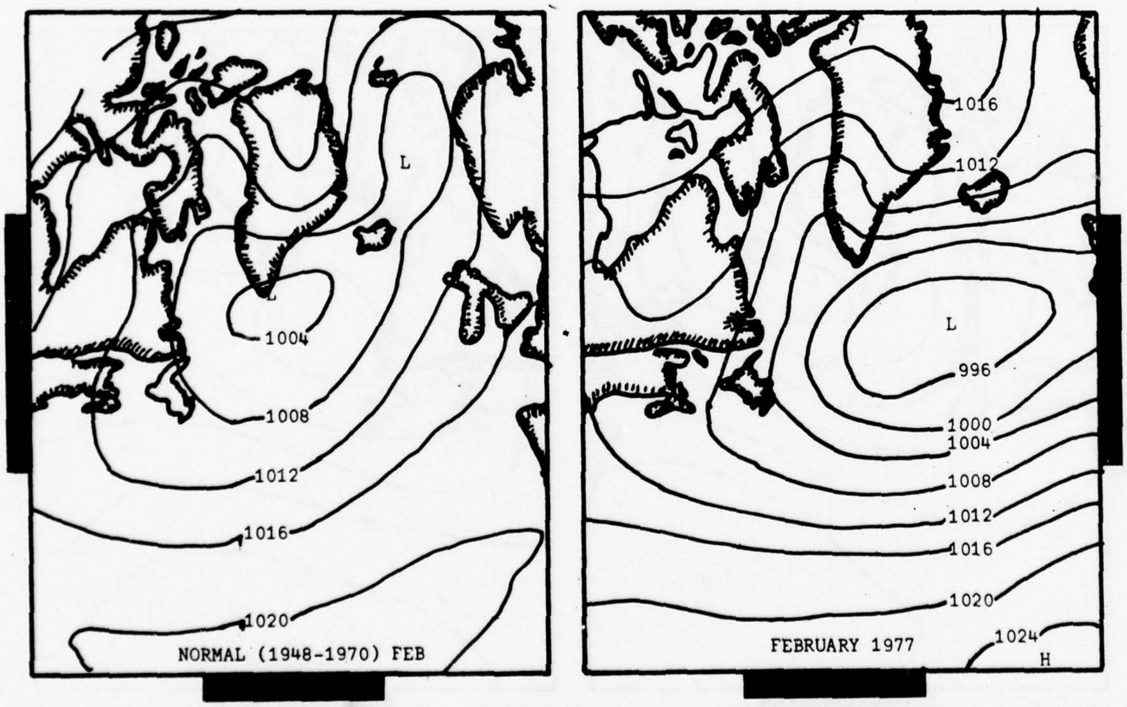


FIGURE 19f.—February 1977 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

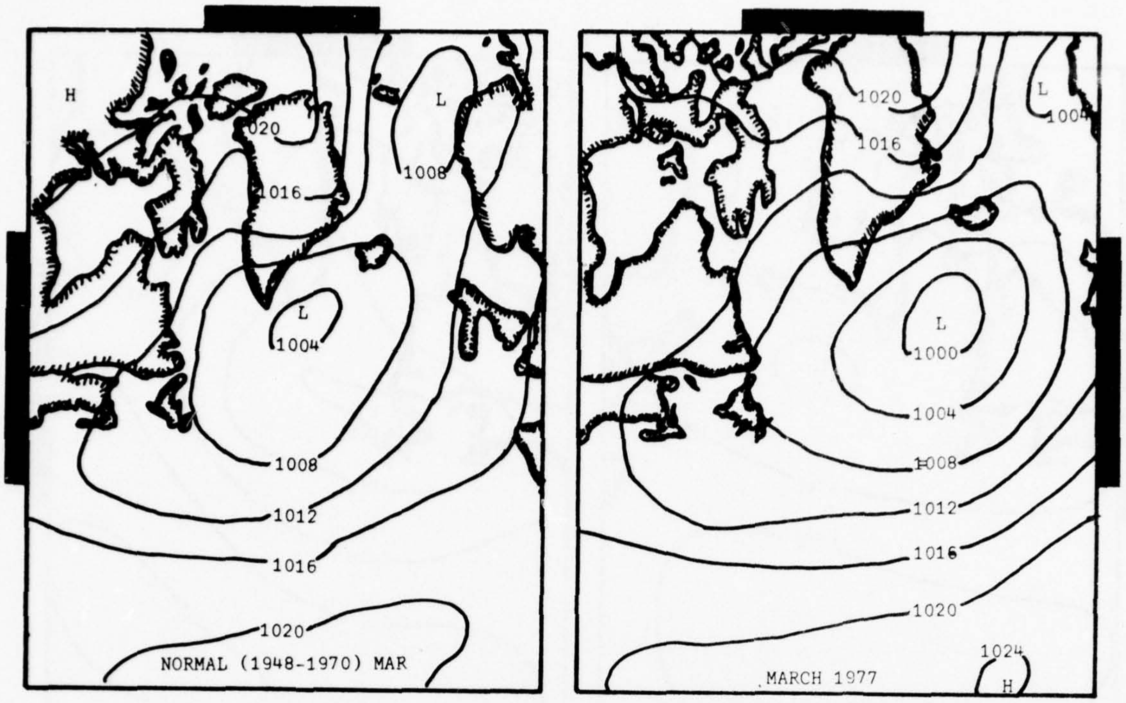


FIGURE 19g.—March 1977 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

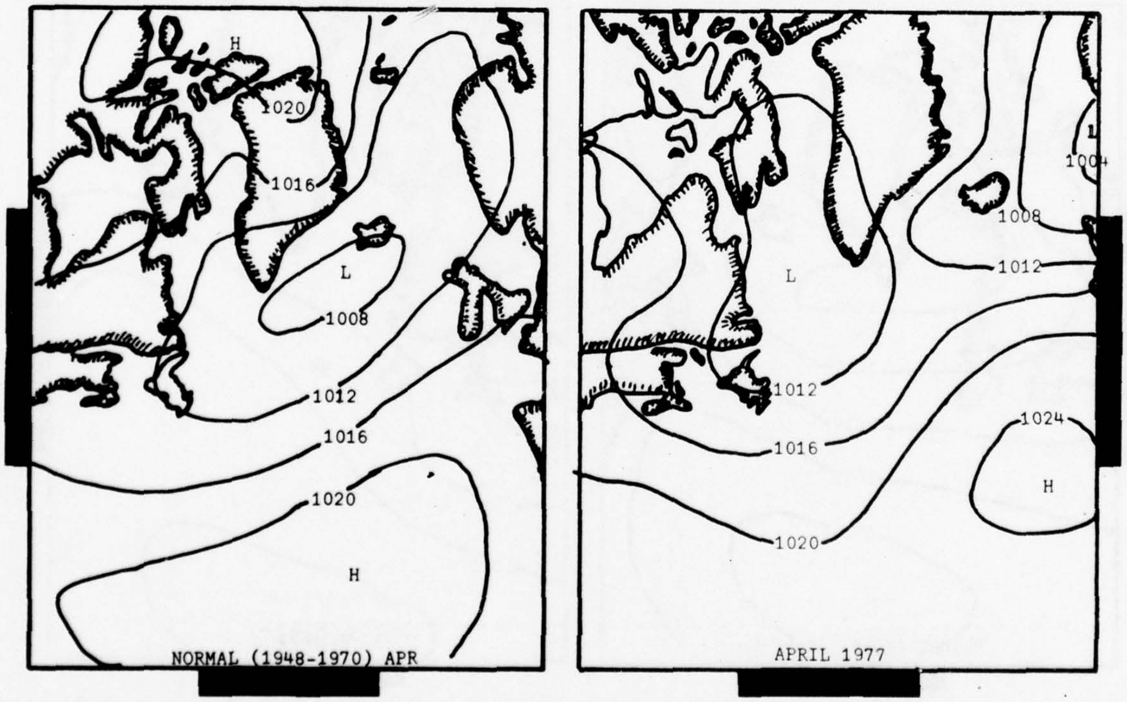


FIGURE 19h.—April 1977 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

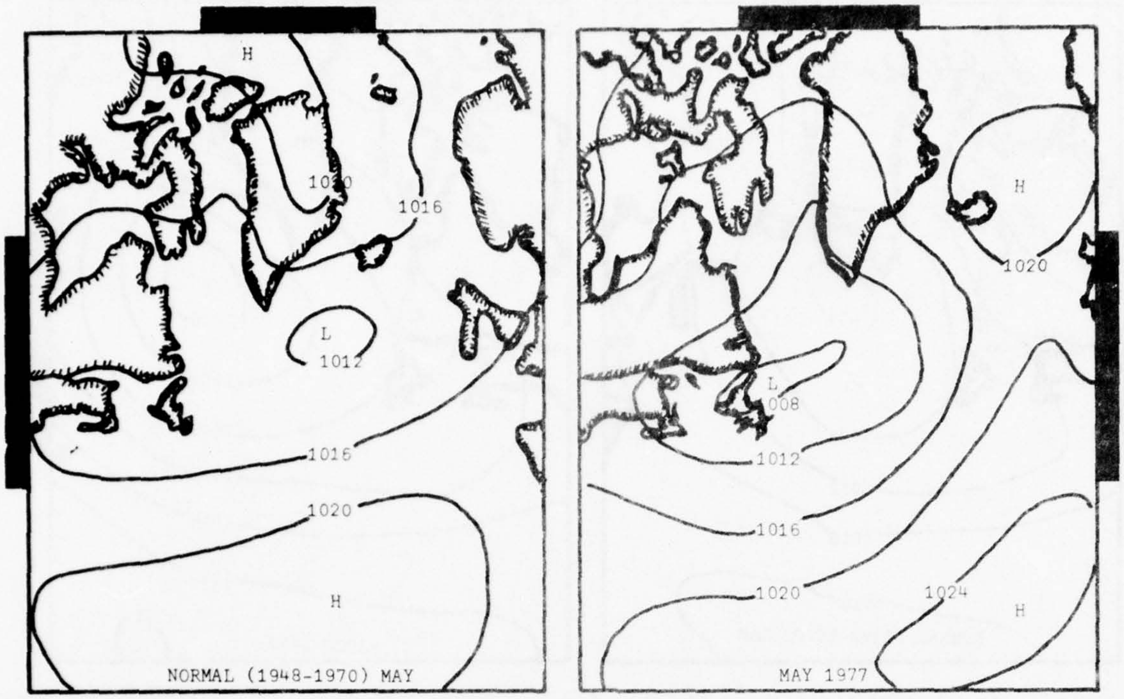


FIGURE 19i.—May 1977 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

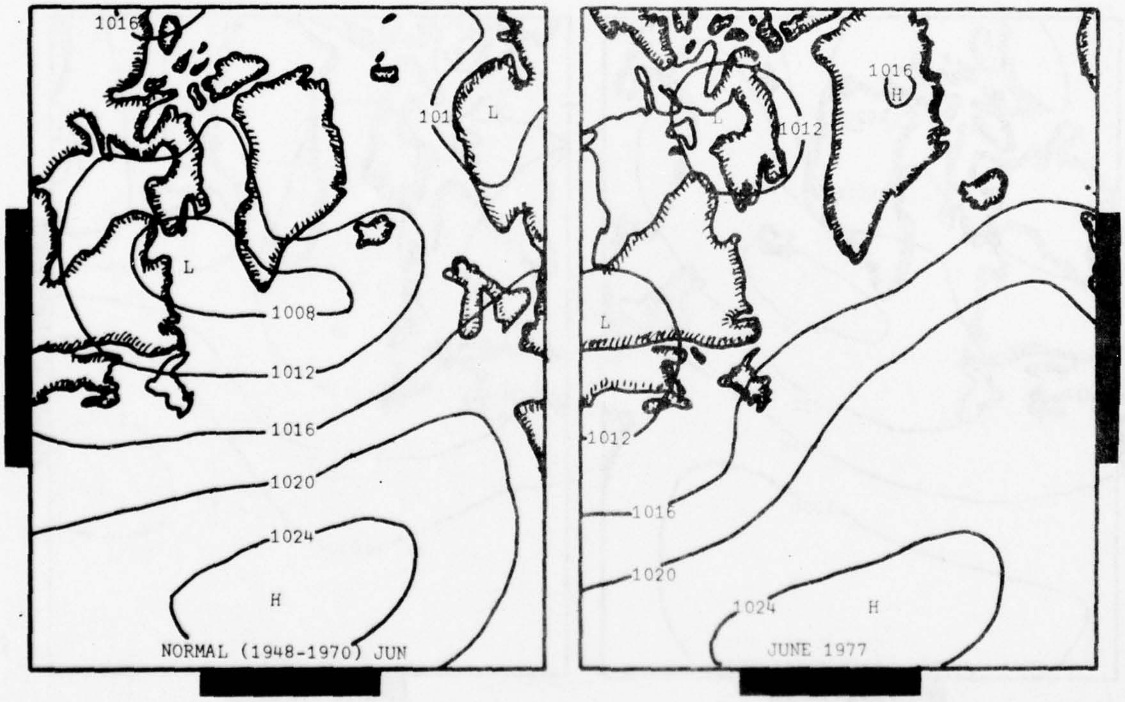


FIGURE 19j.—June 1977 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

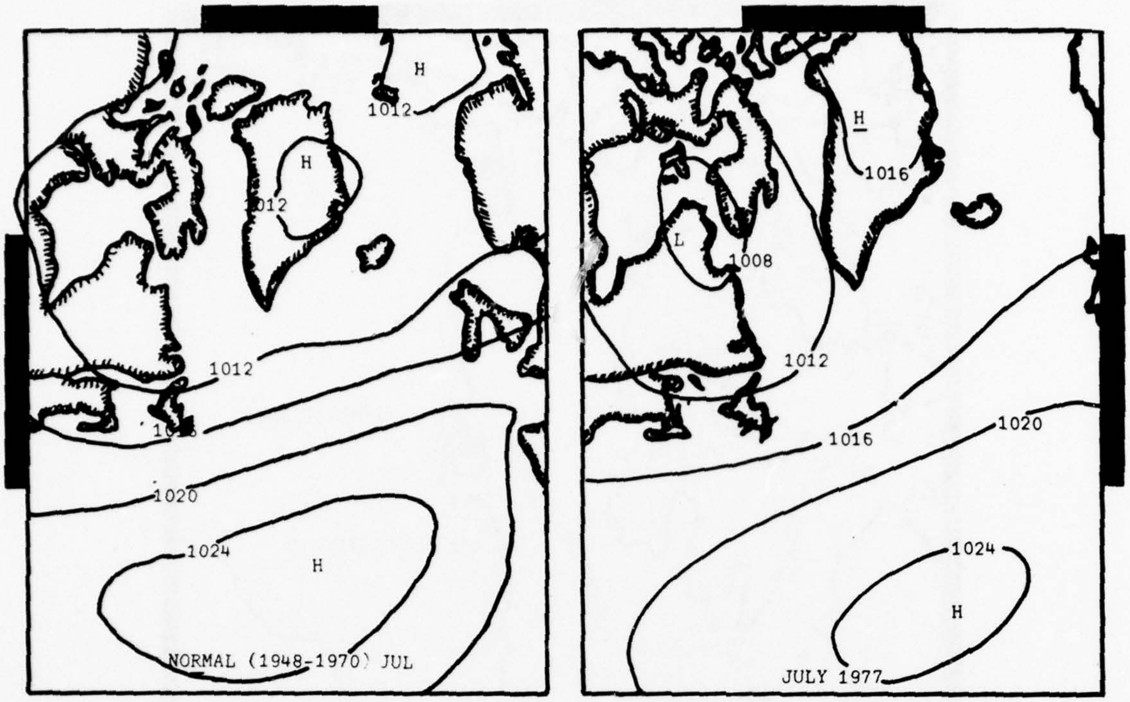


FIGURE 19k.—July 1977 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

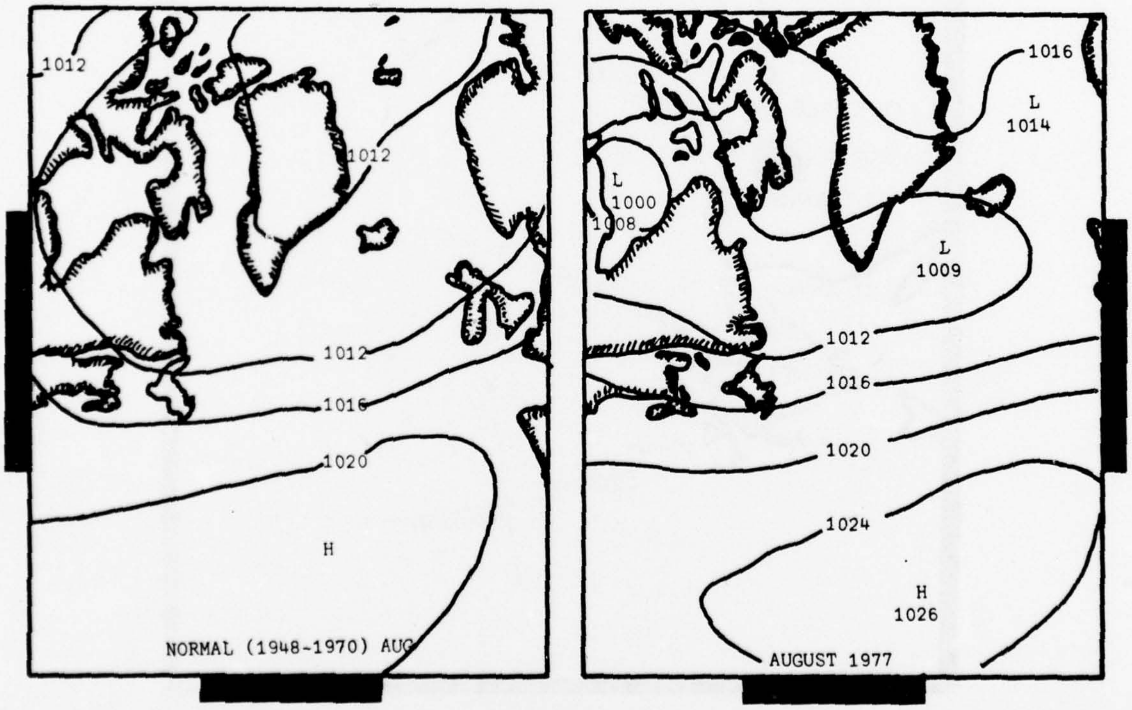


FIGURE 19l.—August 1977 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

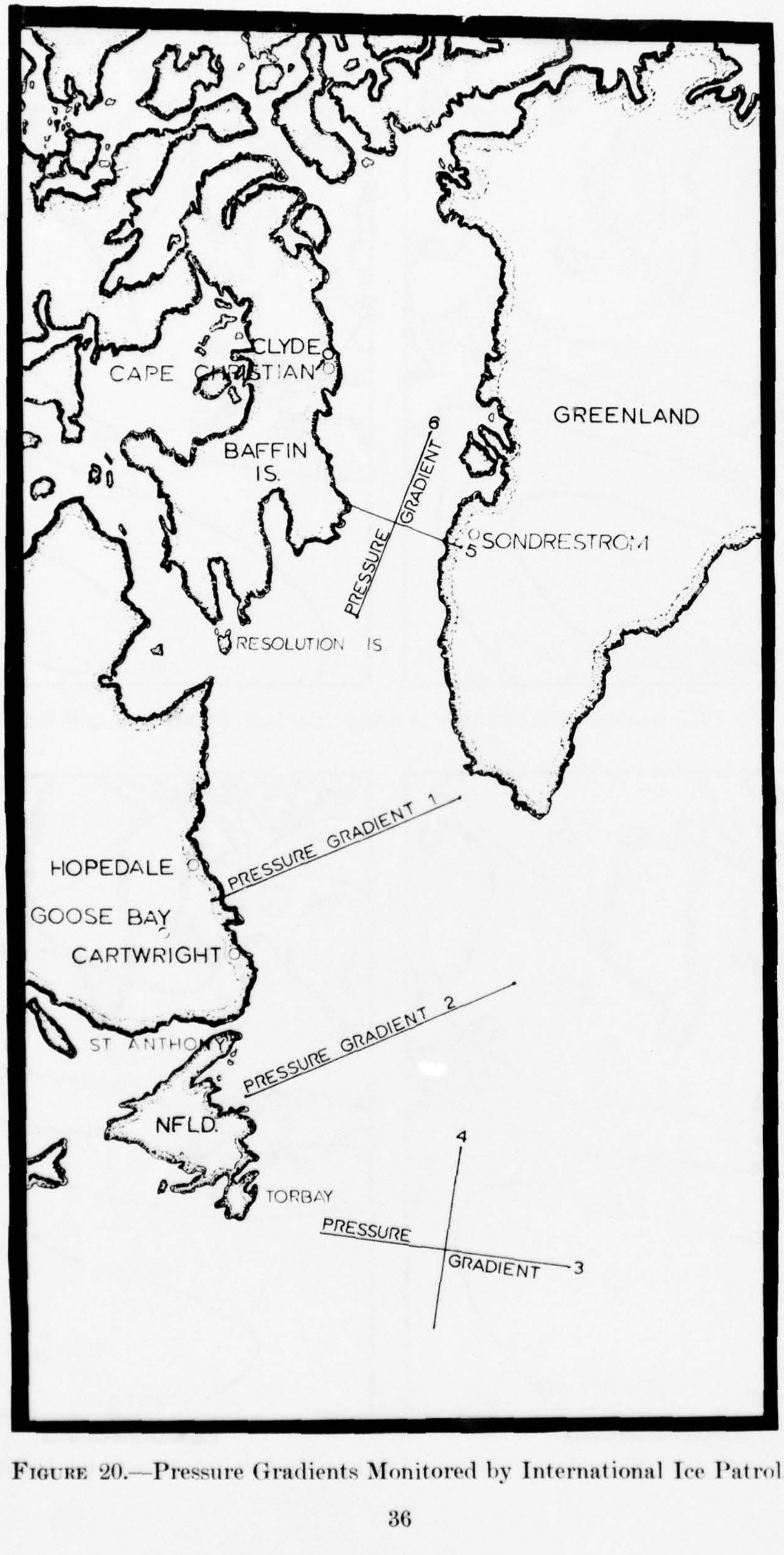


FIGURE 20.—Pressure Gradients Monitored by International Ice Patrol.

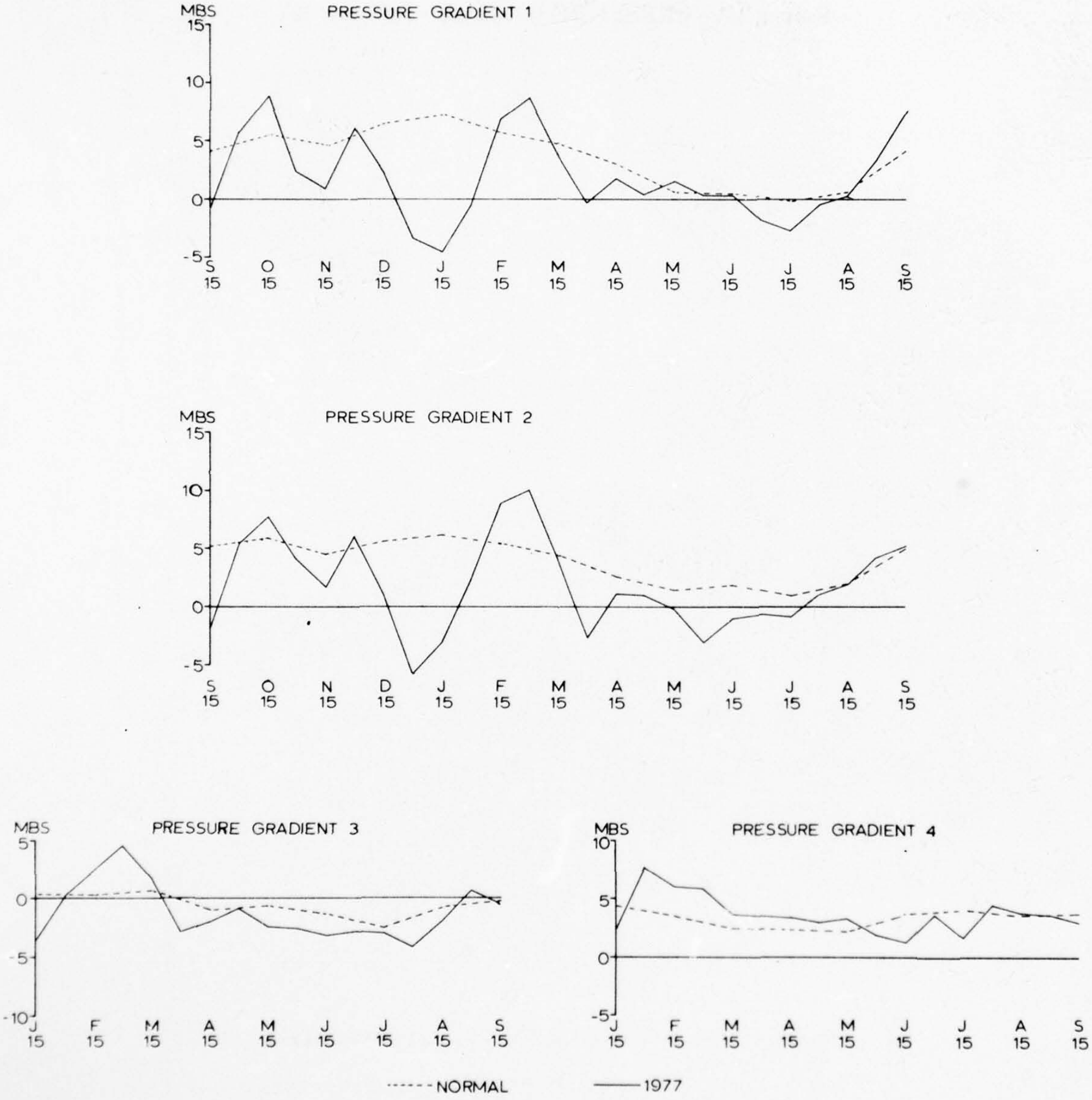


FIGURE 21.—PRESSURE GRADIENTS 1–4.

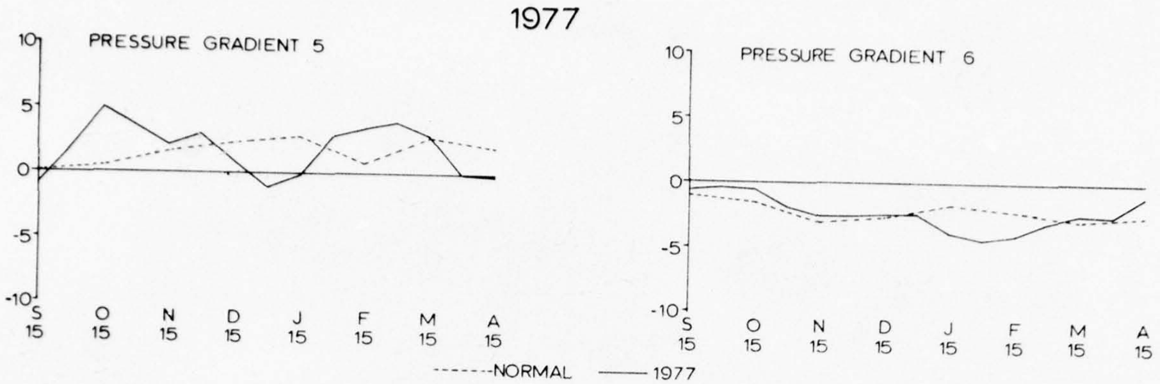


FIGURE 22.—PRESSURE GRADIENTS 5 and 6.

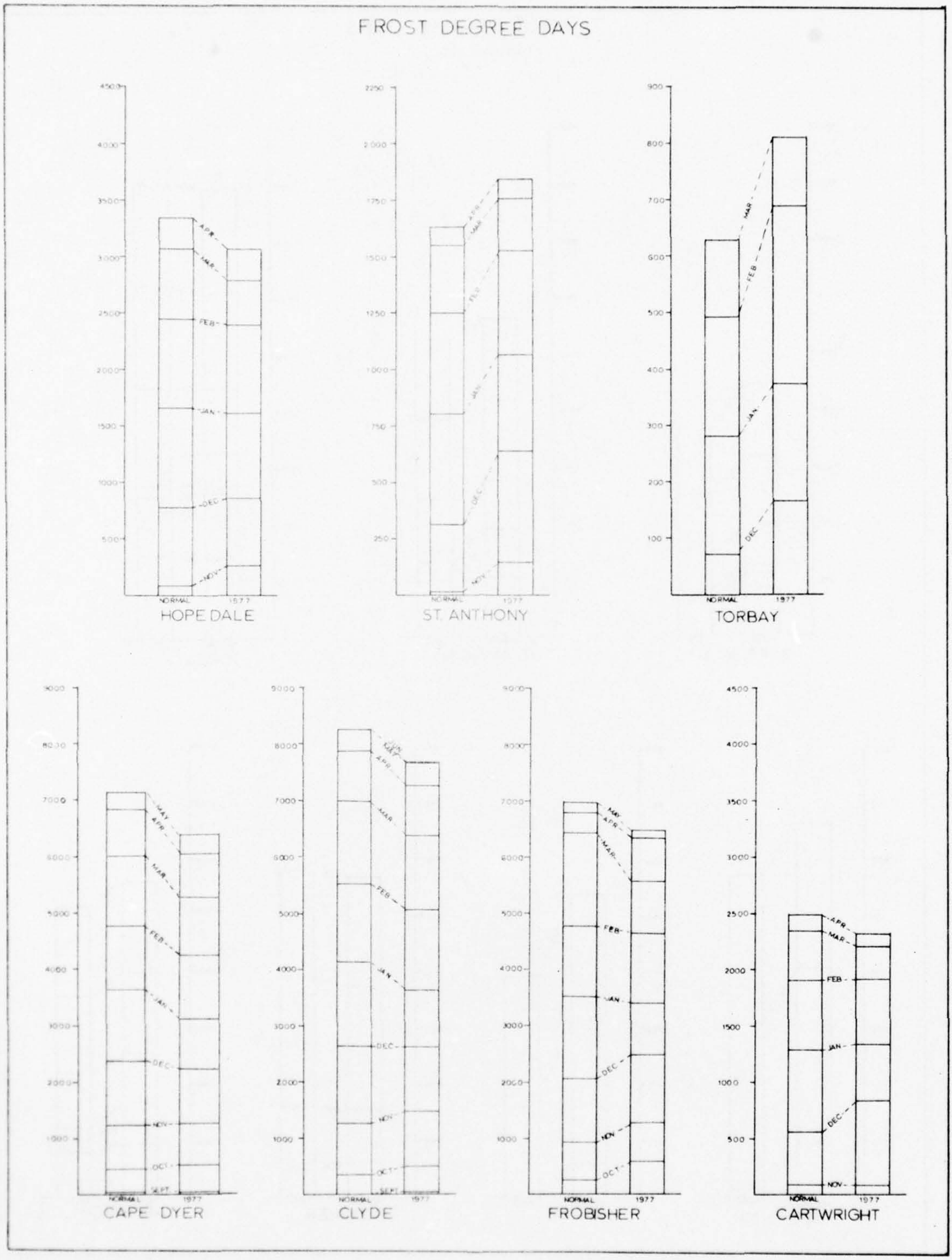


Figure 23.—Frost Degree Day Accumulations Calculated from Monthly Mean Fahrenheit Air Temperatures.

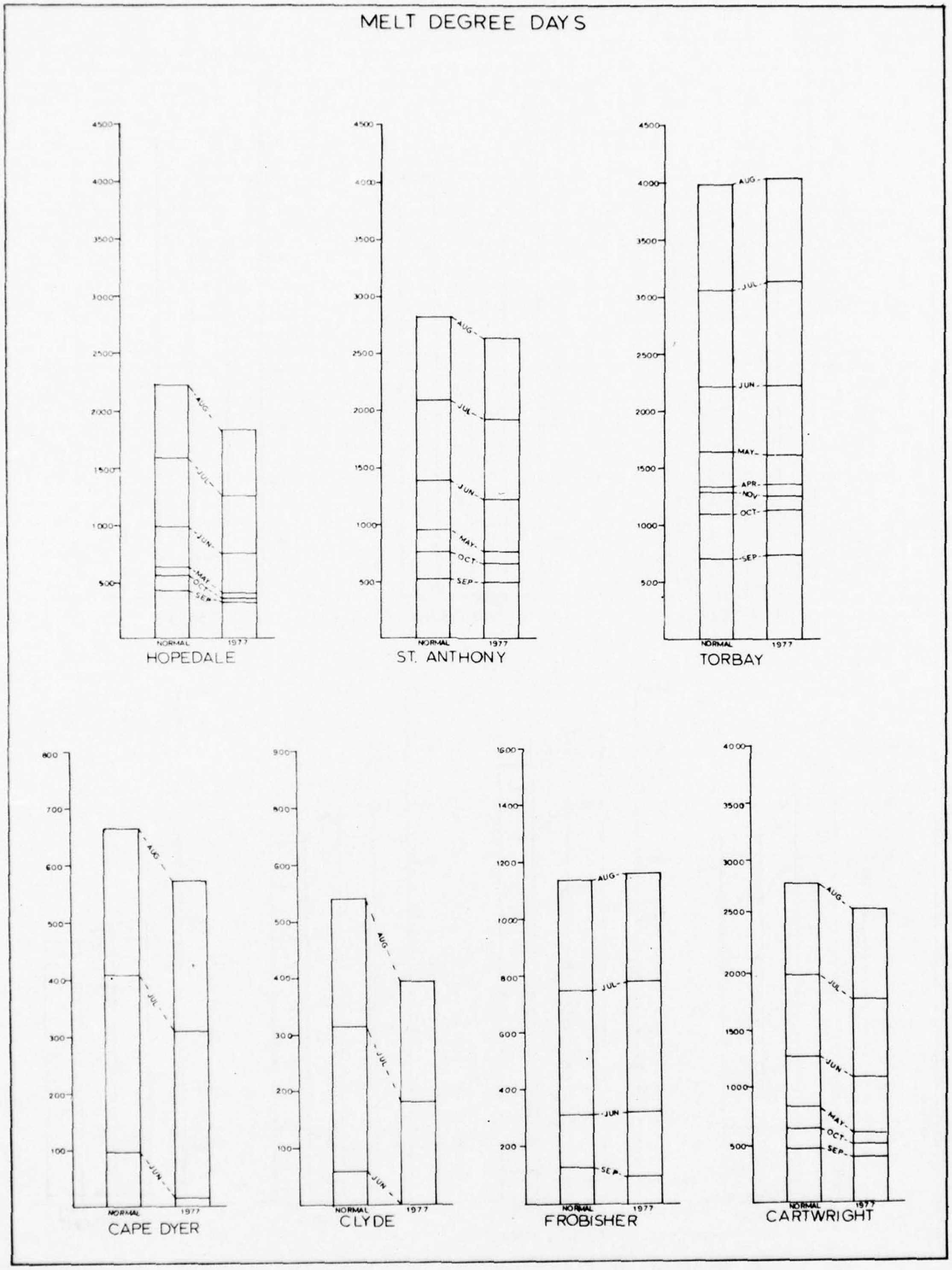


FIGURE 24.—Melt Degree Day Accumulations Calculated from Monthly Mean Fahrenheit Air Temperatures.

RESEARCH AND DEVELOPMENT—1977

During the 1977 Season, Ice Patrol continued the research and development program on remote sensing to provide an all-weather iceberg detection and identification tool. NASA Lewis Research Center provided a solid state Side-Looking Airborne Radar (SLAR), APS-94D model, which was installed in the Coast Guard HC-130B aircraft, CGNR 1351, used primarily on the Great Lakes ICEWARN project. Extensive SLAR data on icebergs and ships were accumulated during the season for use in bench testing for the Radar Image Processor (RIP) currently under development by NASA Lewis. The RIP, which shows promise for SLAR target discrimination, will undergo test and evaluation under operational conditions during the 1978 Ice Season.

The Airborne Oil Surveillance System (AOSS), newly installed in the Coast Guard HC-130B aircraft, CGNR 1347, was also tested during the 1977 Ice Season. This included evaluation of its APS-94D SLAR, Passive Microwave Imager (PMI), and ultraviolet/infrared line scanners.

Both the AOSS and ICEWARN SLAR systems show good potential for providing the all-weather iceberg detection and identification capability required to conduct effective and efficient surveillance. Development of effective methods for data interpretation through operator expertise and NASA Lewis' RIP should eventually eliminate the problem of dependence upon visual reconnaissance in Ice Patrol operating areas where fog and low cloud cover are so prevalent.

Satellite positioning buoys, such as the Buoy Transmit Terminal (BTT) and Air Deployable Remote Access Measurement System (ADRAMS) type, although barely past the test and evaluation stages themselves, have proven to be invaluable tools to Ice Patrol. The buoys continue to serve a variety of uses including location, speed, and direction of ocean currents, tagging of selected icebergs for drift studies, and improved season forecasting and prediction using data from buoys dropped on icebergs in the vicinity of Davis Strait or along the Labrador coast. Two ADRAMS were successfully deployed onto bergs on each side of Davis Strait during the February preseason flight. They functioned well and were tracked for more than four months, using the NIMBUS-6 satellite. The western leg was tracked all the way south to 51°N. More ADRAMS drops are planned for the 1978 season. The continued use of these buoys will greatly improve Ice Patrol operational effectiveness at relatively minimal cost.

This season also saw a continuation of the iceberg drift project. Using the integrating current drogue developed in 1976, a set of iceberg drift data was collected which included current, wind and iceberg velocities. Three sets of drifts were conducted, the first lasting 36 hours, the second 48 hours and the third a little over 24 hours.

In June, the test phase for the iceberg tethering dart was completed. This 35 pound anchoring projectile proved capable of penetrating 0.7 meters when dropped from 200 feet at 130 knots. It is planned to develop an expendable instrument package which will be attached to the tethering dart by means of a buoyant line. Appendix A gives details on this project.

The first remote sensing satellite devoted to oceanographic monitoring, SEASAT-A, will be launched during 1978. The International Ice Patrol and NASA Lewis have developed a joint plan for ground truthing and evaluation of SEASAT-A data applicable to the Ice Patrol mission. The RIP should be capable of interpreting the satellite's Synthetic Aperature Radar

(SAR) data. In this manner, simultaneous comparisons and evaluation of visual, SLAR, and SAR can be made. Ice Patrol aircraft and surface vessels will collect extensive visual and oceanographic data during routine operational missions for comparison with the SEASAT-A products. The SEASAT system has the potential of becoming the Ice Patrol's primary operational surveillance device by the mid-1980's should these first experiments prove successful.

Areas in which Ice Patrol research and development are directed remain unchanged, as can be noted in recent years. In order of priority, the primary problem areas are: (a) all-weather detection and identification of icebergs, (b) iceberg drift prediction, (c) iceberg deterioration. Although advances have been made during this past year in developing systems and devices to solve some of these problems, it is paramount that this vigorous research and development program continues.

ICE AND SEA SURFACE TEMPERATURE REPORTS RECEIVED FROM SHIPS OF PARTICIPATING NATIONS DURING 1977

BULGARIA	*ICE*	*SST*
FLAMINGO	1	
OLUSHA	1	
CANADA		
CAPE HARRISON	1	
HURON	2	39
SIR HUMPHREY	2	
CUBA		
RIO CANIMAR	1	
DENMARK		
ATLANTIC SKOU	1	
TORM ASLAUG	1	
EAST GERMANY		
ER MONTREAL	1	
GORLITZ		1
FINLAND		
GERMUNDOE	1	
FRANCE		
DELCHIM ALSACE		13
L'AGENAIS		8
GREAT BRITAIN		
ANCO TEMPLAR	1	
CAPULET		1
CRAMOND		3
CUNARD CHAMPION	2	
CUNARD CHIEFTAIN	2	
CP DISCOVERER	2	
CP TRADER	1	1
DORCASIA		5
EDEN FISHER	1	
E. W. BEATTY		1
FARNELLA		5
LA CHACRA		4
MANCHESTER CONCORDE	1	
VICTORE	1	
SUGAR REFINER	1	
W. C. VAN HORNE	1	
WAYFARER	1	

GREECE	*ICE*	*SST*
HELLAS IN ETERNITY		2
MARITSAPLEMOS	1	
GUADALUPE		
TOXOTIS		5
ICELAND		
BAKKAFOS		31
GODAFOSS	2	
SLAFTAFELL		7
SELFOSS	1	
INDIA		
JALABALA		1
ITALY		
MARE TIRRENO		1
LIBERIA		
BORDATXOA		1
CAPTAIN CARGILL		12
CARINA		2
HAMBURGER WAPPEN		6
HUNTER BOW	3	3
KATHLEEN	2	7
LORFRI		6
MELTEMI		3
UNIMAR	1	
NETHERLAND		
SMIT LLOYD	1	
NORWAY		
BAHMA		8
BERGE BONDE		8
BERGANDER	1	
BRUNHORN	1	
CORNER BROOK	1	
DYVI OCEANIC	1	
FROSTFJORD	1	
SANDVIKEN	1	1

PANAMA

CLAUDIA KOGEL		4
FIESTA		4
HARMONY		8
ROSEDAPHINE	1	
SEAFOX	1	

POLAND

PEGAZ	1	
FENIKS	1	

PAKISTAN

WARSAK		7

SINGAPORE

OCEAN INTREPID		2
TURICUM	1	

SWEDEN

ATLANTIC SPAN		11
BORELAND		7
JOH. GORTHON		1
MONT ROYAL	15	1

SWITZERLAND

SILVRETTA	1	

UNITED STATES OF AMERICA

ADMIRAL CALLAGHAN	1	1
AMERICAN ARGOSY	1	
LASH ITALIA		1
SEALIFT ARABIAN SEA	1	

UNITED STATES COAST GUARD

USCGC EVERGREEN	12	893
USCGC WESTWIND	3	

UNITED STATES NAVY

USN MIRFAK	1	

U.S.S.R.

KOMSMOLETS KUBANI	1	

WEST GERMANY

COLUMBUS VIRGINIA	1	
STADT WOLFBURG	13	15

YUGOSLAVIA

BANJA LUKA		5
DUBROBNIK		4

APPENDIX A

TAGGING OF ARCTIC ICEBERGS

by R. Q. ROBE and T. S. ELLIS
U.S. Coast Guard Research and Development Center

All of the early work with iceberg drift and deterioration considered the entire population of icebergs because of IIP's limited detection capability (Cheney, 1951). When icebergs were near the southern, western or eastern boundaries of the defined ice area, they were considered highly dangerous to shipping and a surface patrol vessel would be assigned to follow these bergs until they melted (Lenczyk, 1965). Only this continuous contact could assure that the iceberg being tracked remained the same piece of ice. Because of changes in the berg's shape by calving, rolling and melting, even repeated aircraft flights could not make positive identification in most cases (Lenczyk, 1965). During the 1960's, interest in predicting the behavior of individual icebergs increased for a number of reasons. First, IIP now had confidence that aircraft could spot and position bergs reliably over wide areas during periods of good weather. Since the lack of good weather has been a severe problem, a means to predict the position between sightings is needed. Second, even with accurate drift prediction, the berg's rate of deterioration must be estimated so that it will not be carried on the ice plot for much more than a day after it has melted, or worse, be eliminated from the ice plot *prior to melting.*

Answers to questions of drift and deterioration prediction require that many individual icebergs be studied over an extended period of time. These studies require that the researcher be certain he is working with the same bergs and not other icebergs in the same area. Early identification attempts made use of dye to color the sides of the berg. Kollmeyer (1966) used test tubes filled with various dyes and shot them on an arrow from a bow to mark a position on the face of an iceberg. This mark was used as a reference during a deterioration study. Over the years, IIP aircraft have repeatedly "bombed" bergs with dye to aid in their identification. This has limited utility because rolling and melting of the iceberg soon washes the color away. Dye has a life of one to two days depending on weather conditions and melting and rolling of the ice.

In 1974, the Coast Guard Oceanographic Unit began a project to determine the best way to tag an iceberg for identification and relocation. The first approach was to encircle a berg with a floating line (Hayes et al., 1975). The 0.95 cm line made of polypropylene was provided with additional floatation along its length (Figure A–1). Radar reflectors and a Radio Direction Finder transmitter were included as elements in the line.

Two tagging attempts were made using this method. On the first, three bergs were tagged. The arrays were carried away in a storm and only one was recovered. The line on the recovered array was broken in two places. One break occurred with such force that the ends of the fibers were fused. There was no evidence of chafing. The other break appeared to be the result of chafing. The second attempt had quite different results. Weather was fairly calm and several bergs were tracked in dense fog for nine days. However, the tagging arrays slipped repeatedly over or under the bergs. This necessitated early recovery of the equipment which drifted away from the iceberg, although the line circle remained intact. This result was completely unexpected and probably was caused by the berg snagging the line and rolling out of the loop (Hayes et al., 1975). It should be remembered that these icebergs were in an advanced stage of deterioration and quite likely to roll.

A similar experiment was carried out in 1976 (Brooks, 1977). After consultation with the

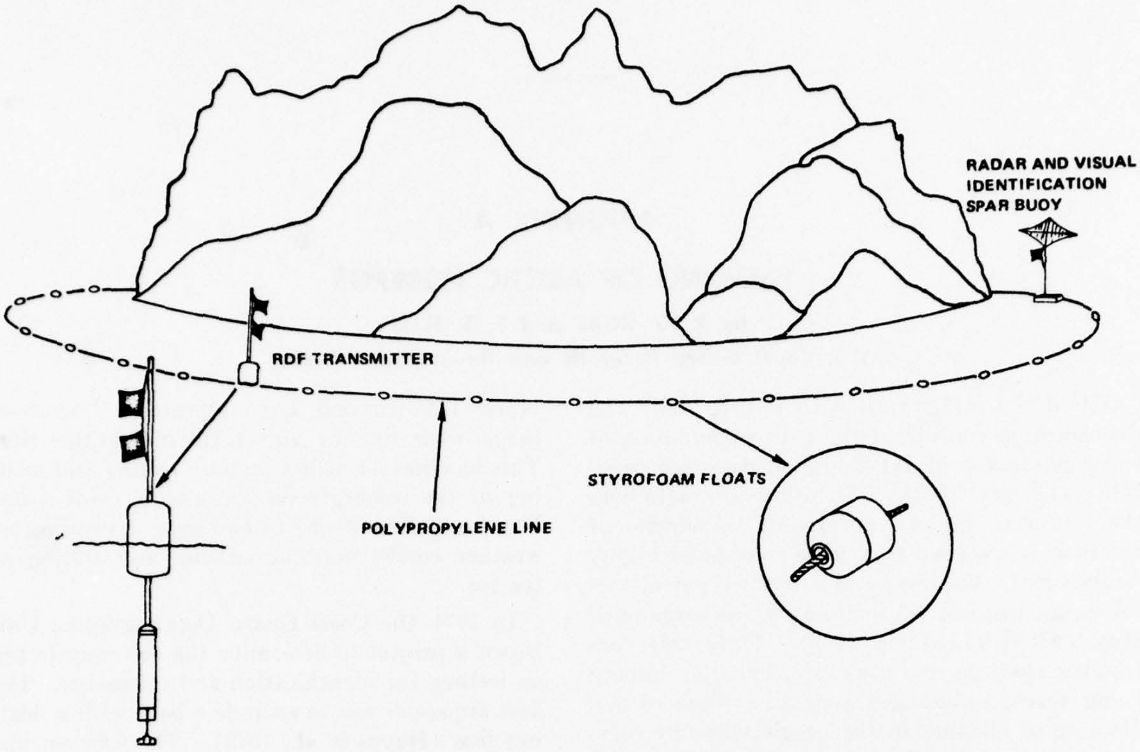


FIGURE A–1.—An Iceberg Tagging Scheme Using a Floating-Line Technique.

Coast Guard, he used a much heavier line (24mm polypropylene). Since the experiment was conducted at nearly 60°N, the icebergs could be expected to be more stable. The array was tracked using the NIMBUS–6 satellite system, but no attempt was made to verify whether the iceberg remained with the transmitter. The transmitter was not recovered.

The development of an instrument package which can be attached to an iceberg requires solutions to three problems; rolling, melting and calving. In 1975, the Coast Guard Research and Development Center tried a new approach to tethering an instrument package to a berg by using a large steel dart with a trailing line which attached to a floating instrument package. This solves the problem of rolling and melting, but not calving. It is not likely that any system can survive calving, since the anchoring piece of ice would drift away rapidly from the iceberg itself, or any conceivable line would be parted by the weight of several hundred tons of ice falling from the side of the berg.

The dart was designed by applying the relatively new branch of dynamics called terradynamics, which is the study of the forces acting on a body in relative motion to solid materials. After several trials, which included about two dozen drops, the present design was arrived at. The requirements were that it be easy to ship and assemble, cheap to build, and have stability and penetration for low altitude drops. The dart was manufactured from 5.72 cm cold rolled steel and 2.54 cm steel rod (Figures T–2 and A–3). It weighs 13.64 kg and has a 46 cm tail assembly of extruded high density polyethylene (Figure A–4).

Using the equations developed by Young (1972), it was possible to calculate the approximate depth of penetration of a steel dart in glacial ice. The empirical equation was:

$$D=0.0117\ K\ S\ N\ \sqrt{W/A}\ (V-30.48)$$

for impact velocities greater than 61 m/s. Where:

D = Depth of penetration, m
K = Scale factor, dimensionless
S = Index of penetrability, dimensionless
N = Nose performance coefficient, dimensionless
W = Dart weight, kg
A = Cross sectional area, cm^2
V = Impact velocity, m/s

The dart was attached to 300 meters of floatable polypropylene line with a small section of cable to reduce chafing. For a drop from 60 to 90 meters altitude, with this length the line is still leaving the aircraft after the dart has hit. This results in the line laying smoothly on the surface and with little or no pull on the instrument package. The instruments can then be allowed to free-fall or be lowered by parachute.

The line was originally placed on a faking board similar to those used with a Lyle lifesaving gun in the late 19th and early 20th centuries (Figure A-5) (Lyle, 1878). The board was mounted vertically on the lowered rear ramp of a C-130 aircraft in flight. Over 300 meters of line feed off the board in less than five seconds. Stress problems developed with the board concept when the bottom layers were reached. A much improved method of deploying the line was developed by Farmer (1977) (Figure A-6). The line was packed in bundles secured by rubber bands. All of the bundles were then placed in a parachute pack which was opened when the dart was thrown from the rear ramp of the C-130, thereby allowing the bundles to smoothly unravel one at a time. The instruments can then be launched just before the last of the bundles unravel.

A final instrument package has not been developed for the tagging system. In tests, we have used a modified sonobuoy as an expendable transmitter.

In addition to ten test drops on icebergs in 1975 and 1977, several tests of the system have been conducted over land at the Coast Guard Elizabeth City Air Station. Drops were made from 61 meters at an airspeed of 130 knots (67 m/s) and ice was assumed to have an index of penetrability of 2.5. The 1975 test gave a penetration of 1.1 meters and the 1977 test (Figure A-7) had a penetration of 0.76 meters. Other penetrations of the iceberg were not accessible from a small boat or were under water. Results are as follows:

(a) *Accuracy*—After several practice runs, pilots can hit an iceberg as small as 20 meters on a side 75 percent of the time from 61 or 91 meters altitude.

(b) *Line Handling*—The parachute pack line handling system developed by Farmer does a superior job of deploying large quantities of line without kinks or tangles.

(c) *Penetration*—The dart which was used in the tests on icebergs in 1975 and 1977 had a predicted penetration characteristic as given in Table 1 (Young, 1972).

(d) *Holding Strength*—The holding power of the 1977 test with 0.76 meter penetration exceeded the strength of a 1.25 cm polypropylene line which is approximately 5,000 pounds.

Further development of an expendable instrument package is planned, permitting the tracking of icebergs both from the surface and from satellite.

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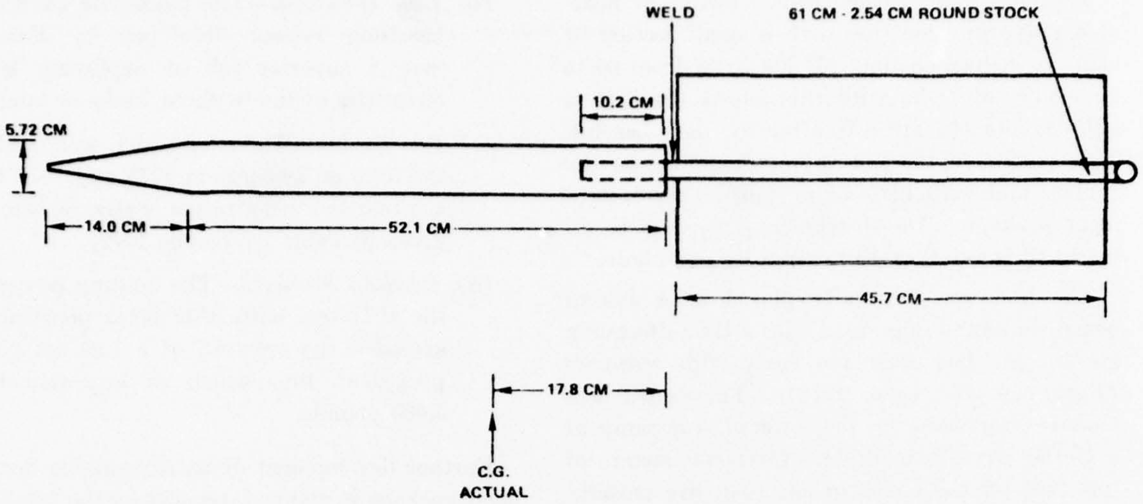

FIGURE A-2.—Iceberg Tethering Dart.

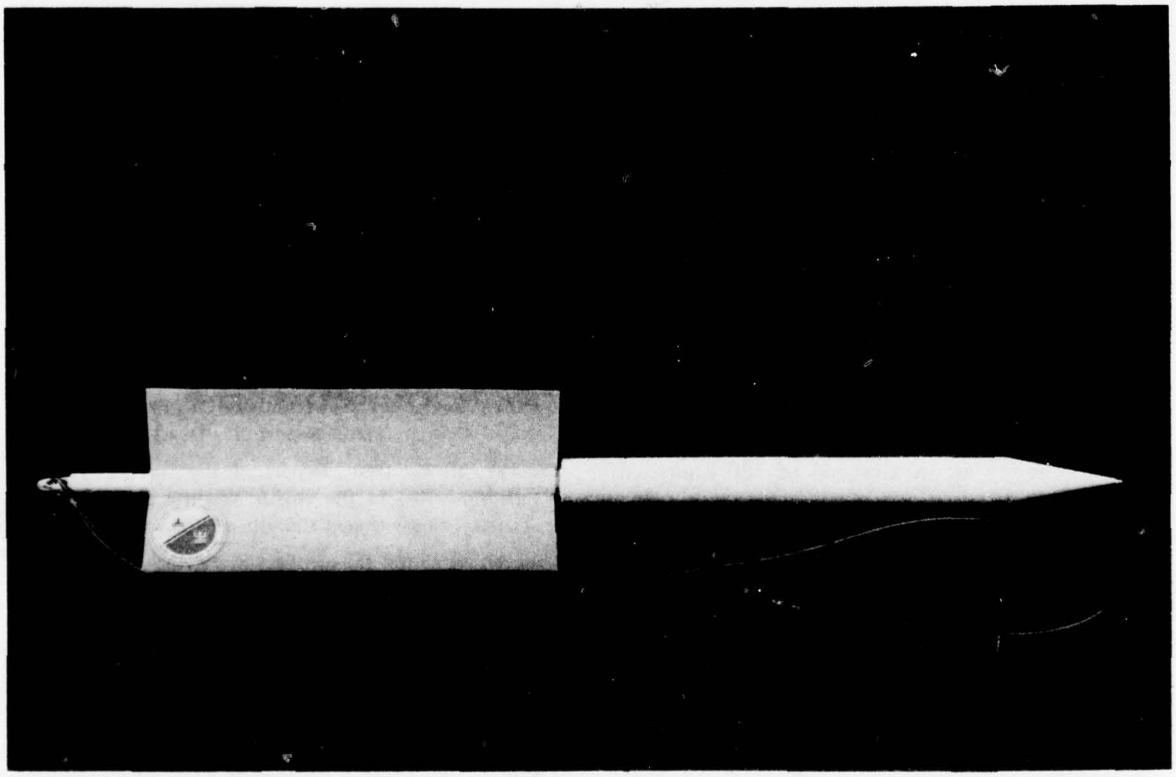

FIGURE A-3.—Iceberg Tethering Dart.

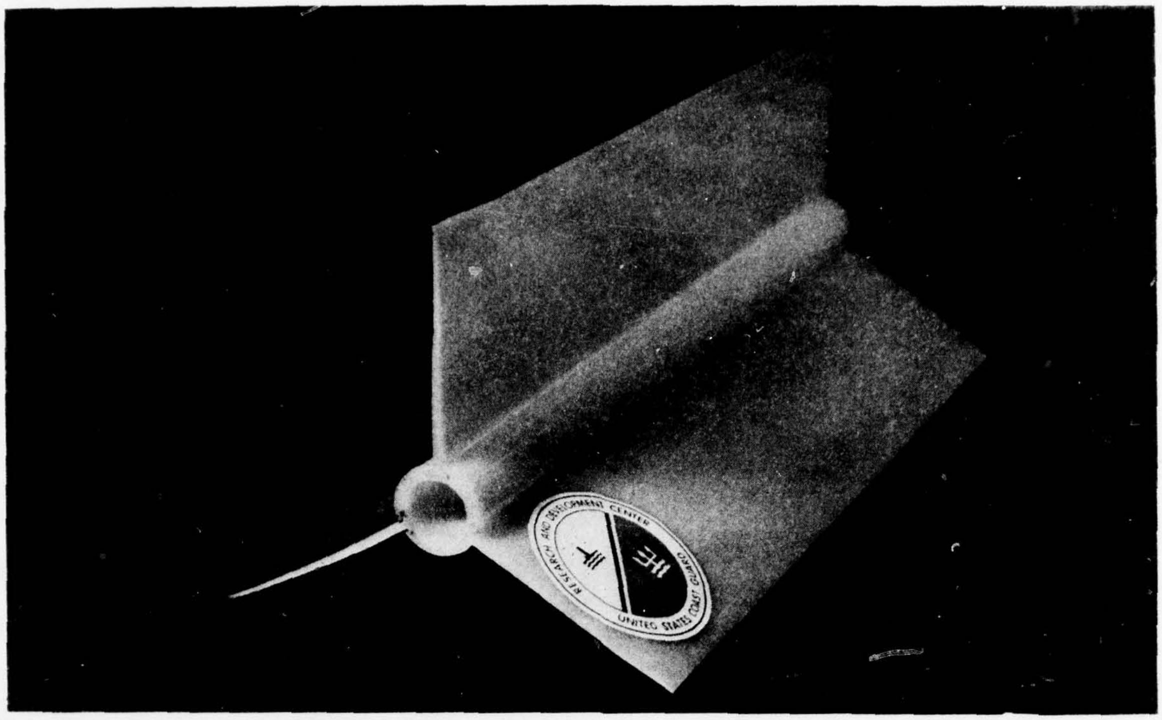

FIGURE A-4.—The Four Piece Extruded Iceberg—Tethering Dart Tail Assembly.

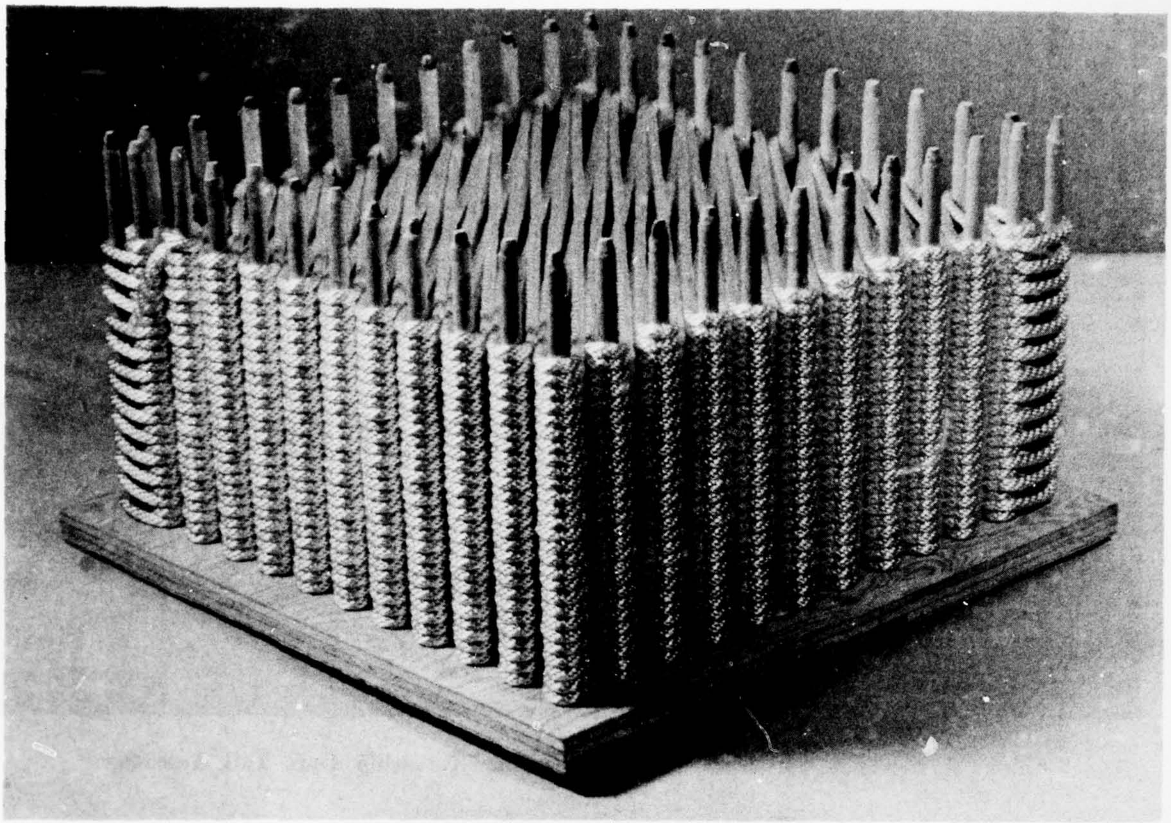

Figure A-5.—Line Faking Board.

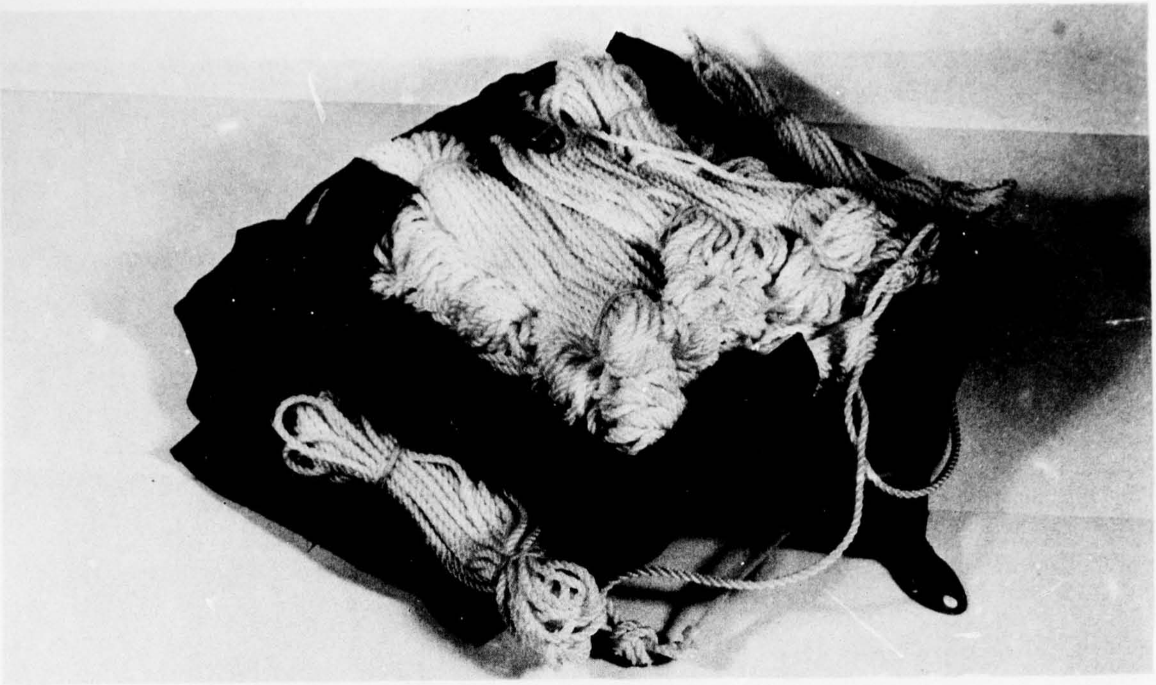

Figure A-6.—Trailing Line Pack.

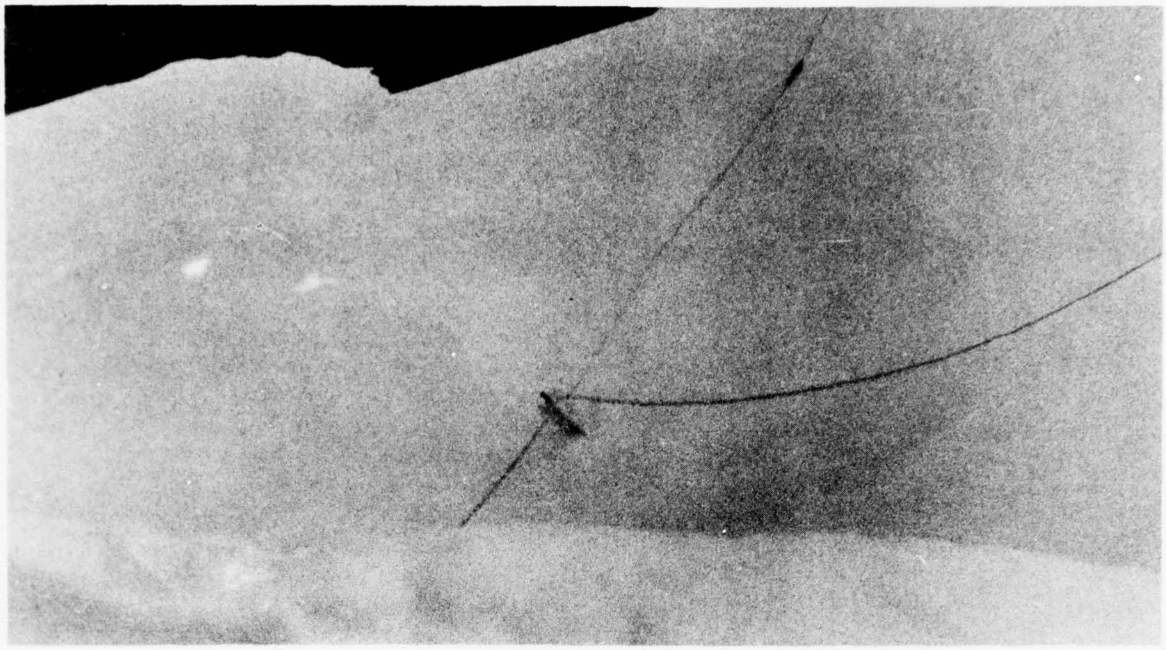

FIGURE A-7.—Iceberg Tethering Dart in the side of an Iceberg, 1975 Tests.

APPENDIX B

LABRADOR CURRENT COMPUTER MODEL

A report on completion of size expansion and suggested operational implementation

by Captain Ronald C. Kollmeyer, Ph.D., USCG

A hydrodynamic numerical predictive computer model of the Labrador Current off the Grand Banks of Newfoundland was completed and tested against collected data in 1974. This model had 4 layers with an area of one degree square of latitude. The region modeled was located at 43°51′N, 49°20′W. This model was further tested in June 1975. For these tests, the model successfully predicted the current induced environmental changes in temperature and salinity distribution for an eight day period.

Further work has been completed on the model (January-July 1977) in the form of larger area coverage, two degree square of latitude, and an increase to six layers. In addition, the model has been made ready for operational testing and use by International Ice Patrol by development of a data handling system that allows direct input of the vertical distribution of temperature and salinity from hydrographic casts. This work is reported on herein.

Successful predictions through model operation depend on the quantity of the collected input data points together with the degree of synopticity. The more closely spaced the hydrographic casts are in both space and time, the more correct will be the output results. For the newly developed larger area model, data collection from a surface vessel in the traditional manner (STD casts) is not sufficiently fast to provide for either the desired sampling density or the required synopticity. It is expected that eventual development by the Navy (NORDA, Bay St. Louis, Miss.) of the air deployable, expendable salinity/temperature/depth sensors will provide the suitable data suite required by the model. Prototype sensing probes are expected to be available by 1980/81 and possibly earlier.

The model predicts currents relative to the 1000 decibar isobaric surface (approximately 1000 meters depth). This isobaric level has been used for current calculations by IIP for the past 50 years. Evidence exists that the 1000 decibar level is itself in motion, and thus knowledge of this motion is needed as a model input to provide for absolute motion drift prediction. Data concerning the sea surface slope in the modeled area would provide the necessary information on which the model could base these absolute motion calculations. Eventually, the SEASAT B satellite may give us that information to the acceptable accuracy of 1 centimeter of elevation per 1 kilometer in the horizontal.

The Labrador Current Model now covers any selected area of the Grand Banks of Newfoundland. The model size compared to the overall problem area is shown in Figure B–1. The coverage is 120 x 120 nautical miles. There are six layers in the model, with thickness of 30, 40, 80, 150, 200 and 500 meters. The model is initiated by introducing a processed data set which is the output of a newly developed data handling program described in later paragraphs. This data set consists of 24,300 layer averaged temperature and salinity data points, 2025 points describing the bathymetry of the area modeled, the wind field (both present and expected during the model's predictive period), the position of the southwesternmost corner of the area modeled, and the commencement time of the predictive period. Upon commencement of model operation, the initial conditions of the current field are calculated and then recalculated each hour as time advances. The recalculations are based on the advection (movement) of the water and the mixing (interaction). These provide the steering mechanism that alters both the velocity and

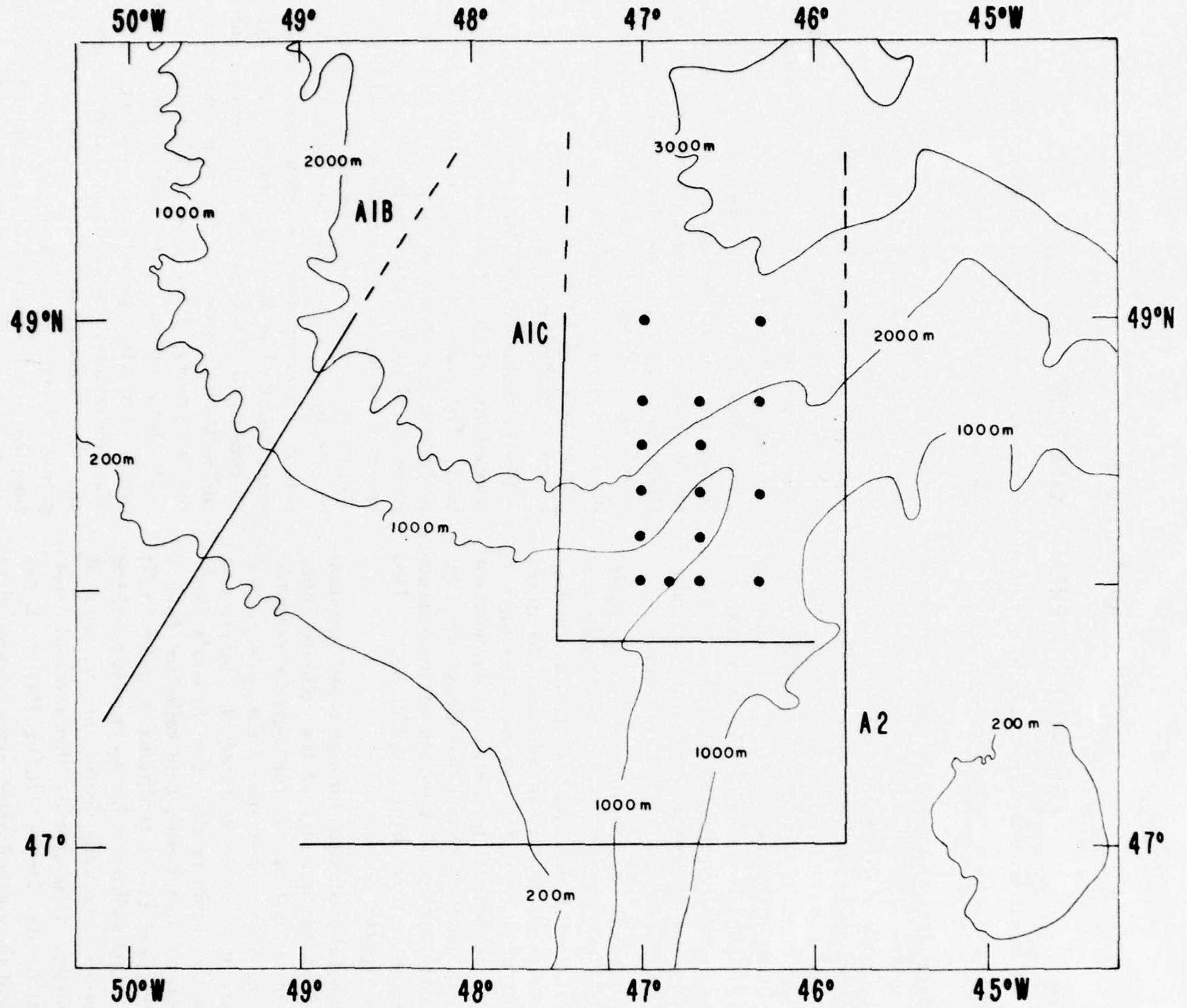

Figure B-1.—The area of primary concern to International Ice Patrol. Solid straight lines indicate Ice Patrol Standard Sections. Solid circles depict survey stations covering an area of the size used by the Labrador Current Model.

```
Southwest corner of model grid is 4351 N. Lat, 4920 W. Long
Prediction starts; MONTH   5  DAY  20  HR    1800  YR    1980
Time step = 3600.SEC   Grid size is 5 KM.
Layer No.     Layer Depths         Lateral Friction     Diffusion Coef.       Vertical Friction
    1          0 - 70 M.               0.3E 07            0.5E 05                 0.005
    2         30 - 70 M.               0.3E 07            0.5E 05                 0.005
    3         70 - 150 M.              0.1E 07            0.3E 05                 0.005
    4        150 - 300 M.              0.1E 07            0.1E 04                 0.005
    5        300 - 500 M.              0.1E 07            0.1E 03                 0.005
    6        500 - 1000 M.             0.1E 07            0.1E 03                 0.005
Vertical Friction Along Bottom/Water Interface is 0.010
```

FIGURE B-2.—Computer Output Heading of the Labrador Current Model.

direction of the current systems with time. Hourly current predictions are available and the model can be instructed as to the frequency of output desired. The output consists of the U and V vector velocities, temperature, and salinity distributions for each layer of the model. In addition, the density distribution of the layers may also be called out if desired. The initial heading of the model output lists such facts as the location of the area modeled, month/day/hour and year of the start of the predictive period, the time step, grid size and the various coefficients used by the model as shown in Figure B-2.

The model is presently being run on an IBM 360/370 computer at the University of Connecticut, Storrs, CT. A 10 day predictive run takes 608,000 words of core memory and will use approximately 95 minutes of Central Processor Unit (CPU) time.

An increase in predictive accuracy of the program can be realized through the boundary monitoring of the modeled area at certain critical locations. Additional data sampling across the Labrador Current and the Gulf Stream where they enter the modeled area will allow for increases in both predictive accuracy and length of prediction. The monitoring of boundaries, if done by air deployable probes every 8 to 10 days, could allow a probable predictive period of up to a month before re-initiation is necessary. The original one degree square model was tested successfully for up to eight days. This expanded model has not been tested against real data, so the length of the predictive period is only speculative at this time.

An extensive data handling system has been developed to speed the preparation of the data into a form which is directly usable by the model. For any given data collection survey, the region to be modeled is selected and the temperature/salinity/depth data are gathered throughout the region using some form of a continuous vertical sampling instrument. Data will generally be in the form of magnetic or punched tapes which contain individual station information. This includes the station number, latitude and longitude, water depth and the serial depth/temperature/salinity distributions. After some degree of quality control, generally in the form of either eyeball analysis or computer processing, a data set is produced. This data set may list depth/temperature/salinity distributions spaced as close as one meter from the surface to the bottom of the hydrographic cast. This quality controlled data set forms the input to the Data Processing Program which prepares the data for use by the Labrador Current Model.

Input data must be in the form of temperature and salinity vertical averages for each of the six model layers. In addition, these averaged values must also be located at each grid point of the model matrix (2025 grid points). The Data Processing Program takes the sampled data, positioned by latitude and longitude, calculates averages for the six layers at the sampled stations, locates these averages in the matrix grid system and proceeds to scale the data at all grid points based solely on those locations sampled and the bottom bathmetry. The program is constructed so that if only two sampled data points existed in any layer, a complete data field would be generated based on those two points. Obviously, the more sampled data, the more accurate will be the scaled data field. The scaling program uses a system developed by several Coast Guard Academy cadets and myself while working on 1975 model tests. This routine iterates for a maximum of 150 cycles or until the temperature and/or salinity data ceases to change by more than .01. The number of iterations used is printed out for both temperature and salinity and for each layer for quality control.

When the sampled data are initially entered into the Data Processing Program, the location of the area to be modeled is also entered. The sampled data locations are checked and are discarded if they lie more than 5 km outside the desired model area. The program gives as a printout; model location, a list of stations used showing their number, grid location, and latitude and longitude. Following this output is the bathymetric data for the area modeled. The next series of outputs is supplied sequentially for each layer: the base matrix indicating the intersection of the continental shelf or the location of open boundaries; location and value of the sampled temperature averaged over the layer followed by a similar one for salinity; the number of iterations used to complete the scaling process; the properly formated data for model input (first temperature then salinity); and lastly a complete temperature and salinity data matrix for that layer which can be quickly scanned or contoured for quality control. The program is presently being run on a UNIVAC 1108 at the Underwater Systems Center, New London, CT. It requires less than 50,000 words of core memory and can be run in less than 15 minutes of CPU time.

A complete system for determination and prediction of the Labrador Current is envisioned as a future goal. This would include the air deployable expendable conductivity-temperature-depth probes under development by the Navy. These instruments could supply sufficient data from the area to be modeled in a timely manner. A peripheral quality control program could ready this raw data for input into the primary Data Processing Program, which could have available to it as a data bank, the complete bathymetry of the Grand Banks region and upon command select the proper bathymetric input for the desired model location. This data program would then produce a complete data set for input into the main model program. At this same time, present and predicted winds would be entered along with satellite information concerning the slope of the sea surface. The model could then produce predictions of the absolute current system which would be valid for up to 10 days, i.e., flights updating data of the boundaries where the Labrador and the Gulf Stream enter the model would be required for extended predictions. These would consist of short flights using the air deployable data probes to check on the location, salinity and temperatures of the major currents entering the modeled area. A summary of this IIP Labrador Current Determination System is shown in Figure B–3. The shaded area reflects the work which has already been accomplished. Completion of the other parts of the system must wait for the technology to develop. However, the bathymetric data bank for the entire region could be prepared at this time to facilitate present use of the model as a substitute for the Dynamic Height method used by IIP.

Further model development possibilities have emerged in the form of vorticity modeling work

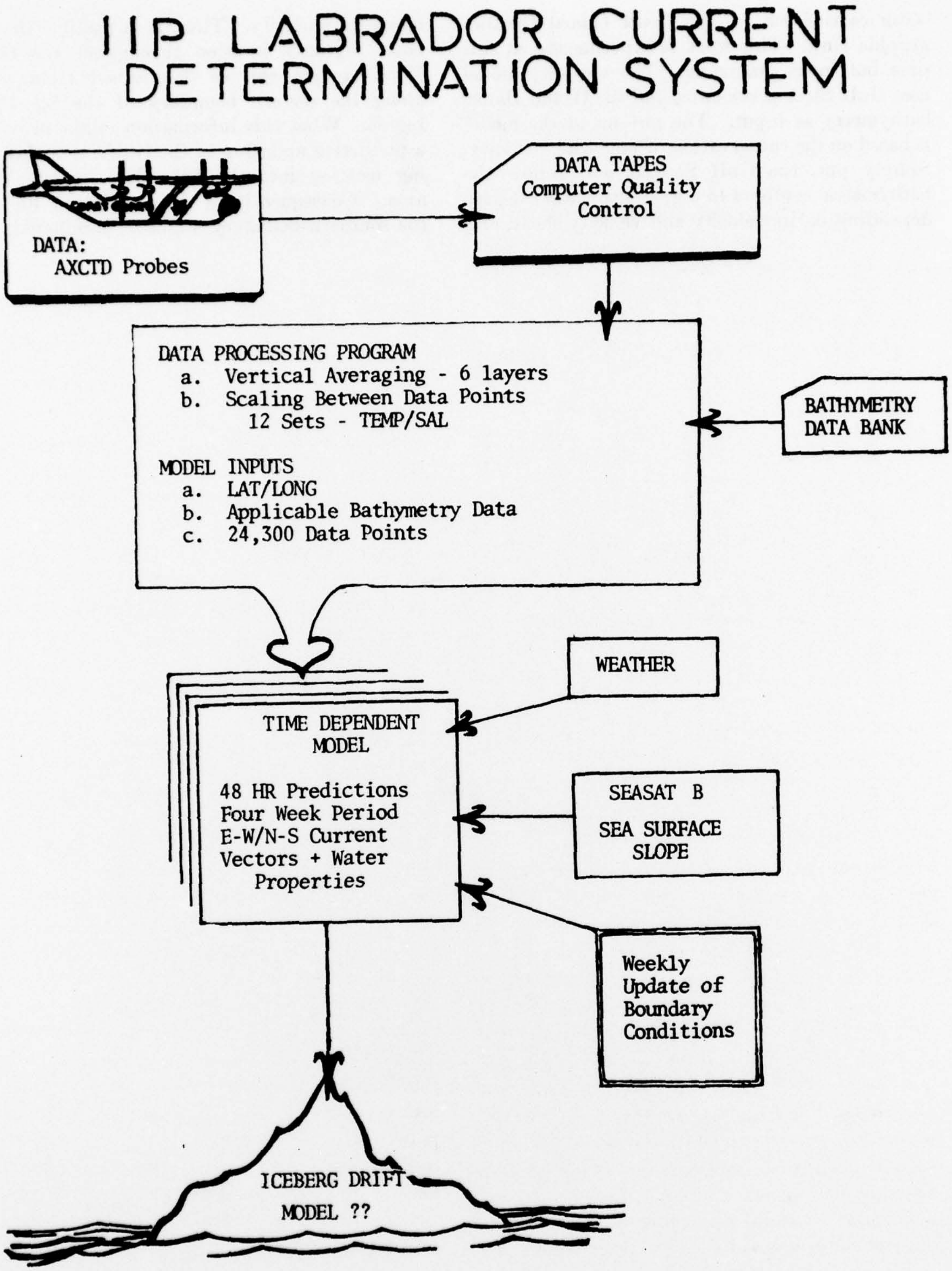

FIGURE B-3.—A suggested CIIP current determination system for the prediction of absolute currents in the Ice Patrol area. The shaded portions of the system have been completed.

being carried out by the Coast Guard Oceanographic Unit. This work is experimental at this time but looks promising. The vorticity model uses Gulf Stream velocities and the Grand Banks bathymetry as input. The physics of the model is based on the conservation of potential vorticity. Simply put, the Gulf Stream will follow the bathymetric contours to a greater or lesser degree depending on its velocity and velocity shear, and hence its vorticity. Thus, it is possible that the Gulf Stream's location throughout the Grand Banks region can be determined from points along the eastern boundary of the Ice Patrol region. What this information might provide is a predictive updating of the Gulf Stream's entering location into the Labrador Current Model area. Consequently, a data updating flight to the southern boundary might be eliminated.

APPENDIX C

ICEBERG POPULATIONS SOUTH OF 48°N SINCE 1900

by Lieutenant H. Gregory KETCHEN, USCG

International Ice Patrol has traditionally maintained counts of the number of icebergs crossing latitude 48° North. Icebergs south of this latitude are at best a potential and at worst a real hazard to the safety of primary North Atlantic shipping.

Table C-1 provides a breakdown by month of the estimated number of bergs crossing 48°N since 1900. This is an update of and provides some corrections to the table last published in the 1968 Ice Patrol Bulletin No. 54. The counts are broken down into two groups, 1900 through 1977 and 1946 through 1977. This separation is done because after World War II, aircraft reconnaissance became the primary method used by IIP for locating and tracking icebergs. Prior to that time, iceberg distributions were determined from surface observations made from Coast Guard cutters patrolling the southern limit of icebergs plus sightings by merchant and fishing vessels transiting the area. Since aerial coverage proved to be much more complete and frequent, data collected subsequent to 1945 represent more accurate counts.

Figure C-1 is a bar graph of the estimated numbers of icebergs crossing 48°N during each year since 1900. The variability in the record is obvious, with counts ranging from 0 bergs in 1966 to 1,587 in 1972. Monthly average counts for the full record and for recent years are depicted in figure C-2. Although a good indicator of relative importance of a particular month, those averages are biased by the high counts of a few extremely severe years. A better figure for the number of icebergs that might be expected to cross 48°N in a "typical" year is provided by the median of the counts. For the period 1900 through 1977 the median of the annual iceberg counts is 279, while the average is 383. For the period 1946 through 1977, the corresponding median is 107 while the average is 300.

Further analysis of the variability of iceberg distributions is provided in an article by C. W. Morgan titled "Long Term Trends in the Iceberg Threat in the Northwest Atlantic" published in the 1971 Ice Patrol Bulletin No. 57.

Season	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	TOTAL
1900	0	0	0	0	10	0	0	5	32	33	6	1	87
1901	1	1	0	0	1	0	0	4	13	29	22	6	77
1902	5	1	2	5	3	0	1	1	13	5	16	1	53
1903	0	1	0	0	0	2	400	166	151	52	23	7	802
1904	0	0	0	1	0	0	12	63	82	89	14	3	264
1905	2	0	0	0	3	2	168	373	109	100	50	9	816
1906	8	8	0	15	14	11	77	49	133	87	18	16	436
1907	0	0	0	0	0	1	11	162	248	138	64	11	635
1908	0	0	0	3	1	0	7	39	82	51	2	2	187
1909	20	15	3	0	0	55	147	134	321	181	121	45	1,042
1910	19	1	0	0	0	0	0	34	10	3	3	0	70
1911	0	0	0	0	0	8	41	112	72	77	21	40	371
1912	3	0	8	14	1	0	34	395	345	159	63	19	1,041
1913	0	0	3	0	2	4	37	109	292	71	14	4	536
1914	7	0	6	4	1	41	32	27	419	71	22	46	676
1915	52	13	1	6	14	72	67	96	97	71	28	17	534
1916	5	0	1	0	0	0	0	0	25	29	0	0	60
1917	0	0	0	0	0	0	13	3	3	9	10	0	38
1918	0	0	0	0	0	0	12	23	26	37	27	34	159
1919	22	1	14	3	3	4	5	25	75	56	26	36	270
1920	69	2	12	4	6	43	20	5	211	86	18	5	481
1921	18	19	10	4	17	5	43	210	198	175	53	24	776
1922	4	10	1	6	0	3	35	71	245	83	21	11	490
1923	6	27	21	0	0	3	28	65	83	42	10	3	288
1924	2	0	0	0	3	0	6	2	0	0	0	0	13
1925	0	0	0	0	0	3	5	8	58	22	13	0	109
1926	0	0	0	0	0	3	15	58	168	85	4	6	339
1927	2	3	1	0	4	10	26	93	153	95	5	3	395
1928	0	0	0	0	0	0	14	156	190	87	55	5	507
1929	0	4	4	0	0	0	45	332	460	376	107	1	1,329

TABLE C–1.—Estimated Monthly and Annual Counts and Averages of icebergs crossing 48°N latitude during the years 1900–1977.

Season	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	TOTAL
1930	0	0	18	12	14	116	87	89	101	62	3	1	503
1931	1	1	0	0	0	0	2	1	10	0	0	0	15
1932	0	0	0	0	0	1	43	321	90	58	1	0	514
1933	0	0	0	0	0	2	4	12	162	36	0	0	216
1934	0	0	0	0	1	0	0	245	228	87	14	1	576
1935	0	0	0	0	0	0	46	177	501	134	11	3	872
1936	0	0	0	3	0	0	0	8	14	0	0	0	25
1937	0	0	0	0	20	53	121	124	137	14	1	0	470
1938	0	0	0	0	2	3	38	212	286	110	13	0	664
1939	0	0	0	0	0	0	22	173	471	150	28	6	850
1940	0	0	0	0	0	0	0	0	1	0	0	0	1
1941	0	0	1	0	0	0	0	1	1	0	0	0	3
1942	0	0	0	0	0	0	30	0	0	0	0	0	30
1943	0	0	0	0	0	0	25	90	298	270	150	7	840
1944	0	0	0	0	0	0	31	319	213	106	30	1	700
1945	0	0	0	0	0	6	352	253	256	92	109	15	1,083
Total 1900-45	246	107	106	80	120	451	2,102	4,845	7,083	3,518	1,196	389	20,243
Average 1900-45	5	2	2	2	3	10	46	105	154	77	26	8	440
1946	0	0	0	0	0	2	67	98	168	88	7	0	430
1947	0	0	0	0	3	1	2	5	11	26	15	0	63
1948	0	0	0	0	0	0	60	210	185	68	0	0	523
1949	0	0	0	0	0	0	1	23	20	3	0	0	47
1950	0	0	0	0	0	12	61	183	135	58	7	0	456
1951	1	1	2	0	0	3	2	0	0	0	0	0	9
1952	0	0	0	1	0	0	0	12	2	0	0	0	15
1953	0	0	0	0	0	0	21	11	18	6	0	0	56
1954	0	0	0	0	1	16	47	165	65	16	2	0	312
1955	0	0	0	0	0	0	10	32	14	5	0	0	61

Season	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	TOTAL	
1956	0	0	0	0	0	0	9	13	34	21	3	0	80	
1957	0	0	0	0	3	43	41	172	265	288	113	6	931	
1958	0	0	0	0	0	0	0	0	0	0	1	0	1	
1959	0	0	0	0	0	0	14	266	180	186	43	0	689	
1960	0	0	2	3	3	0	0	41	161	44	4	0	258	
1961	0	0	0	0	0	6	60	30	16	1	0	1	114	
1962	0	1	0	1	0	0	14	72	21	10	3	0	122	
1963	0	0	0	0	0	0	4	20	0	1	0	0	25	
1964	0	0	0	0	0	3	88	225	19	28	5	1	369	
1965	0	0	0	0	0	1	19	33	22	1	0	0	76	
1966	0	0	0	0	0	0	0	0	0	0	0	0	0	
1967	0	0	0	0	0	0	25	134	209	65	8	0	441	
1968	0	0	0	0	0	0	0	104	44	60	14	4	226	
1969	4	0	0	0	0	0	0	0	35	17	1	0	57	
1970	0	0	0	0	0	0	0	5	2	70	8	0	85	
1971	0	0	0	0	0	0	31	4	20	7	11	0	73	
1972	0	0	0	0	0	40	185	501	559	225	48	26	1,584	(1,587)
1973	4*	0	0	6	54	110	134	212	159	151	19	1	850	(847)
1974	0	0	0	0	0	1	99	345	446	266	168	61	1,386	
1975	1	0	0	0	0	24	41	10	20	5	0	0	101	
1976	0	0	0	0	0	0	33	13	67	35	3	0	151	
1977	0	0	0	0	0	3	7	12	0	0	0	0	22	
Total 1946-77	10	2	4	11	64	265	1,075	2,951	2,897	1,751	483	100	9,613	
Average 1946-1977	0	0	0	0	2	8	34	92	91	55	15	3	300	
Total 1900-1977	256	109	110	91	184	716	3,177	7,796	9,980	5,269	1,679	489	29,856	
Average 1900-1977	3	1	1	1	2	9	41	100	128	68	22	6	383	

*The 1972 Season ended on September 4th. Three of these bergs actually drifted south of 48°N during the 1972 Ice Season. To provide statistical continuity they are included in the September monthly tabulation for the 1973 Ice Season.

Note:

1. Totals for 1900-45 are based mainly on ship reports.
2. Totals for 1946-1977 are based mainly on Ice Patrol aircraft reconnaissance.
3. Monthly estimates for the years 1939 and 1944 have been adjusted to reflect the total annual berg estimates as reported in the Bulletins for these years.

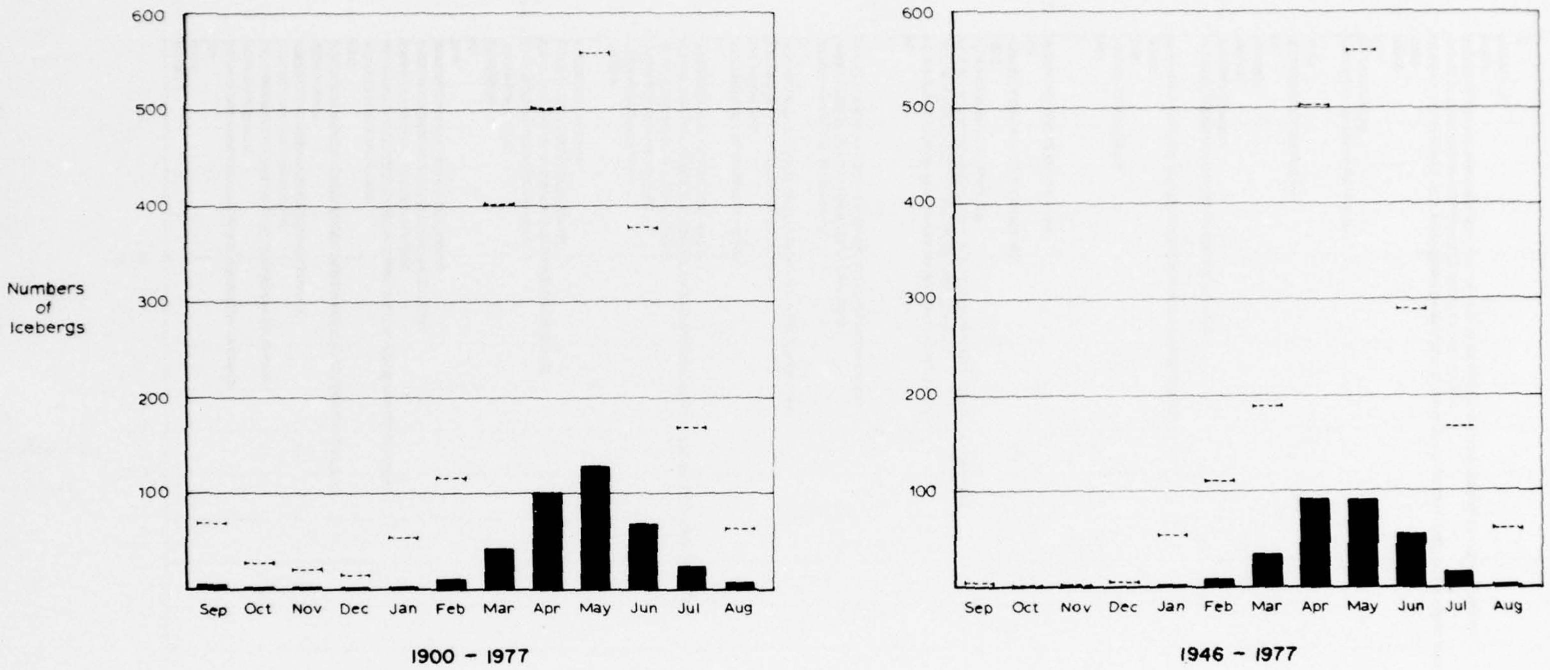

FIGURE C-2.—Monthly averaged number of icebergs crossing 48°N latitude for the two periods—1900 to 1977 and 1946 to 1977. The dashed lines indicate the most crossings for each month during the two periods. A record of 559 icebergs crossed 48°N during May 1972.

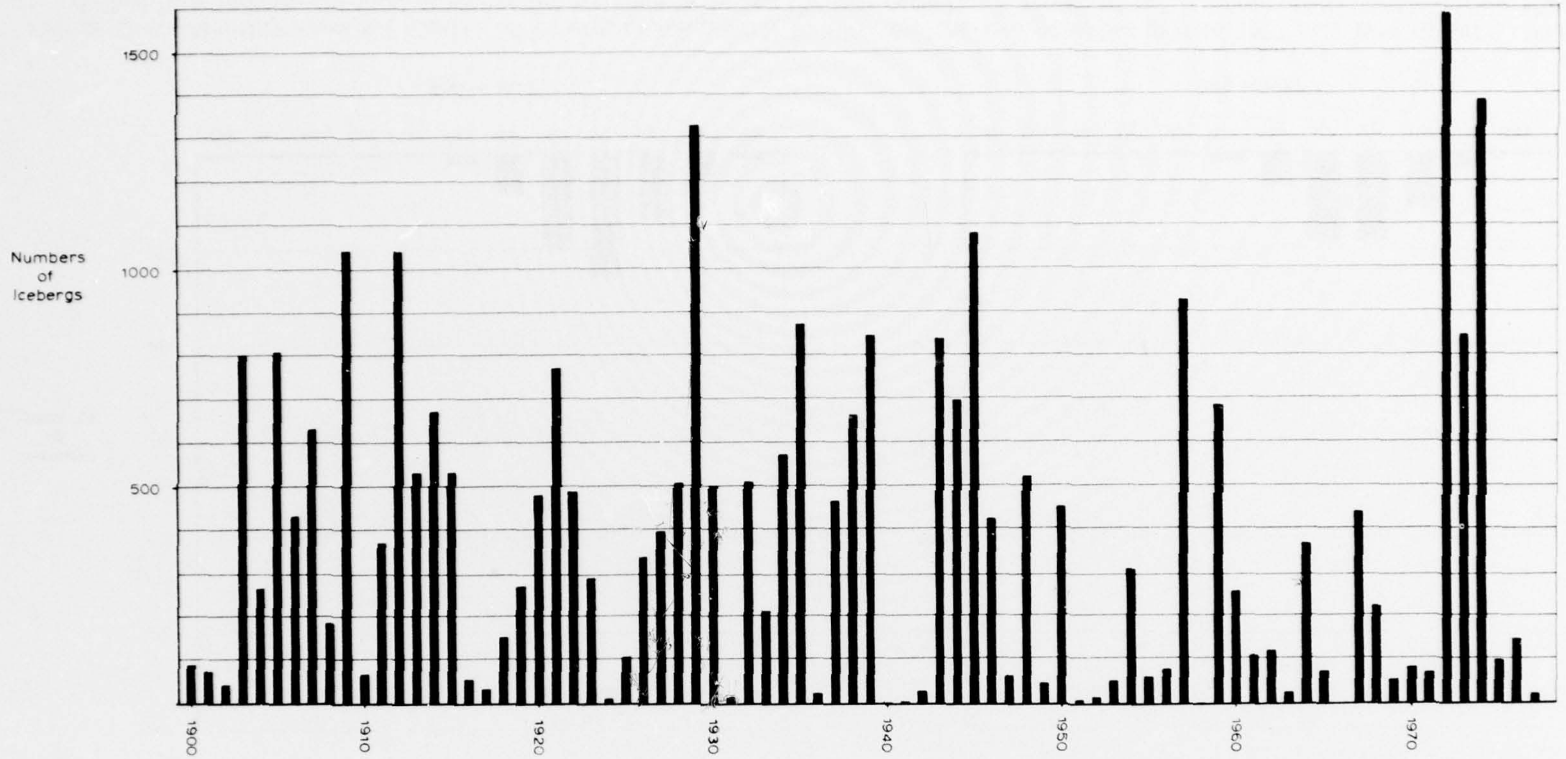

Figure C–1.—Estimated Numbers of Icebergs having crossed 48°N latitude during the years 1900 to 1977. The average for this record is 383 icebergs and the median is 279.

APPENDIX D

UNUSUAL ICEBERG SIGHTING

by Lieutenant H. Gregory KETCHEN, USCG
and
Marine Science Technician First Class R. N. HILDENBRAND, USCG

Icebergs are carried into the North Atlantic Ocean on the cold waters of the southward flowing Labrador Current arriving on the Grand Banks off Newfoundland during the spring of the year. The icebergs that reach these latitudes have survived a drift in excess of 1000 miles—most having originated from west Greenland glaciers north of 69°N. As these bergs approach the major shipping lanes south of 48°N, they present a serious threat to trans-Atlantic shipping. The danger near the Grand Banks is increased by a number of factors including: the large volume of vessel traffic passing through this area, the high density of fishing vessels working these very productive fisheries, and the frequent occurrence of fog and intense storms typical of the area.

The southerly drift of most of these icebergs ends with their final deterioration in the warm waters of the North Atlantic Current. This current, running along the southern and off the eastern edges of Grand Banks, serves as a barrier preventing the further distribution of icebergs throughout the North Atlantic Ocean. Occasionally, under the right environmental conditions, some icebergs survive to drift through the North Atlantic Current reaching positions far from those expected to be the normal maximum drift limits. The Ice Patrol has maintained a record of most of the unusual ice sightings reported during this century and a few earlier reports. Figure D–1 shows the maximum mean iceberg limit and reported unusual iceberg sightings. Not all of these reports were confirmed. A few of them may have been sightings of objects mistakenly identified as ice or the positions erroneously recorded. Enough of the sightings were verified to show that on rare occasions icebergs can reach far beyond the normal limits.

Although the International Ice Patrol's area of responsibility is limited to the vicinity of the Grand Banks off Newfoundland, it maintains an interest in iceberg information and sightings from throughout the world. Mariners are encouraged to report any significant or unusual ice sightings to the Ice Patrol.

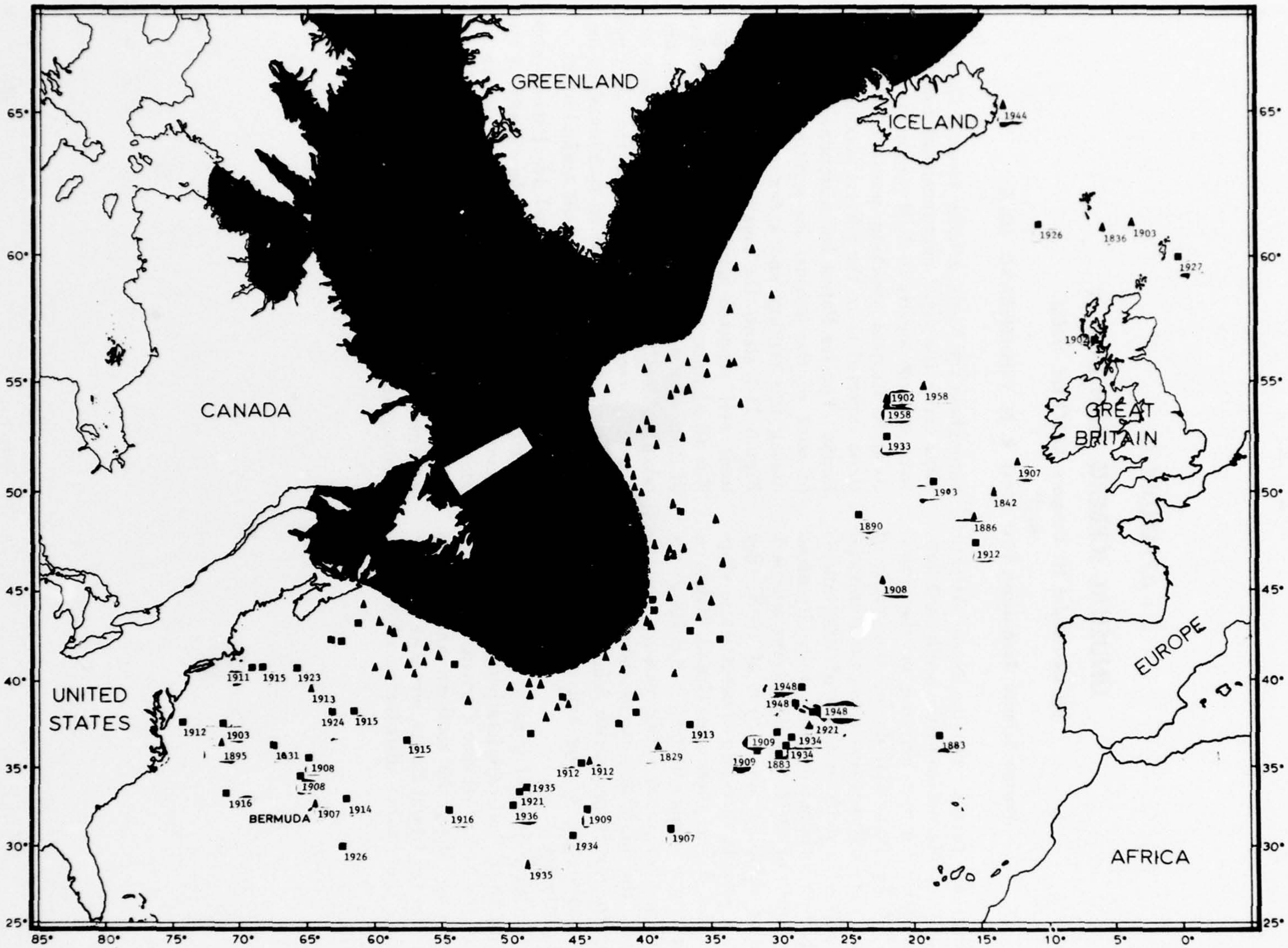

Figure D-1.—Maximum Mean Iceberg Limit and Reported Unusual Iceberg Sightings.

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16. Abstract

The 1977 International Ice Patrol Service in the North Atlantic Ocean was conducted by the United States Coast Guard under the provisions of Title 46 United States Code, Sections 738, 738a through 738d, and the International Convention for the Safety of Life at Sea, 1960, Regulations 5 through 8. The International Ice Patrol is a service for observing and dissiminating information on ice conditions in the Grand Banks Region of the Northwest Atlantic Ocean. During the ice season, the southeastern, southern and southwestern limits of the regions of icebergs in the vicinity of the Grand Banks of Newfoundland are guarded for the purpose of informing passing ships of the extent of this dangerous region. The International Ice Patrol also studies ice conditions in general with emphasis on the formation, drift and deterioration of icebergs, and assists ships and personnel requiring aid within the limits of operation of the Ice Patrol forces.

The International Ice Patrol is directed from the Ice Patrol Office located at the U.S. Coast Guard Base, Governors Island, New York. The Office gathers ice and environmental data from a variety of sources, maintains an ice plot, forecasts ice conditions, prepares the twice-daily Ice Bulletin, replies to requests for special ice information, and executes operational control of the Aerial Ice Reconnaissance Detachment, the Ice Patrol oceanographic cutter, and the Surface Patrol cutter when assigned.

contd.

17. Key Words
Ice Patrol, North Atlantic Ocean
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Abstract contd.

Vice Admiral William F. REA III, U.S. Coast Guard, was Commander, International Ice Patrol. Commander Albert D. SUPER, U.S. Coast Guard, was directly responsible for the management of the Patrol.

Preseason Ice Patrol flights were made in January and late February-early March 1977. The Aerial Ice Reconnaissance Detachment was deployed to St. John's, Newfoundland, on 15 March 1977. The Detachment returned to the United States on 22 June 1977, after completion of a Post Season flight on 21 June 1977.

The 1977 Ice Season officially commenced at 0000 GMT, 13 March 1977, when the first Ice Bulletin was broadcast by International Ice Patrol Radio Station Boston/NIK; U.S. Navy LCMP Broadcast Radio Stations Norfolk/NAM; Canadian Maritime Command Radio Station Mill Cove/CFH; and Canadian Coast Guard Radio Station St. John's/VON. Ice Patrol Radio Station Boston broascast an ice radio facsimile chart once a day.

The USCGC EVERGREEN, commanded by Lieutenant Commander Joseph H. DISCENZA, USCG, conducted oceanographic cruises for the Ice Patrol from 1 April to 1 May and 23 May to 28 June 1977.

During the 1977 season, an estimated 22 icebergs drifted south of 48 degrees North.