COAST GUARD

BULLETIN NO. 56

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

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SEASON OF 1970

CG-188-25

NOTE

Report of the International Ice Patrol Service in the North Atlantic Ocean, Season of 1968, CG–188–23, and *Report of the International Ice Patrol Service in the North Atlantic Ocean*, Season of 1966, CG–188–21, incorrectly report the iceberg counts for the season of 1960. The correct count for the season of 1960 should be as given below.

Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
0	0	2	3	3	0	0	33	54	44	4	0	143

The report for 1968 also reports the 1900–1968 May average iceberg count as 24.0. This figure should be 124.0. New totals and averages reflecting the corrected 1960 data are included in this report.

Figure 16D of *Report of the International Ice Patrol Service in the North Atlantic Ocean*, Season of 1969, CG–188–24, is incorrectly labeled. The charts labeled "Normal May" and "May 1969" should have been labeled "Normal June" and "June 1969." Similarly, the two charts labeled June should have been labeled May.

DEPARTMENT OF TRANSPORTATION

UNITED STATES COAST GUARD

Address reply to:
Commandant (OMS)
U.S. Coast Guard
Washington, D.C.
20590

28 September 1971

Transmitted herewith is *Report of the International Ice Patrol Service in the North Atlantic Ocean, Season of 1970.*

R. E. Hammond
Chief, Office of Operations.

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PREFACE

This report is 56th 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, on ice and environmental conditions and their relationship in 1970, and an analysis of preseason iceberg surveys made by the U.S. Coast Guard since 1948.

The authors of the report acknowledge ice and weather data supplied by the Canadian Department of Transport, weather data supplied by the U.S. National Weather Service, and oceanographic data supplied by the U.S. Coast Guard Oceanographic Unit. Acknowledgement is also made to Yeoman Second Class Roy J. MOFFETT, USCG, Marine Science Technician Third Class John D. JENNE, USCG, and Marine Science Technician Third Class Robert O. LAPREY, USCG, for assistance in the preparation of the manuscript and illustrations for this report.

INTERNATIONAL ICE PATROL, 1970

The 1970 International Ice Patrol Service in the North Atlantic Ocean was conducted by the U.S. 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 North Atlantic. 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, and affords assistance to ships and crews requiring aid within the limits of operation of Ice Patrol forces.

The International Ice Patrol is directed from the Ice Patrol Office located on U.S. Coast Guard Base, Governors Island, New York. The Ice Patrol Office gathers ice and other environmental reports from various sources, maintains an ice plot, forecasts ice conditions, prepares the Ice Bulletin, answers requests for special ice information, and maintains operations control of the Ice Reconnaissance Detachment, the Ice Patrol oceanographic ship and the Surface Patrol ship when assigned.

Responsibility as Commander, International Ice Patrol, was held as indicated below:

Rear Admiral Mark A. WHALEN, USCG —until 1 June 1970

Captain James M. McLAUGHLIN, USCG 1–29 June 1970.

Rear Admiral Benjamin F. ENGEL, USCG —after 29 June 1970

Commander James R. KELLY, USCG, was directly responsible for the management of the Patrol.

Preseason Ice Patrol flights were made in September and December, 1969, and in January, February, and March, 1970. In February 1970, the Ice Patrol was notified that the U.S. Naval Station at Argentia, Newfoundland, would be "phased down" in the spring of 1970. In the past the station had been the site of Ice Patrol Radio Station NIK and the airfield from which the Ice Reconnaissance Detachment operated.

The Ice Reconnaissance Detachment deployed to Argentia on 17 March, then redeployed to Canadian Forces Base Summerside, Prince Edward Island, on 30 April. The detachment returned to the United States on 24 July.

The 1970 ice season officially commenced at 0000 GMT 24 March when the first Ice Bulletin was issued, and continued until 25 July. The twice daily Ice Bulletin was broadcast by International Ice Patrol Radio Station, Boston/NIK, U.S. Naval Radio Station, Washington/NSS, Canadian Forces Radio Station, Mill Cove/CFH, and Canadian Coastal Radio Station, St. Johns/VON. Commencing 11 June the Ice Bulletin was included on the U.S. Marine Information Broadcast for the High Seas of the North Atlantic, a voice broadcast. The facsimile ice chart was unable to be transmitted during the 1970 season.

The USCGC *Evergreen*, commanded by Lieutenant Commander Robert E. PHELPS, USCG, conducted oceanographic cruises for the Ice Patrol during the periods 1–27 April, and 13 May–6 June. For the eleventh consecutive year it was unnecessary to use a surface patrol ship.

During the 1970 season 85 icebergs drifted south of 48N, a relatively light season.

AERIAL ICE RECONNAISSANCE

During the period 1 September 1969 to 31 August 1970, a total of 78 ice observation flights were made. Preseason flights made in September, December, January, February, and March accounted for 18 flights, and 60 flights made during the season accounted for the remainder. The purpose of the preseason flights was to study iceberg distribution patterns in Baffin Bay and the Labrador Sea, and to evaluate the iceberg potential of the developing ice season. The purpose of the flights during the season was to guard the southeastern, southern, and southwestern limits of icebergs, to evaluate the short term iceberg potential of the waters immediately north of the Grand Banks, and occasionally to study the iceberg distribution along the Labrador coast. Flight statistics are shown in table 1, and are exclusive of time required to deploy from U.S. Coast Guard Air Station, Elizabeth City, to the operating base.

Aerial ice reconnaissance was accomplished by U.S. Coast Guard Lockheed HC130B aircraft from the U.S. Coast Guard Air Station at Elizabeth City, North Carolina. During the preseason flights the aircraft operated from U.S. Naval Station Argentia, Newfoundland; U.S. Air Force Base Goose Bay, Labrador; U.S. Air Force Base Sondrestrom, Greenland; and U.S. Air Force Base Thule, Greenland. During the iceberg season Ice Patrol aircraft have in the past operated from U.S. Naval Station Argentia, however in February 1970 it was announced that operations there were to be phased down, and it became necessary to locate another airfield from which to operate, thus terminating the long and fruitful association of the International Ice Patrol with the Naval Station. This association dates back to the postwar reactivation of the International Ice Patrol in 1946 when two U.S. Coast Guard PB4Y-1 Liberators, based at the U.S. Naval Operating Base, Argentia, became the first Ice Patrol reconnaissance aircraft.

Table 1.—Aerial Ice Reconnaissance Statistics—September 1969 August 1970

Month	Number of flights	Flight hours
PRESEASON		
September	5	30.9
October	0	0
November	0	0
December	3	20.0
January	3	15.0
February	2	12.3
March (through 23d)	5	25.4
Preseason totals	18	103.6
SEASON		
March (from 24th)	5	24.3
April	17	96.9
May	15	105.1
June	14	84.5
July (through 24th)	9	61.9
Season totals	60	372.7
POSTSEASON		
July (from 25th)	0	0
August	0	0
Postseason totals	0	0
Annual totals	78	476.3

After consideration of several alternatives it was decided to operate from the Naval Station in 1970 until instrument landing facilities were discontinued, and then to deploy to Canadian Forces Base Summerside, Prince Edward Island, for the remainder of the season.

On 17 March the Ice Reconnaissance Detachment deployed to Argentia from Elizabeth City and operated there until 30 April when the move was made to Summerside. Summerside, approximately 500 miles west of the Grand Banks, was the operating base for the Ice Reconnaissance Detachment until 24 July when it returned to the United States.

The generosity and cooperation of the Canadian Forces in permitting the International Ice Patrol to operate from their base at Summerside is gratefully acknowledged. In spite of the distance from the patrol area Ice Patrol operations were conducted smoothly from Summerside. This was certainly due in large measure to the excellent logistic and communication support provided by the Canadian Forces, as well as their efforts to make the Ice Patrol feel genuinely welcome.

COMMUNICATIONS

Ice Patrol communications included reports of ice and environmental conditions, Ice Bulletins, voice broadcasts, and administrative traffic necessary to operate the patrol. The Ice Bulletin was disseminated by teletype from the Ice Patrol office in New York to about 28 addresses, including the Naval Oceanographic Office, the Canadian Department of Transport, the British Admiralty, and cooperating radio stations. International Ice Patrol Ice Bulletins were broadcast twice daily by Coast Guard Radio Station, Boston/NMF/NIK, U.S. Naval Radio Station, Washington/NSS, Coastal Radio Station, St. John's/VON, and Canadian Maritime Radio Station, Mill Cove/CFH. The Ice Bulletins disseminated this year made no reference to the effective lane of the North American Atlantic Lane Track Agreement. This was because the agreement, which had been in existence since 1890, was abrogated by the contracting parties effective 1 September 1969.

The phase down of the U.S. Naval Station at Argentia and the resulting closure of the Coast Guard Radio Station, Argentia, NJN/NIK, necessitated a number of changes in Ice Patrol communications. Coast Guard Radio Station, Boston/NMF, assumed most of the duties of Ice Patrol Radio Station/NIK, transmitting the Ice Bulletin to shipping daily at 0018 GMT and 1218 GMT. Each transmission was preceded by a simultaneous "CQ" call on 5320, 8502, and 12750 kHz. After a 2-minute series of test signals transmitted on these frequencies, NMF/NIK transmitted the Ice Bulletin first at 25 words per minute and then at 15 words per minute.

A new service of the Ice Patrol was inaugurated 11 June 1970, when a voice summary of the International Ice Patrol Bulletin was included as part of the United States Marine Information Broadcast for the High Seas of the North Atlantic. This summary was broadcast daily by Coast Guard Radio Station, Boston/NMF, on 7865.4 kHz (8764.0) upper sideband mode commencing at 0130, 0730, 1330, and 1930 GMT and on 8764.0 kHz double side band mode commencing at 0149, 0749, 1349, and 1949 GMT. After 24 June 1970, the NMF double side band broadcasts were made at 0200, 0800, 1400, and 2000 GMT.

Merchant ships calling to transmit Ice Patrol traffic were requested to use the regularly assigned international call signs of the Coast Guard Ocean Station, East Coast AMVER Radio Stations, or Canadian Coastal Radio Station, St. John's. Coast Guard Stations were alert to answer NIK/NJN/NIDK calls, if used. When communicating with the above stations, merchant ships were requested to call and pass traffic as shown in table 2.

Table 2.—Communications With International Ice Patrol

Purpose	*Frequencies which should be used*
Calling	500 kHz (if 500 kHz is being used for distress traffic then 512 kHz may be used as supplementary calling frequency), 2182 kHz (voice) assigned HF (CW) calling frequencies.
Transmission of traffic by merchant vessels	Assigned MF, 2 MHz (voice), HF (CW) maritime mobile working frequencies.
Transmission of traffic by the following Coast Guard Stations:	
Ocean Station Vessels 4YB, 4YC, 4YD, 4YE, 4YH	466 kHz (CW), 2670 kHz (voice).
AMVER Radio Stations:	
NMF (Boston)	472, 8465 kHz (CW).
NMY (New York)	486, 2670, 12718.5, 17002.4 kHz (CW).
NMN (Norfolk-Portsmouth)	466, 2670. 8465 kHz (CW).
Transmission of traffic by Canadian Coastal Radio Station, St. Johns/VON	478 kHz (CW).

Communication statistics for the period 1 September 1969, through 31 August 1970, are shown in table 3.

Table 3.—Communication Statistics

Number of Ice Reports received from ships	439
Number of Sea Surface Temperature Reports received from ships	1,014
Number of ships requesting special information	22
Number of Ice Bulletins issued	248

ICE CONDITIONS, 1970 SEASON

September-December

After the close of the 1969 Ice Patrol season occasional icebergs continued to drift south along the Labrador coast. During September there were eight reports of iceberg sightings, all north of the Strait of Belle Isle. Occasional reports continued to be received throughout October, November, and December, including one large iceberg reported in the vicinity of Fogo Island on 1 November. On 13 November there was a report of an iceberg sighted midway between Cape Farewell, Greenland, and Goose Bay, Labrador. It is uncertain whether this iceberg came from east Greenland or Baffin Bay. There were several reports of iceberg sightings southeast of Cape Farewell, Greenland, as far offshore as 270 miles. Although iceberg sightings this far southeast of Greenland are relatively infrequent, they are by no means rare.

During the period 18–23 September 1969, a preseason iceberg survey was made of the Labrador coast and Baffin Bay. The purpose of the survey was to study iceberg distribution patterns and to assess the iceberg potential for the coming season. The number of icebergs counted per one degree rectangle is shown in figure 1. The count in the area between Cape Dyer and Cape Christian off the Baffin Island coast was about 85% higher than the 1964–69 average count of 364 in this area, thus indicating that the iceberg potential for a heavy iceberg season on the Grand Banks in 1970 was good.

A preseason flight along the Labrador coast and into southwestern Baffin Bay was also conducted during the period 11–16 December. The iceberg counts on this survey are shown in figure 2. Counts in the area offshore Baffin Island between Cape Dyer and Cape Christian were about 90% higher than the 1963–69 average of 257. Counts in the area between Hudson Strait and Cape Dyer were about 30% higher than the 1963–69 average of 201. The counts in both of these areas continued to indicate a heavier than normal iceberg season on the Grand Banks. Sea ice was encountered during the December survey about 60 miles south of Hudson Strait.

January

Only three icebergs were reported to the Ice Patrol office in January. All three were north of 56N. One was approximately 60 miles off the Labrador coast at 56N, one was near Ocean Station Bravo, and the third was about 100 miles south of Cape Farewell, Greenland. During the period 20–24 January a preseason flight was made along the Labrador and Baffin Island coasts as far north Cape Dyer. The results of this flight are shown in figure 3. Counts in the area between Hudson Strait and Cumberland Sound were about the same as the 1963–70 average of 162. Counts south of Hudson Strait were about 90% higher than the 1963–70 average of 80. At the time of the January survey sea ice was beginning to drift across the approaches to the Strait of Belle Isle.

February

During February 1970 occasional reports of icebergs or growlers were made by Coast Guard ships enroute or on Ocean Station Bravo. The southernmost of these reports was a growler reported at about 52–00N 51–30W on 16 February. A group of six icebergs was also reported at 57–00N 49–10W by an aircraft on 2 February. A preseason iceberg reconnaissance was made along the Labrador coast during the period 27 February–4 March. The results of the survey are discussed in the section on March ice conditions.

March

By early March, sea ice extended from the general area of Fogo Island and Cape Freels northeastward to about 52N, and then generally ran northward paralelling the Labrador coast about 150 to 180 miles offshore. The final leg of the preseason iceberg survey started in late February was completed on 4 March with a flight from Goose Bay to Argentia. Unfortunately the visibility was bad south of 53N on this flight.

However many radar targets were observed during this portion of the flight, and in view of a 2 March report of two icebergs near 52–10N 51–30W, all of the radar targets were evaluated as icebergs although some may undoubtedly have been ships in the sealing fleet. The results of the survey between 27 February and 4 March are shown in figure 4. Counts in the area between Hamilton Inlet, Labrador and Hudson Strait were about 95% higher than the 1963–70 average of 300 icebergs. Counts south of Hamilton Inlet were about 5% lower than the 1963–70 average of about 62 icebergs. On the basis of the above average number of icebergs sighted on this survey a special iceberg bulletin forecasting a heavy iceberg season on the Grand Banks was issued on 9 March.

A series of preseason flights between 18 and 20 March showed that sea ice extended past Cape Freels to about 49N, and that icebergs were located in two general groupings; one in the sea ice centered near 51N 54W, the other as a group of radar targets east of the sea ice centered near 51–40N 52–00W. A lone growler was observed outside the sea ice in position 49–50N 50–20W. The observations made on these flights are shown in figure 5. By the end of March the icebergs previously sighted in sea ice had moved as far south as 49–50N and the group outside the sea ice, now positively identified as icebergs, had moved south to about 51–00N 51–00W. This is shown in figure 6 which shows the results of a series of flights made 26–29 March. Between the beginning and end of March the sea ice did not appreciably change in its southern extent; however it did move about 50 miles westward toward Cape Freels. Throughout most of the middle and end of March there was generally open water to be found in the form of wide shore leads between Cape Freels and White Bay. The maximum extent of sea ice in March is approximately as shown in figure 6. This is considerably less than the 1898–1938 average extent shown in the Ice Atlas of the Northern Hemisphere published by the U.S. Naval Oceanographic Office. For comparison the average sea ice extent for March is also shown in figure 6. It is estimated that no icebergs drifted south of 48N in March 1970.

April

By the end of the first week of April sea ice was found south of Cape Bonavista to about latitude 48–20N, and extended as far east as 51–00W. This was a net movement of about 50 miles southeastward from its position during the series of flights in late March. A number of icebergs and growlers were found along and south of the sea ice edge by the end of the first week of April. See figure 7. The icebergs shown in figure 7 are believed to be those found inside the sea ice during the last part of March. By mid-April the eastern limit of sea ice had retreated to about 53–00W, maintaining the same southward extent to between 48–00N and 49–00N. By this time a few growlers were poised slightly north of 48N along the Newfoundland coast, as shown in figure 8. Throughout the remainder of the month sea ice continued to withdraw northwestward. By 20 April Cape Freels was clear of sea ice, and by the end of the month half of Notre Dame Bay was clear as far north as Fogo Island. As the sea ice withdrew a few icebergs began to drift south along the Avalon Peninsula, as revealed by iceberg reports received during the latter part of April. See figure 9. The first iceberg found south of 48N was reported on 21 April by the Ice Reconnaissance Detachment at 47–20N 52–25W. It is estimated that approximately five icebergs drifted south of 48N during April. Four of these drifted along the Avalon Peninsula and evidently melted within 60 miles south of Cape Race. The fifth iceberg was reported in position 47–20N 50–50W on 1 May, having drifted south of 48N a few days previously. Numerous radar targets were reported on the northern Grand Banks in latter April; however it is believed that few, if any, of these were icebergs, but rather were passing ships. The maximum extent of sea ice for April 1970 was that found during the first week as shown in figure 7. Comparison with the Ice Atlas average for April reveals that there was much less sea ice than normal in April 1970.

May

Throughout May the southern limit of sea ice hovered northeast of Cape Bonavista, Newfoundland, and a fairly extensive shore lead was usually present between Cape Freels and the Notre Dame Bay area. By the end of the month the southern sea ice limit had withdrawn to approximately 45 miles north of Cape Freels. During the first half of May the sea ice limits were generally to the west of 53W. During the later half of the month the width of the ice off Belle Isle

Strait increased until it extended as far east as 51W. The maximum extent of sea ice in May is shown approximately in figure 10. Flight operations during the first half of May were hampered by poor visibility in the iceberg patrol areas and definite information on the iceberg threat during this period is sketchy. Comparing the information obtained on the good series of flights on 16–18 April with the next good series on 17–20 May, it appears that the net movement of icebergs between mid-April and mid-May was only from near 49–30N 53–00W to the southern edge of the sea ice near 49N 52W (figure 10). Many radar targets were reported in the Grand Banks area during the first half of the month, however, it is believed that very few of them were icebergs. The only positive indication that some of the radar targets may have been icebergs drifting in advance of the general mass of icebergs further north was a ship report of an iceberg near 48–00N 49–00W on 16 May. The few icebergs that had drifted to the Cape Race area in late April were last seen on 1 May. They evidently melted during early May, and no other icebergs are believed to have been present in the vicinity of the Avalon Peninsula during May. During the last few days of May, icebergs began to drift south and east of Cape Bonavista. On 30 May about 25 icebergs and several growlers were reported strung out to 200 miles eastward of Trinity Bay. It is estimated that only two icebergs drifted south of 48N during the month of May 1970.

June

The month of June saw the only significant threat by icebergs to the Grand Banks area. Flights on 5 and 6 June (see figure 11) indicated that the icebergs sighted strung out eastward on the flight of 30 May were beginning to drift down the eastern slopes of the Grand Banks. On 7 June there were numerous reports from shipping of icebergs in the general vicinity of 48N 48W, as well as reports of icebergs near 46N 47W. Icebergs continued to drift south, and on 10 June an iceberg was reported at position 45–35N 47–45W. This iceberg, shown on figure 13, was the southernmost reported iceberg for the 1970 season and was about 120 miles north of the 1946–65 average position of the southernmost iceberg of the season. A series of flights on 14, 15, and 16 June covered most of the area between 43–20N and 49–00N, and showed that there were approximately 12 icebergs to be found south of 48N, and approximately 80 icebergs strung out towards the east from Newfoundland between 48–00N and 49–00N (see figure 12). A flight on 27 June found approximately 100 icebergs between 48–30N and 50–00N, thus indicating that there were still icebergs to be found on routes into the Strait of Belle Isle as of late June when sea ice had cleared from the entrance to the Strait enough so that shipping could pass through the Strait.

It is estimated that approximately 70 icebergs drifted south of 48N during the month of June.

At the beginning of June the southern extent of sea ice was to approximately 50N. By the end of June all sea ice had cleared to north of Belle Isle Strait. Sea ice conditions during June were approximately normal in comparison to the Ice Atlas.

July

Flight operations in early July were hampered by poor visibility. However, based on ship reports and occasional flights it became apparent that very few icebergs were drifting south of 48N, although reports from shipping through Belle Isle Strait indicated that there were numerous icebergs still to be found north of 51N. A series of flights between 19 and 23 July, see figure 13, and reports from shipping indicated that there was little iceberg threat remaining for the Grand Banks during the 1970 season. The easternmost iceberg observed during the 1970 season was found on 3 July at 48–50N 44–15W, somewhat less to the east than the 1946–65 average. It is estimated that 8 icebergs drifted south of 48N during the month of July. There was no known sea ice south of Belle Isle Strait.

August

During August there were three reports of icebergs between 48–00 and 50–00N as well as numerous reports of icebergs in the approaches to the Strait of Belle Isle. There were no known icebergs south of 48N in August.

Table 4.—Estimated Number of Icebergs South of Latitude 48°N, Season of 1970

Season	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
1970	0	0	0	0	0	0	0	5	2	70	8	0	85
Average 1900-1945	5	2	2	2	3	10	46	105	154	76	26	8	440
Total 1946-1970	5	2	4	5	10	87	545	1,846	1,519	1,061	235	12	5,331
Average 1946-1970	0	0	0	0	0	3	22	74	62	42	9	1	229
Total, 1900-1970	251	109	110	85	130	538	2,647	6,691	8,602	4,579	1,431	401	25,574
Average 1900-1970	4	2	2	1	2	8	38	94	121	64	20	6	361

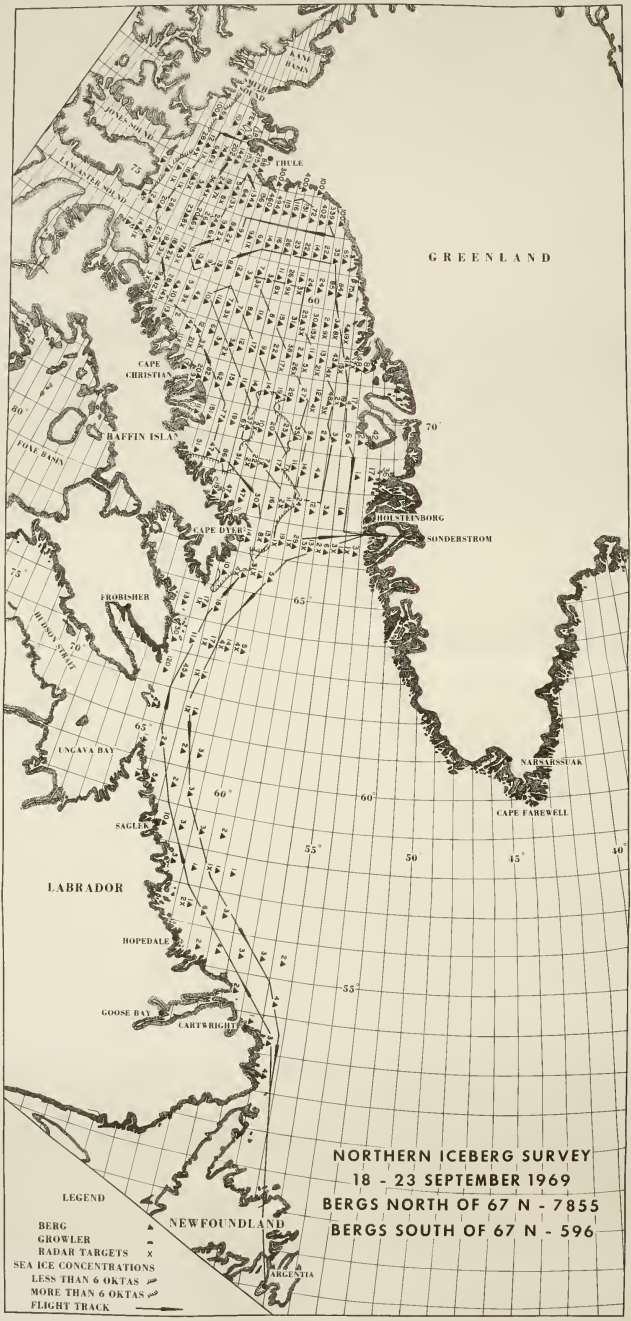

Figure 1.—Northern Iceberg Survey, 18-23 September 1969.

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Figure 2.—Northern Iceberg Survey, 11-16 December 1969

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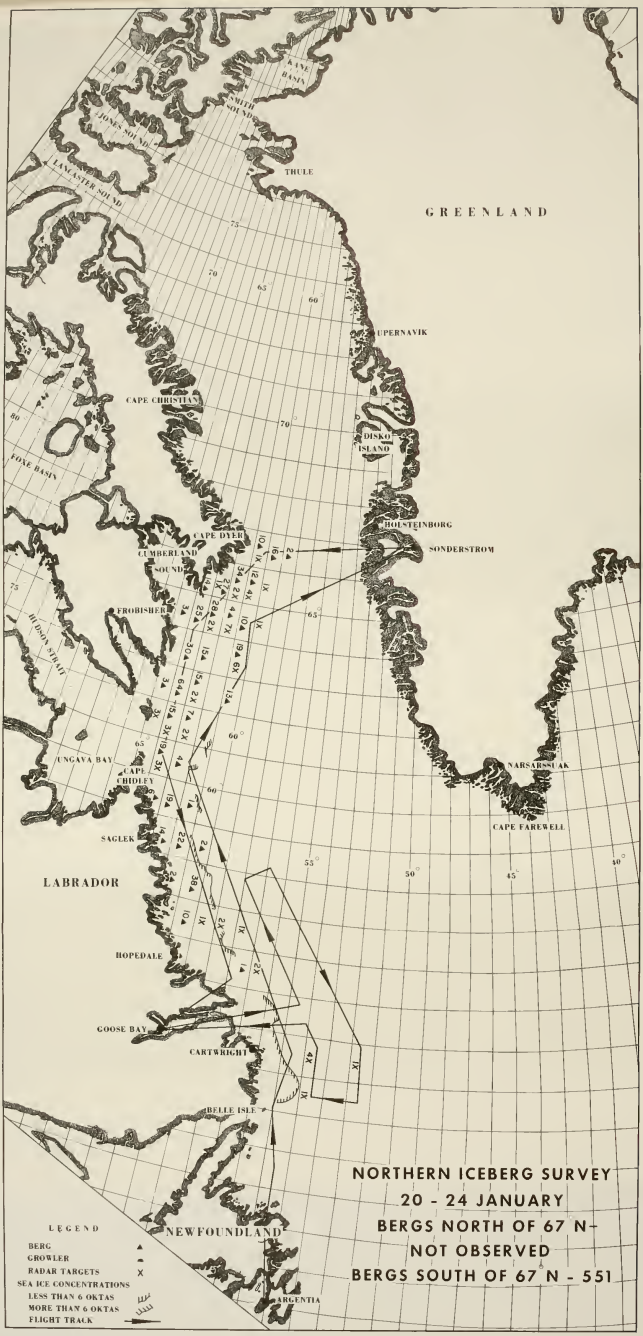


Figure 3—Northern Iceberg Survey, 20-24 January 1970.

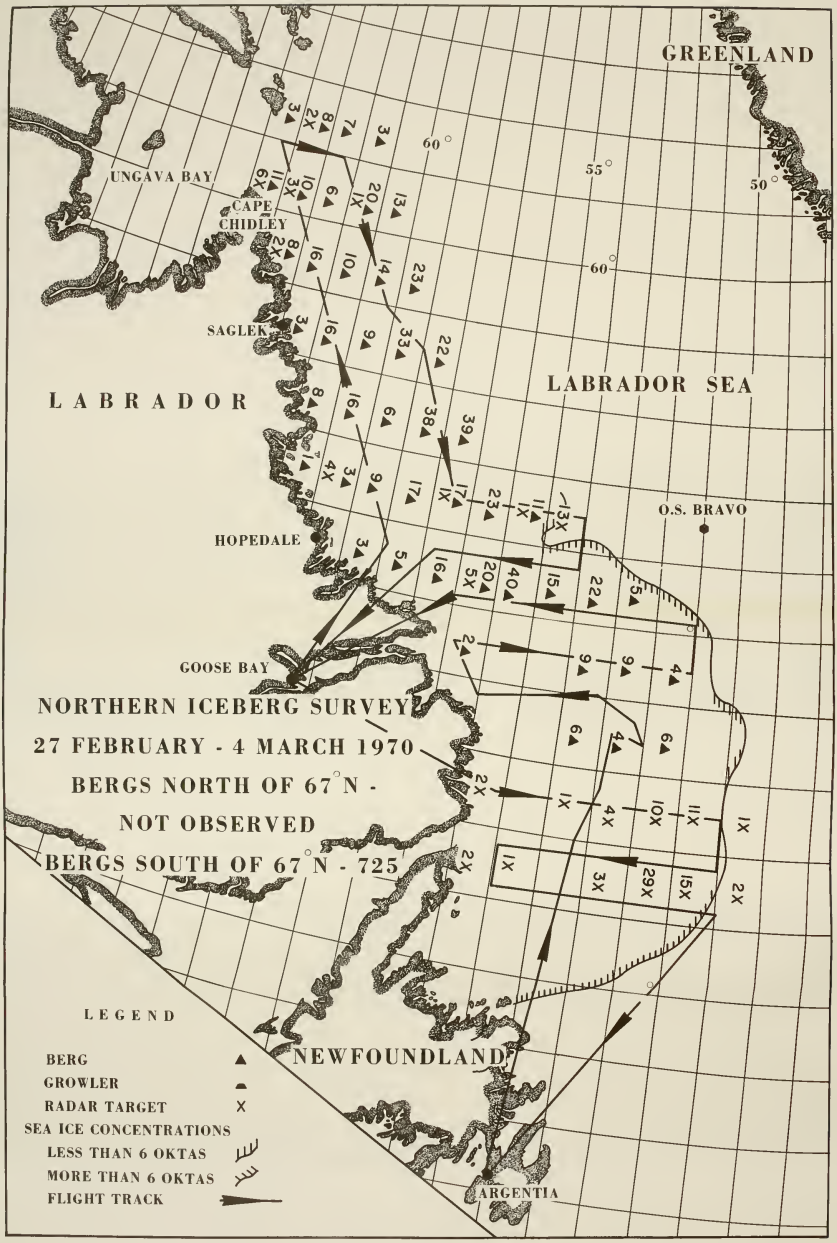


Figure 4.—Northern Iceberg Survey, 27 February-4 March 1970.

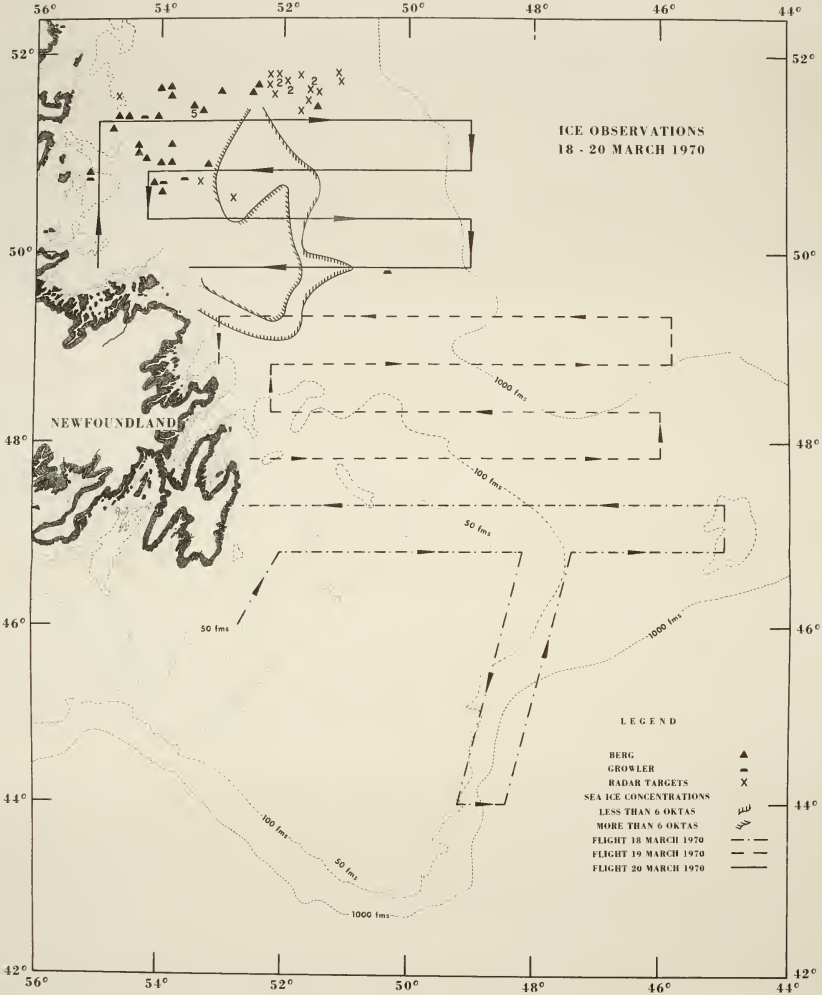


Figure 5.—Ice Observations, 18-20 March 1970.

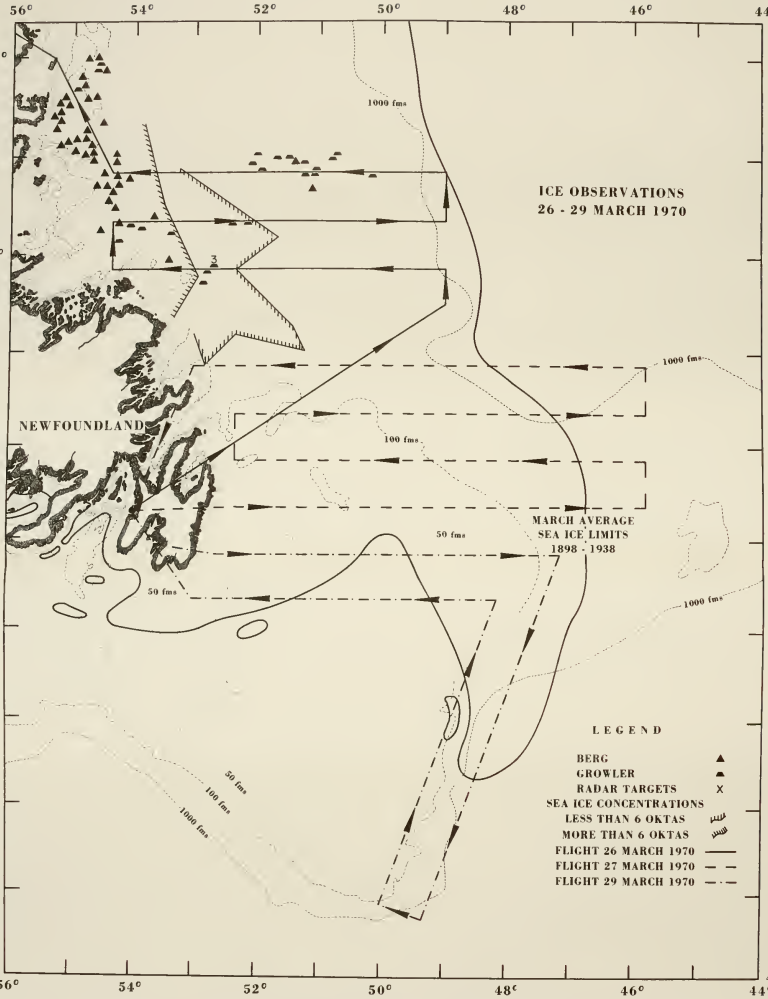


Figure 6.—Ice Observations, 26-29 March 1970.

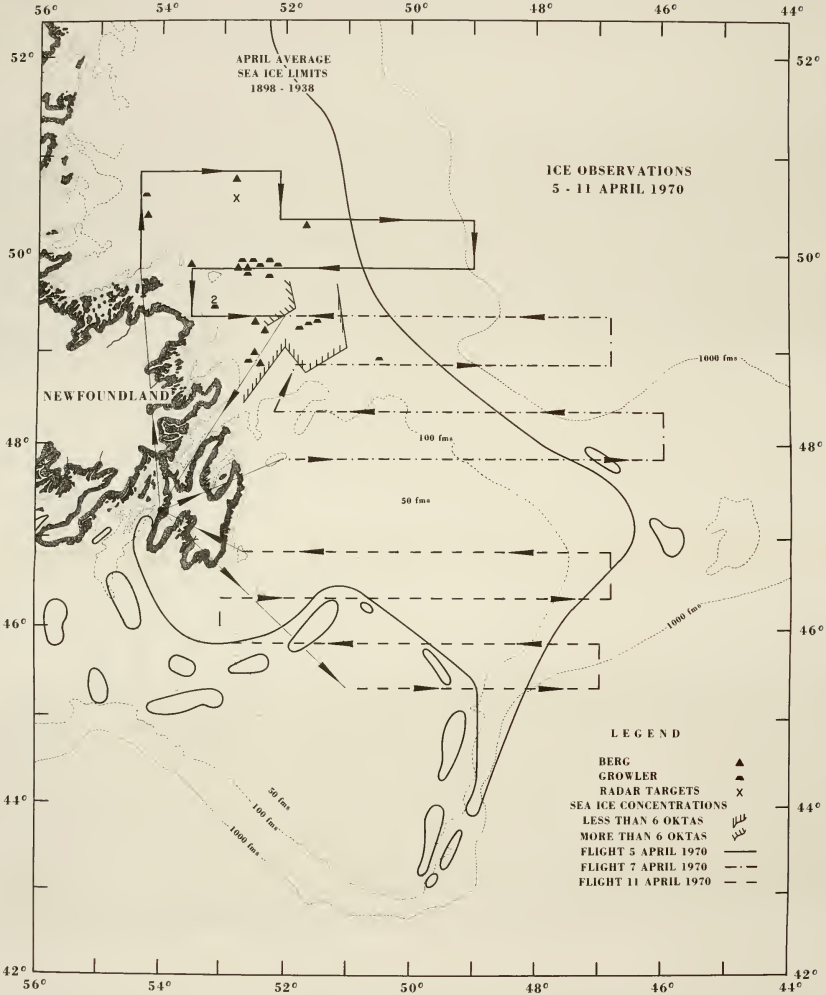


Figure 7.—Ice Observations, 5-11 April 1970.

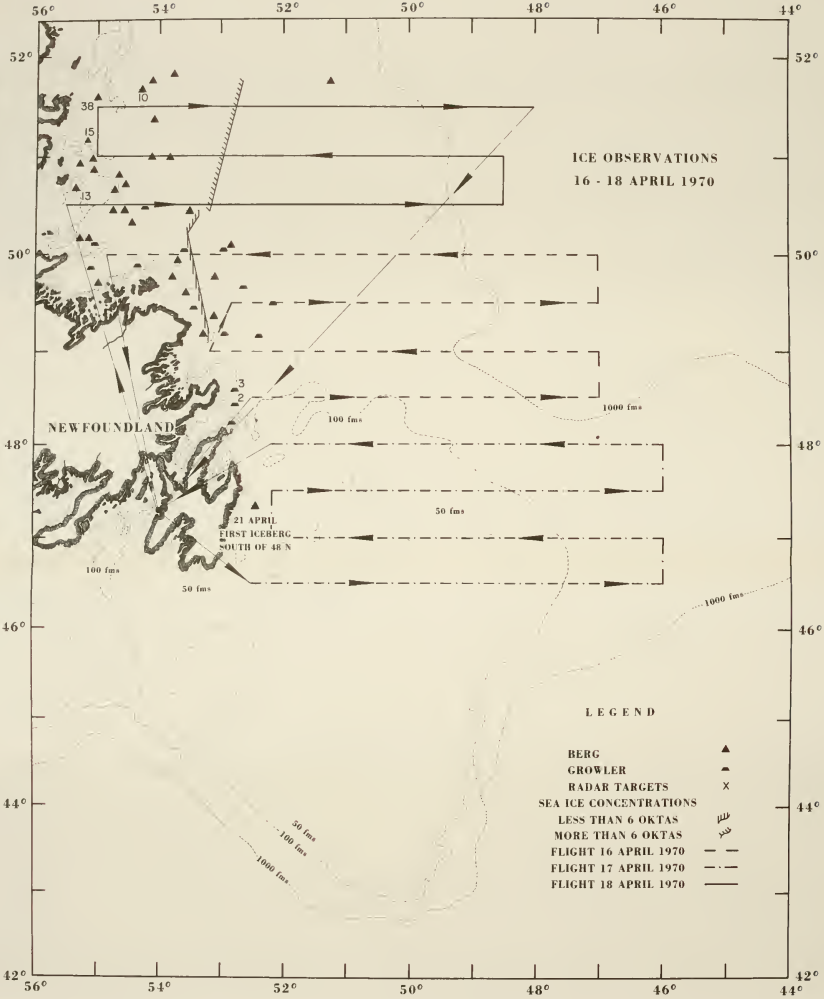


Figure 8.—Ice Observations, 16-18 April 1970.

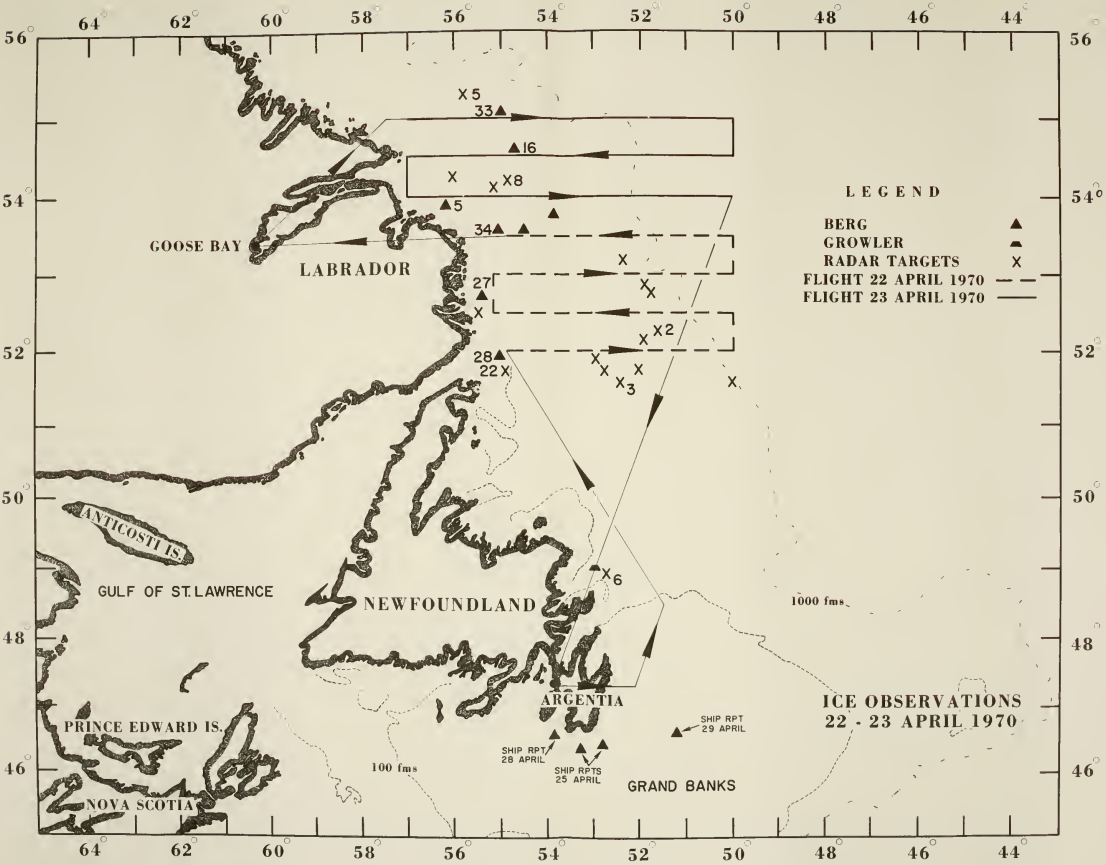


Figure 9.—Ice Conditions, 22-23 April 1970.

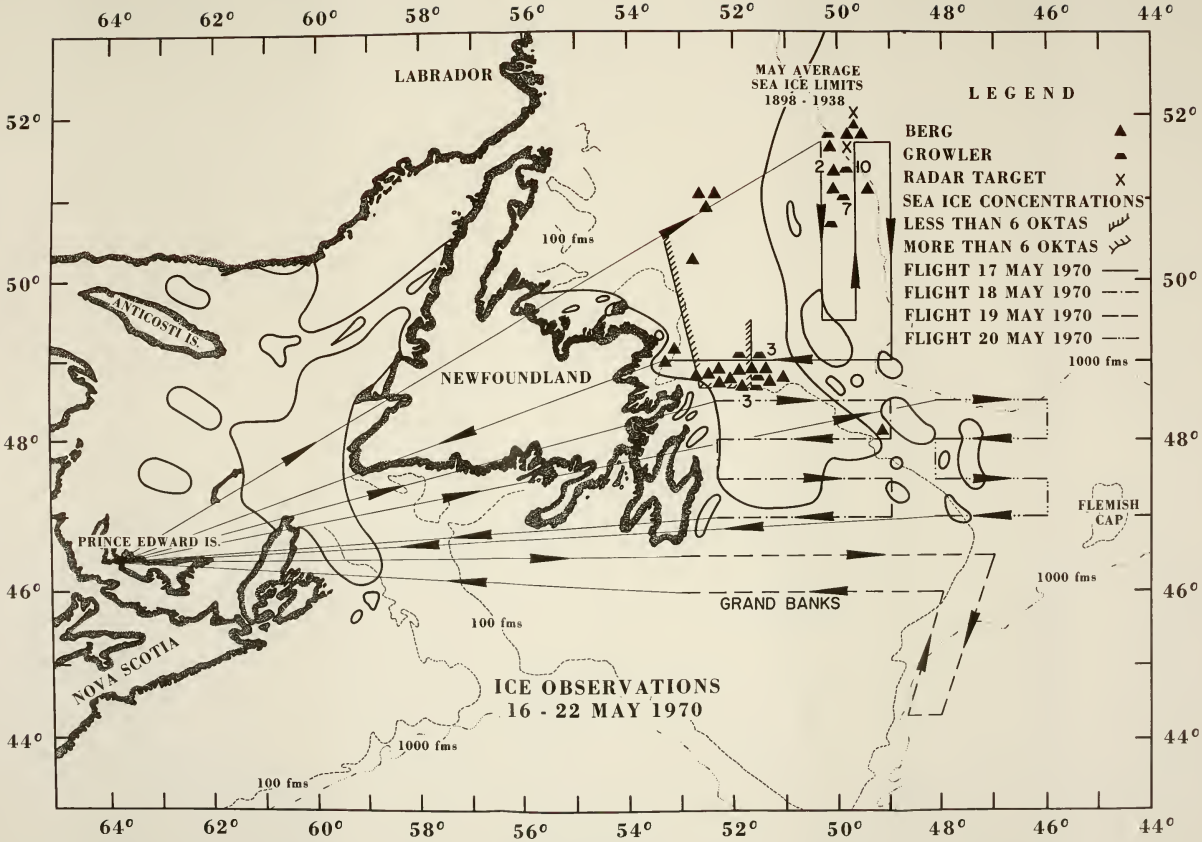


Figure 10.—Ice Observations, 16-22 May 1970.

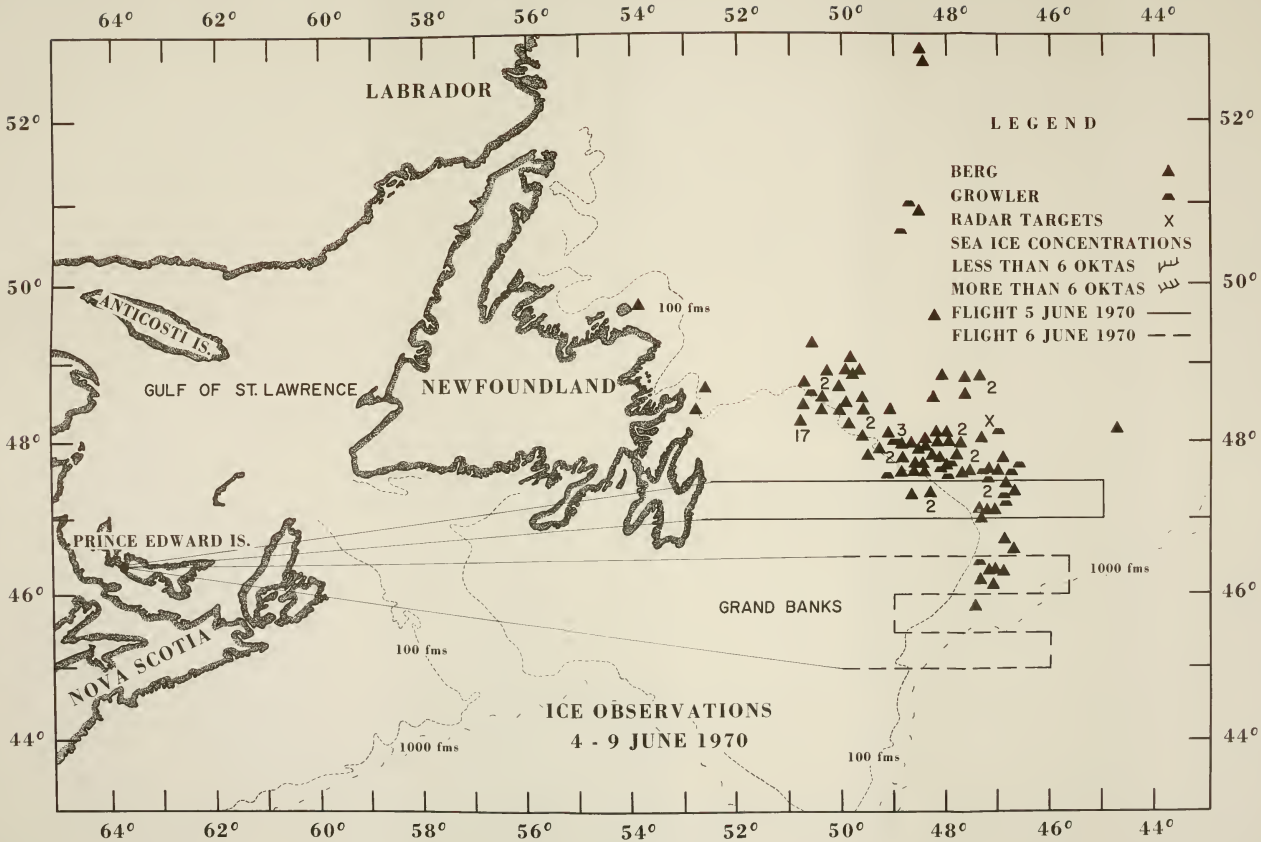


Figure 11.—Ice Observations, 4-9 June 1970.

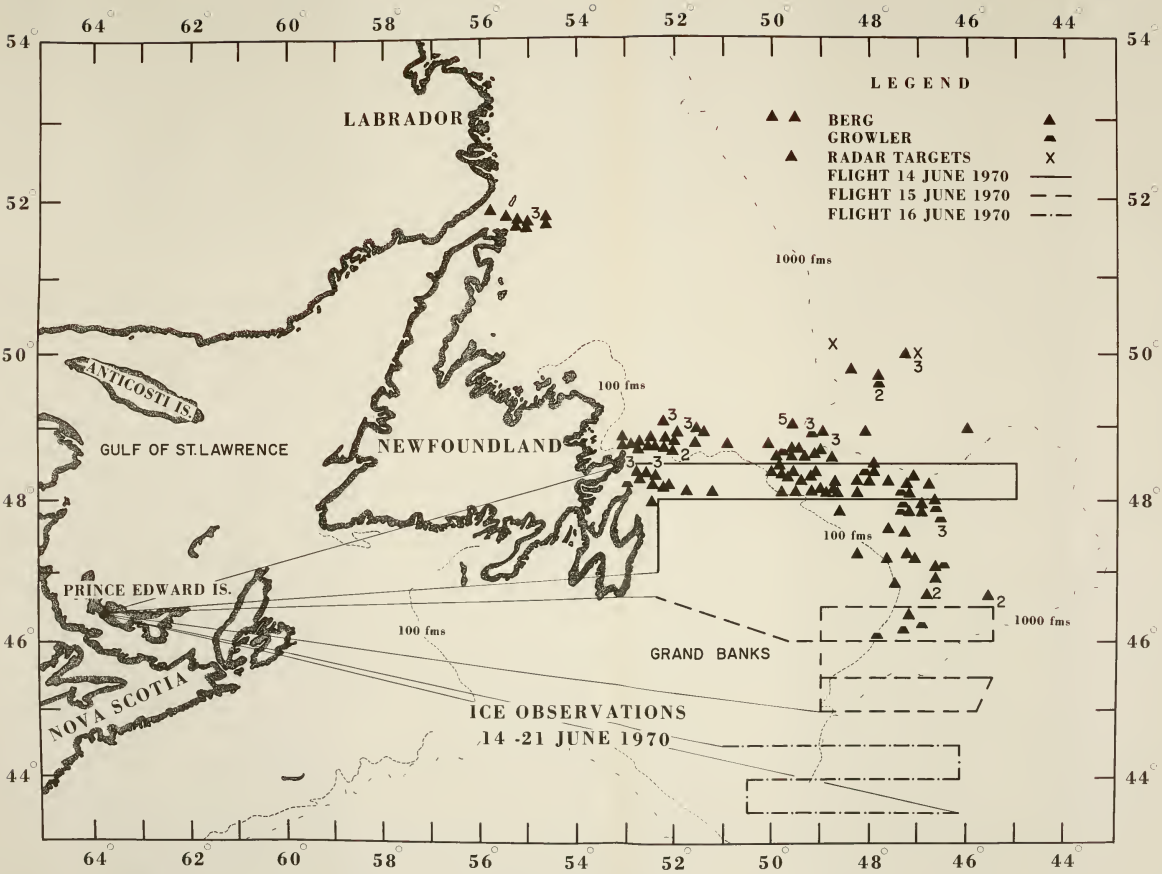


Figure 12.—Ice Observations, 14-21 June 1970.

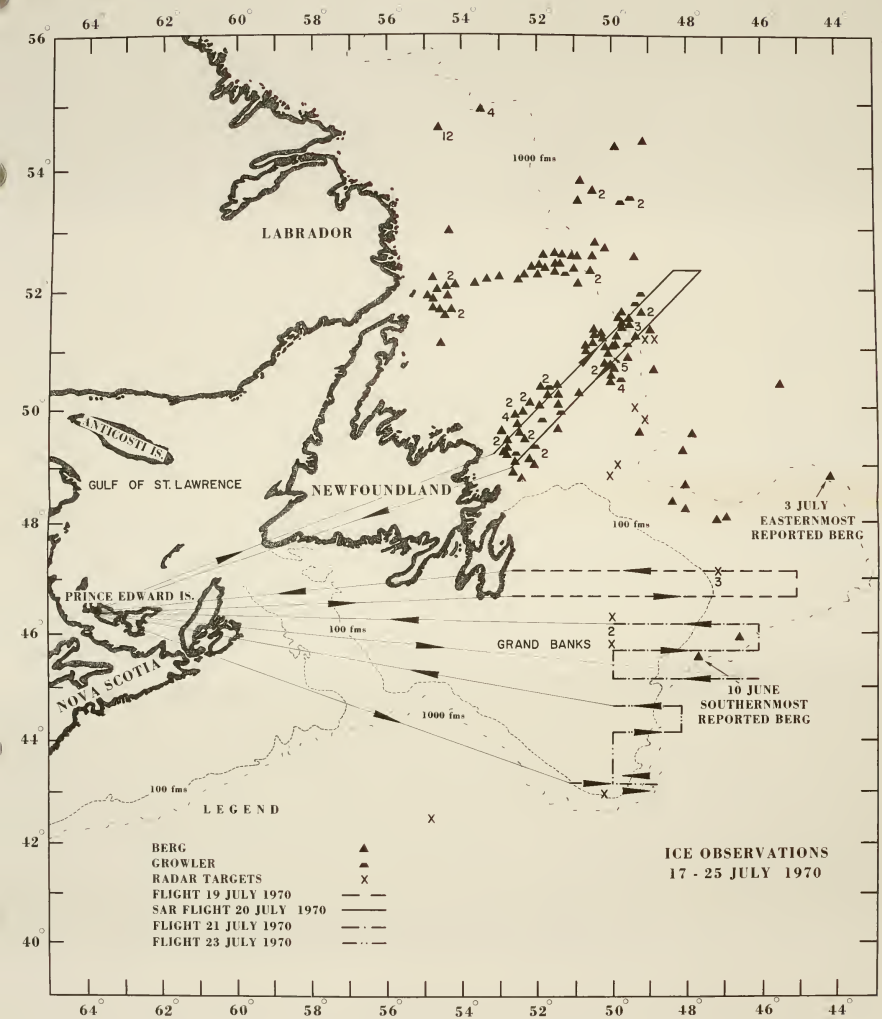


Figure 13.—Ice Conditions, 17-25 July 1970.

OCEANOGRAPHIC CONDITIONS, 1970

(Provided by U.S. Coast Guard Oceanographic Unit)

Two oceanographic cruises were conducted during the Ice Patrol season aboard USCGC *Evergreen* (WAGO 295). The dynamic topography of the sea surface relative to the 1000 decibar surface was obtained from these cruises (figures 14–17). The most prominent feature of the circulation was the Labrador Current flowing southward along the eastern slope of the Grand Banks. Farther east was the dynamic trough that separates the Labrador Current from the northwestward flowing North Atlantic Current.

Conditions found during the 1970 season differed somewhat from the normal or average conditions. There was evidence of an additional dynamic low in the vicinity of 44N, 47W (figures 15 and 16). This low was caused by an unusual clockwise dynamic high to the north at 45N, 47W (figures 16 and 17). The features of this high could be observed at least as deep as 1200 meters. The Labrador Current had a particularly intense geostrophic current (2.5 knots) on 31 May–1 June at 44–30N 48–50W. This occurred because the sea surface in the trough fell 10 dynamic centimeters during the preceding 6 days.

A detailed survey off the southeast slope of the Grand Banks was made to determine the circulation over the Newfoundland Rise. The charts of normal dynamic topography do not adequately define the circulation of this region because of its high variability. The circulation indicated by the mass distribution was much more complicated than expected (figure 16). There was a great deal of difference observed in the circulation by two oceanographic surveys of roughly the same area (figures 15 and 16). These differences may result from two factors. First, the circulation may have changed during the interval between the two surveys. Second, the section spacing was greater on the first cruise than on the second, thus much of the detail may have been lost on the first cruise.

A more detailed analysis of the oceanography of the Grand Banks and the Labrador Sea in 1970 will be published in the U.S. Coast Guard Oceanographic Report Series (CG–373).

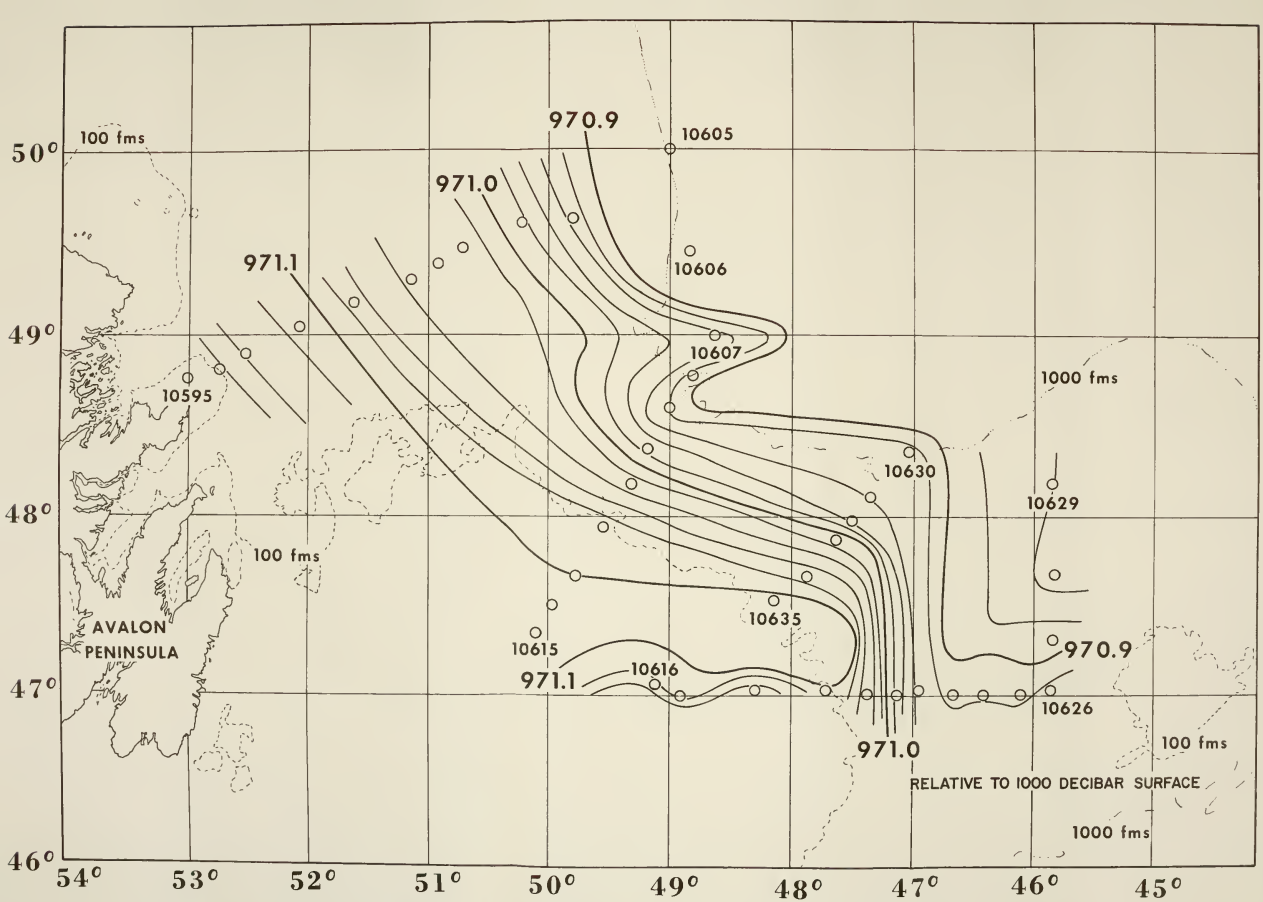


Figure 14.—Dynamic Topography of the Sea Surface With Reference to the 1000 Decibar Surface. First Cruise, First Segment (7 to 10 April 1970).

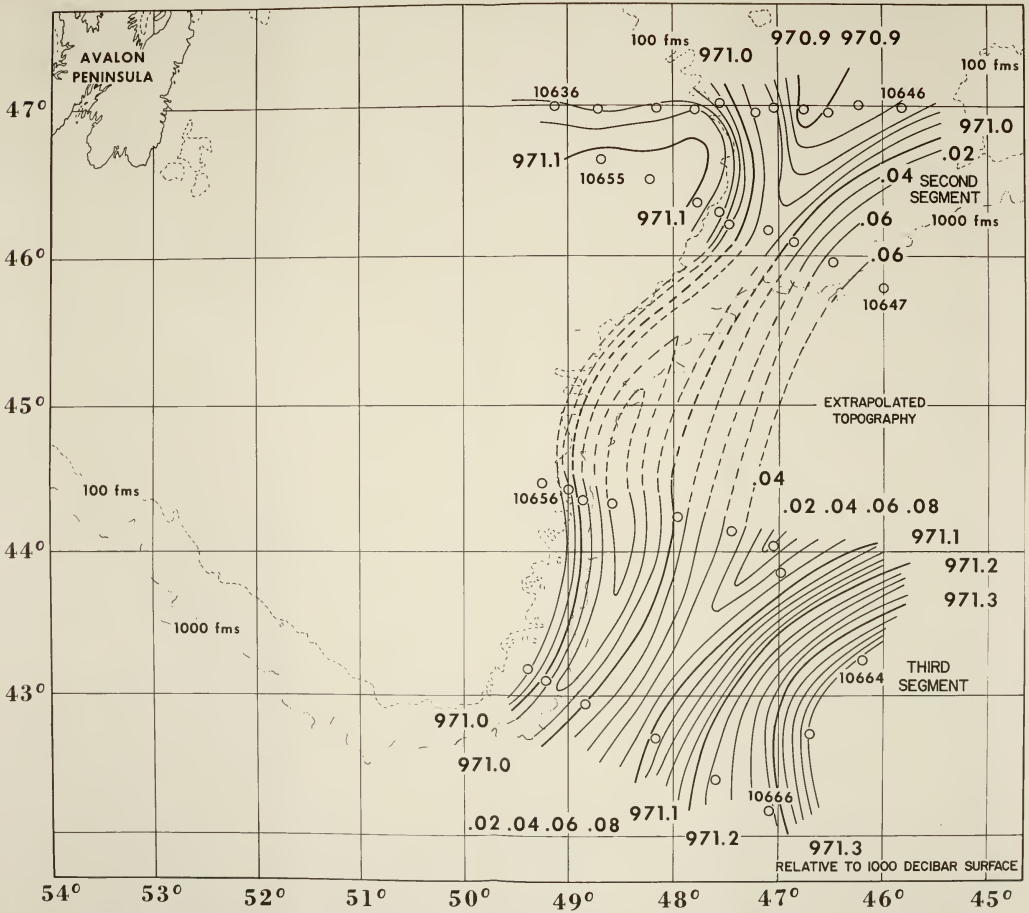


Figure 15.—Dynamic Topography of the Sea Surface With Reference to the 1000 Decibar Surface. First Cruise, Second Segment (15 to 17 April 1970) and Third Segment (21 to 24 April 1970).

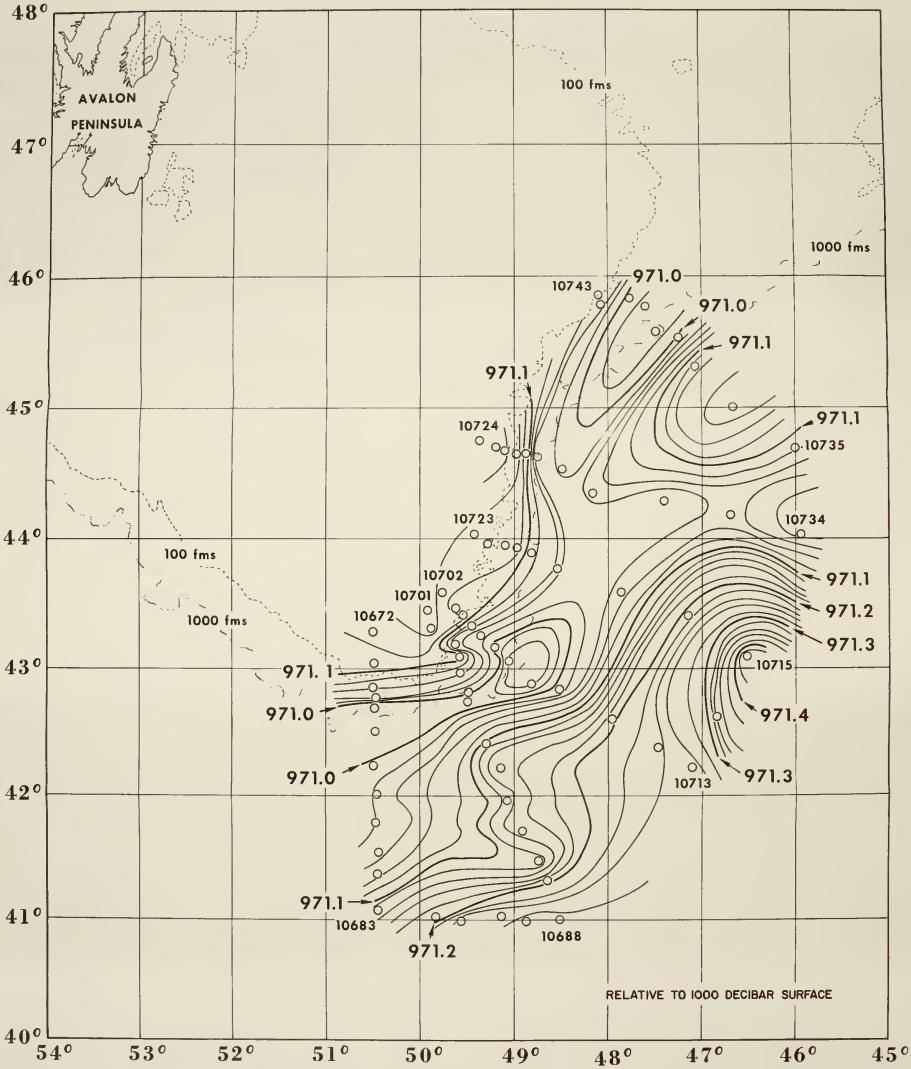


Figure 16.—Dynamic Topography of the Sea Surface With Reference to the 1000 Decibar Surface. Second Cruise, First Segment (17 to 25 May 1970).

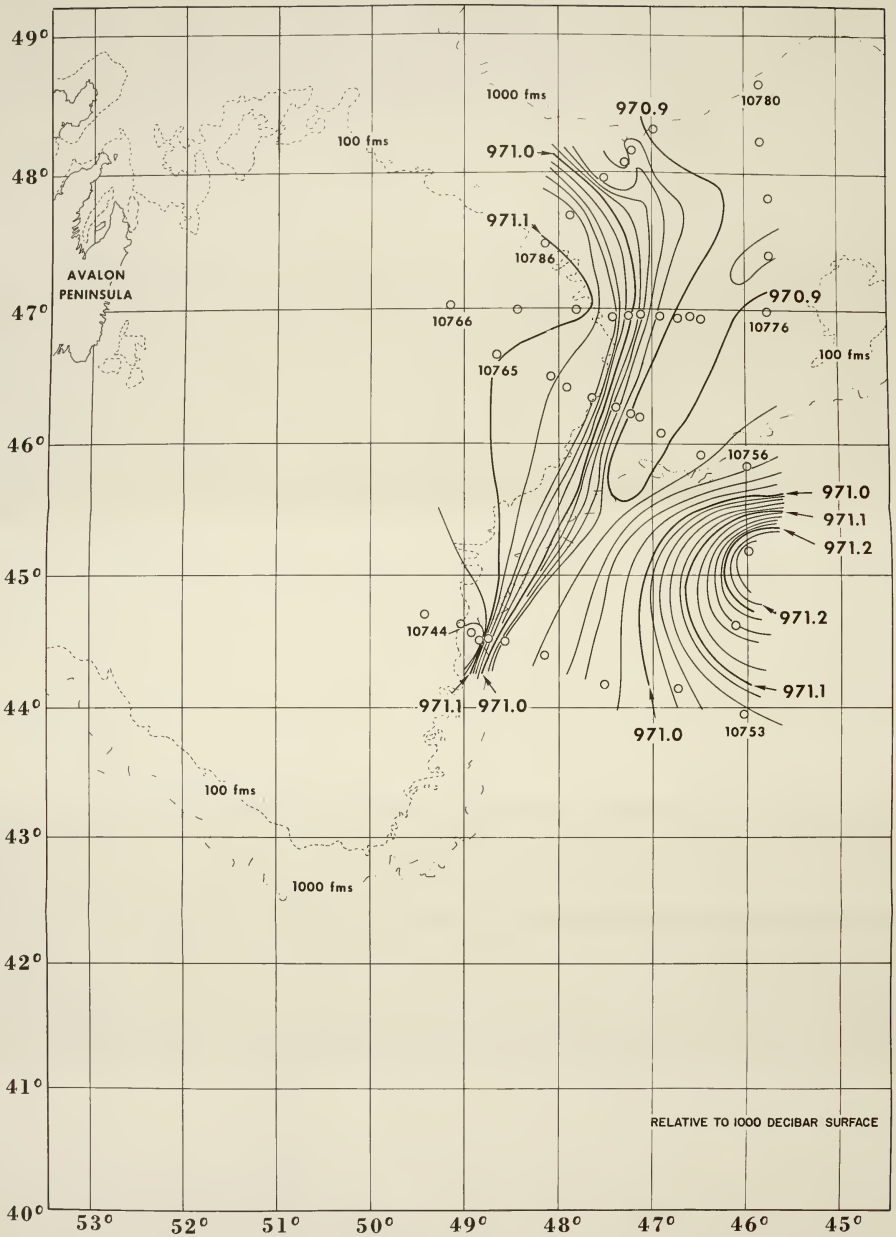


Figure 17.—Dynamic Topography of the Sea Surface With Reference to the 1000 Decibar Surface. Second Cruise, Second Segment (29 May to 2 June 1970).

DISCUSSION OF ICEBERG AND ENVIRONMENTAL CONDITIONS DURING 1970 SEASON

The question of how and why the iceberg season develops as it does is always of interest to the Ice Patrol. This is particularly true when the season does not develop as expected, as happened in 1970. The three major factors which influence the development of the season are (1) the number of icebergs available to drift onto the Grand Banks, (2) the strength of the northwesterly winds which transport the icebergs south, and (3) the rate of deterioration the icebergs experience due to melting and wave action. In early March, as described in the section on ice conditions, there were 95% more icebergs present north of Hamilton Inlet than normal. Therefore the potential for a heavy iceberg season was present, and it was the factors which influence iceberg drift and deterioration which led to a light season.

The features of the Labrador Current, as described in figures 14–17, appear sufficiently well developed to play their usual role in transporting icebergs along the eastern slopes of the Grand Banks. The recurvature of isotachs at about 45N to 46N on all four surveys indicates that some icebergs in the Labrador Current would be unable to drift south of about 45N or 46N. In fact the southernmost iceberg of the season was located at about 45–35N in the southern part of the eddy indicated by the 970.9 dynamic meter isotach on figure 17. At the end of the second cruise there does not appear to be any significant eastward branching of the Labrador Current between the northeast slope of the Grand Banks and Flemish Cap; however this could occur later.

Sea surface temperatures on the northeast slopes of the Grand Banks, as revealed by comparison of sea surface temperature charts from Fleet Weather Central Norfolk with normal sea surface charts given in Report of the International Ice Patrol in the North Atlantic, Season of 1964, appeared to be about a degree Fahrenheit or more warmer than average from late April through at least early June. This probably had some effect in hastening the melting of icebergs.

Figures 18a through 18d show the normal and the 1969/1970 surface atmospheric pressure patterns for November through June. Pressure patterns through January do not appear as if they would impede the southward drift of icebergs to any unusually great degree. This, in connection with the above normal iceberg counts noted in December and in the fall, probably accounts for the higher than average iceberg count along the Labrador coast in February. In March there is a splitting of the Icelandic low, with a secondary low forming over Newfoundland. The average cyclonic circulation associated with this low would have been unfavorable to any strong eastward drift of icebergs from the area of Belle Isle Strait or north. The average pressure pattern for April shows that the secondary low still exists, however it is now centered slightly to the east of Newfoundland. In this position winds would continue to be generally unfavorable for the drift of icebergs along the eastern slopes of the Grand Banks, however the winds would not generally oppose the drift of icebergs along the Avalon Peninsula. In fact the five icebergs that did drift south of 48N in April all did so to the west of 50° west longitude. During May the secondary low near Newfoundland disappeared and a fairly intense Icelandic low was established. This resulted in winds with a westerly component predominating in the coastal areas of Newfoundland and southern Labrador. These average westerly winds continued through June.

As a more quantitative indicator of the wind, one may examine the difference in atmospheric pressure along a line as a measure of the average wind perpendicular to the line. Four such lines are labeled gradients 1 through 4 in figure 19. Gradients 1 and 2 measure the winds which are important in transporting icebergs to the general area of the waters off northeast Newfoundland. Gradient 3 is a measure of the winds which assist

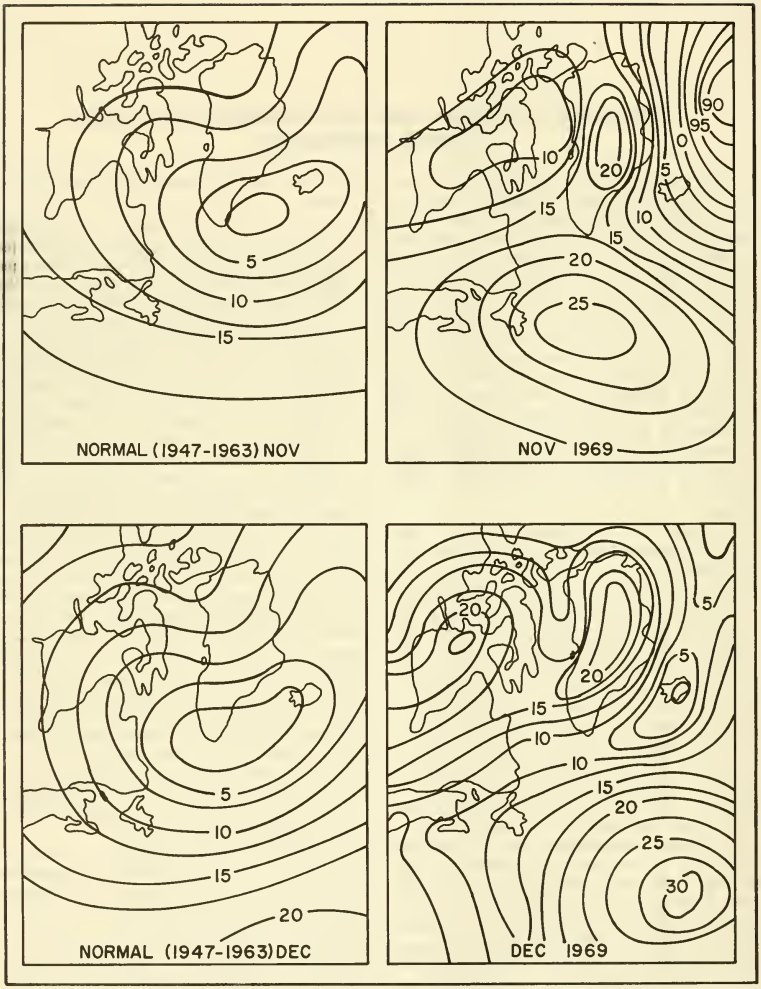


Figure 18a.—November and December Normal and 1969 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

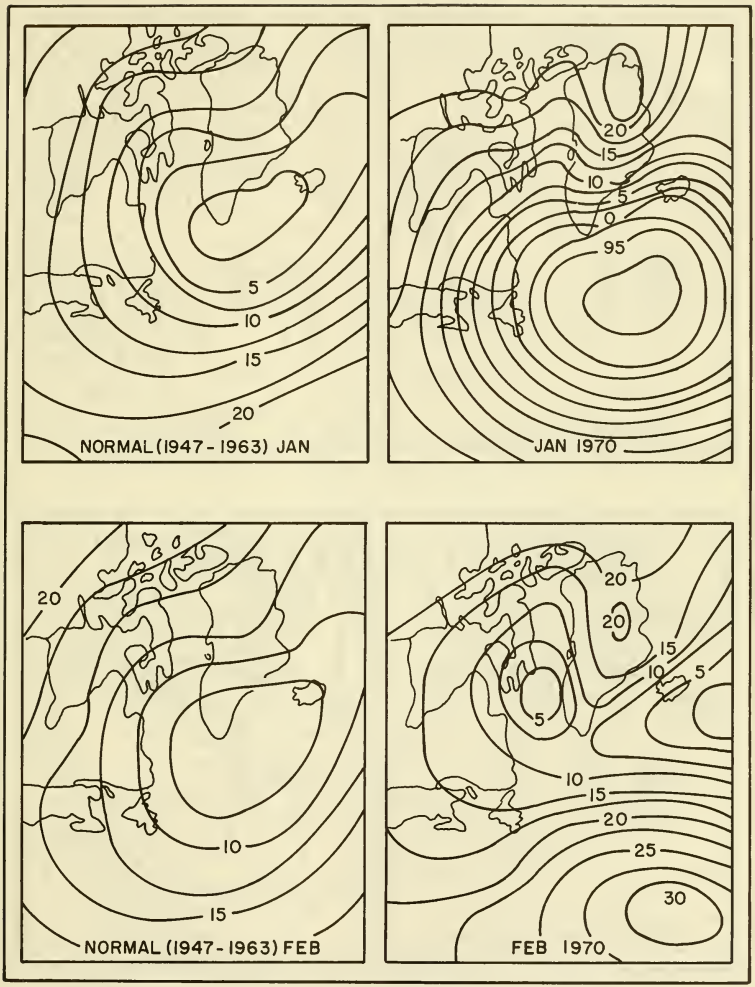


Figure 18b.—January and February and 1970 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

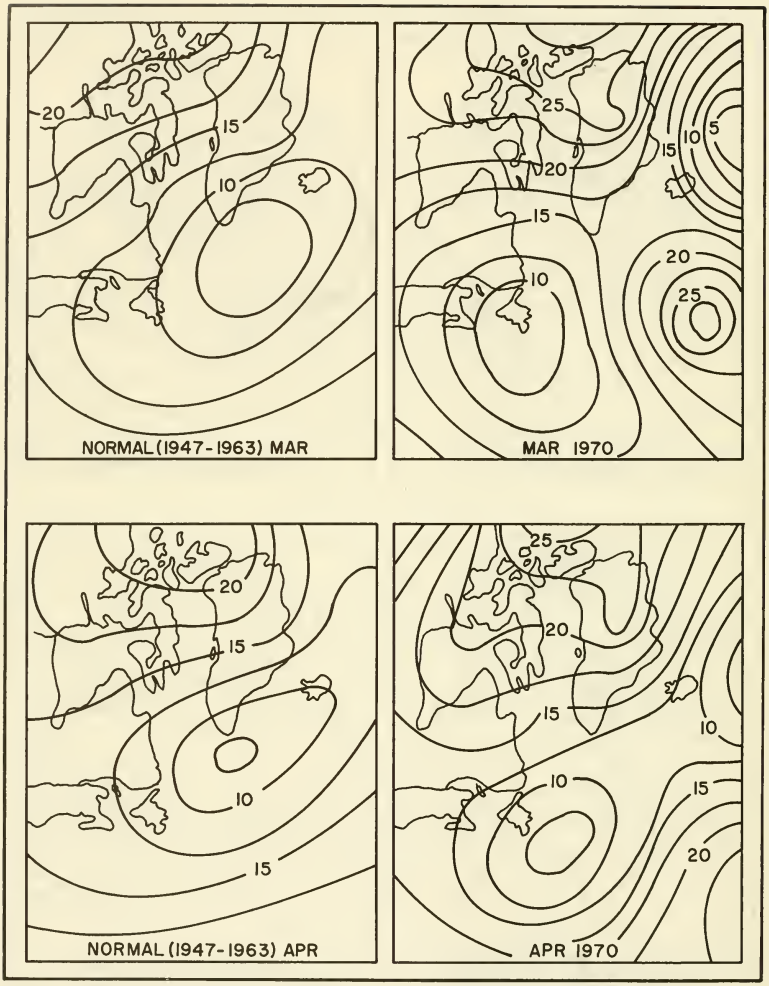


Figure 18c.—March and April Normal and 1970 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

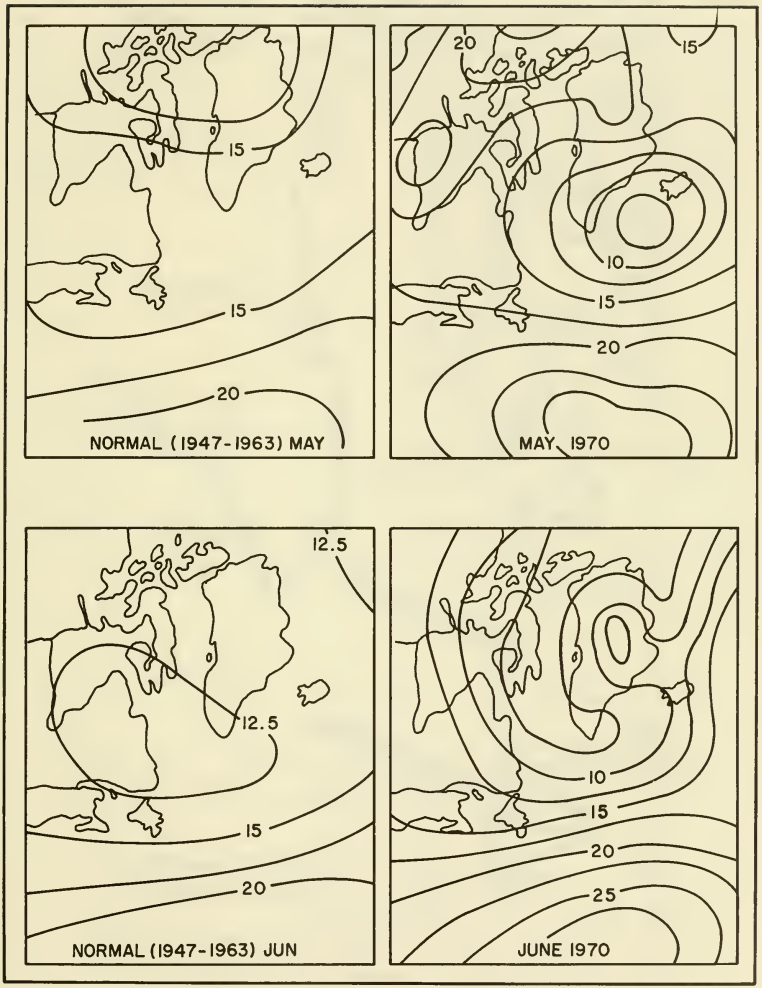


Figure 18d.—May and June Normal and 1970 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

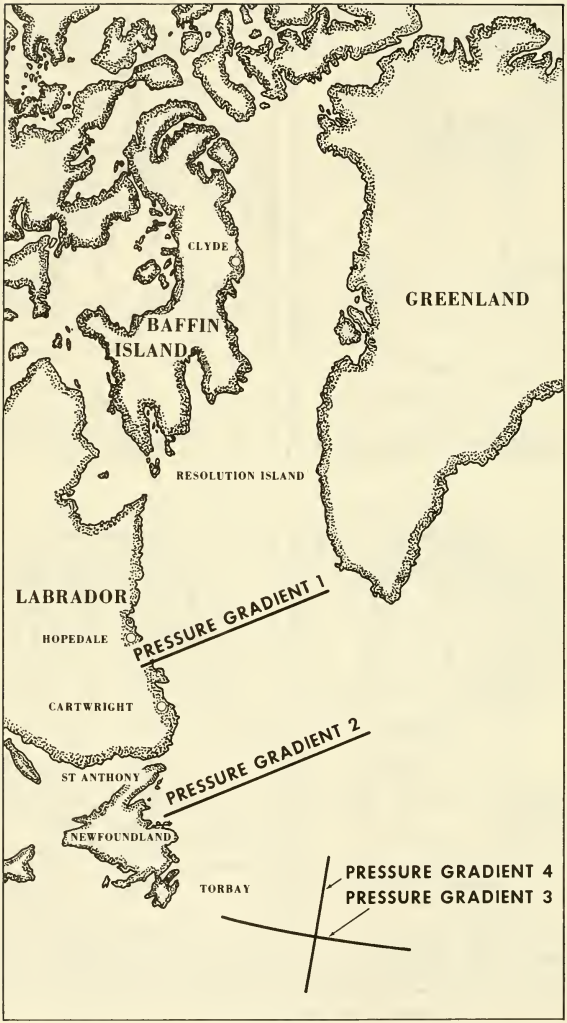


Figure 19.—Locator Chart.

or impede icebergs as they drift along the eastern slopes of the Grand Banks. Gradient 4 is a measure of the strength of generally westerly winds along the north slopes of the Grand Banks. These winds are often important in carrying icebergs away from the northeast Newfoundland coast and out into the Labrador Current. However, if they are too strong when icebergs reach the northeast corner of the Grand Banks where the Labrador Current turns south, then the icebergs may be carried eastward out of Labrador Current and into warmer waters which drift generally northeastward.

Gradients 1 and 2 (see figure 20) indicate winds more unfavorable for the southward drift of ice than normal in March and early April, and more favorable than normal in later April, May, and June. This appears to have had the effect of initially limiting the supply of icebergs to the northern Grand Banks. The fact that there were only two icebergs south of 48N in May be attributed to the time required for icebergs to drift

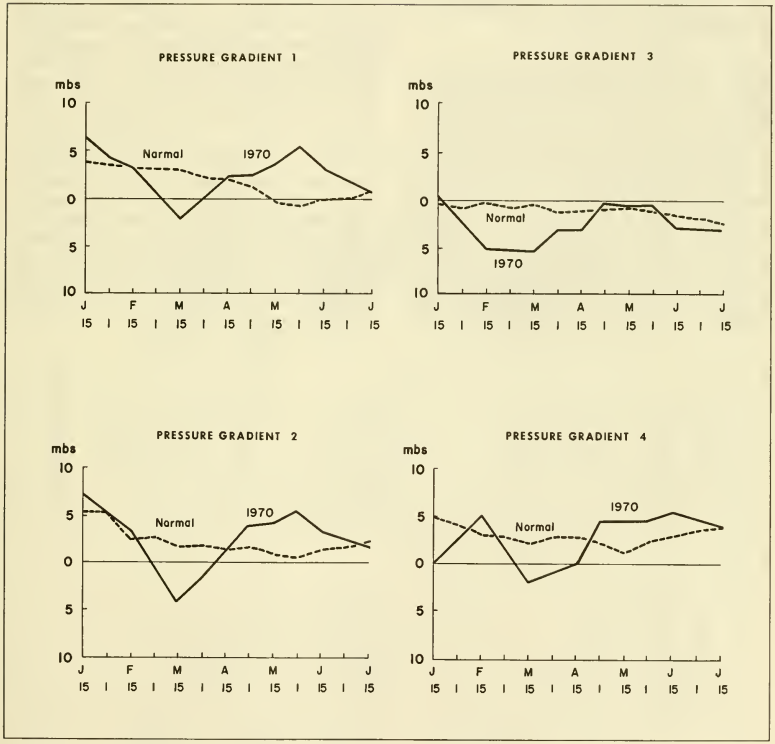


Figure 20.—Pressure Gradients 1-4.

south to 48N after winds became favorable in later April. Gradient 3 shows that winds were generally unfavorable for iceberg drift along the eastern slopes of the Grand Banks until early May when conditions became neutral and remained so through early June when they again became unfavorable. Pressure gradient 4 shows that winds would have tended to hold icebergs in along the Newfoundland coast until early May. As the iceberg supply on the northern Grand Banks became adequate in early June there appears to have been a tendency for winds, as measured on gradient 4, to carry them eastward out of the Labrador Current.

Winter and spring air temperatures along the Baffin Island, Labrador and Newfoundland coasts were generally warmer than normal, as can be seen in figure 21. The locations of the stations given on figure 21 are shown on figure 19. A frost degree-day, as used in figure 21, is defined as one day at a temperature of one fahrenheit degree below 32°. Thus one day at 20°F would be 12 frost degree-days. Similarly a melting degree-day is defined as a day at a temperature of one Fahrenheit degree above 32°. Actually figure 21 was calculated on the basis of the average monthly temperature and multiplied by the number of days in the month rather than on the basis of the average daily temperature for each day.

The only station which was not below normal in frost degree-day accumulations was Resolution Island. Along the Labrador and Newfoundland coasts it appears that the reason for the low frost degree-day accumulations was a late winter. Once temperatures dropped below freezing monthly frost degree-days were usually only slightly lower than normal. An exception to this was St. Johns where the frost degree-days in February and March were much below normal. The effect of these below normal frost degree-days would be to inhibit the formation of sea ice, which in turn would hasten the deterioration of icebergs since sea ice generally serves to protect icebergs from the eroding influence of wave action. The below normal extent of sea ice has already been mentioned in the section on ice conditions during 1970.

Melting degree-days at St. Johns in May and June were above normal. This would tend to cause increased melting of icebergs in the area.

To summarize, it appears that in spite of a large supply of icebergs, a heavy 1970 iceberg season failed to materialize because wind, air temperature, sea surface temperature, and sea ice conditions were not favorable for the transport of icebergs south of 48°N.

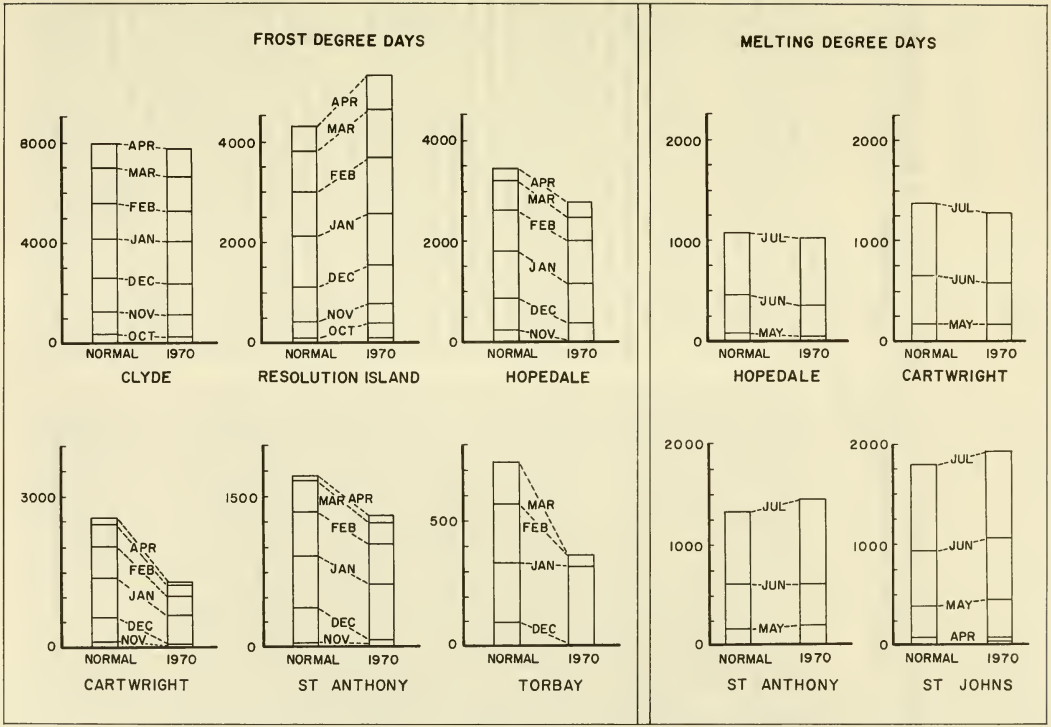


Figure 21.—Frost Degree Day and Melting Degree Day Accumulations Calculated From Monthly Mean Fahrenheit Air Temperature.

ICEBERG DISTRIBUTION IN BAFFIN BAY AND THE LABRADOR SEA AS DETERMINED FROM PRESEASON ICE PATROL FLIGHTS BY THE UNITED STATES COAST GUARD

By C. W. Morgan, U.S. Coast Guard

Abstract

The purpose and background of preseason Ice Patrol flights by the U.S. Coast Guard is discussed. The technique of preseason aerial iceberg reconnaissance is described. The results of the flights are analyzed in terms of average and observed icebergs per two square degrees for Baffin Bay in summer and fall, for southwestern Baffin Bay and the Labrador coast in early December and January, and for the Labrador coast in February. Deviations from the average are analyzed for the fall Baffin Bay data.

Data from the preseason flights show that patterns of iceberg concentration are generally the same from year to year, although there are usually changes in the overall level of concentration. Patterns of iceberg concentration in Baffin Bay indicate that the movement of icebergs directly across Baffin Bay may be as important as the route north through Melville Bay. Analysis of the dissipation of a large positive iceberg anomaly off Cape York during the period 1966–69 indicates that it takes about 3 years for a heavy accumulation of icebergs in northern Baffin Bay to clear out. Analysis of the February data indicates that there is a fair positive correlation (0.61) between iceberg concentrations observed on the February flight and the severity of the iceberg season on the Grand Banks. There is also fair positive correlation (0.77) between the southernmost extent of icebergs observed on the February flight and the date when icebergs arrive on the Grand Banks.

Introduction

The icebergs which drift south in the spring of each year to threaten shipping in the area of the Grand Banks of Newfoundland come mostly from the glaciers which terminate in Baffin Bay. The questions of exactly how icebergs drift from their source glaciers to the Grand Banks, how long it takes, and how icebergs are distributed in Baffin Bay and along the Labrador coast have been of interest to the U.S. Coast Guard in managing the International Ice Patrol and to others, for many years.

The interest of the U.S. Coast Guard concerning icebergs in Baffin Bay and along the Labrador coast grew from a desire to understand better the entire iceberg problem. Following the R.M.S. *Titanic* disaster of 1912 the Coast Guard was assigned the duty of operating the Ice Patrol. It was readily apparent that an understanding of the natural factors controlling the drift and deterioration of icebergs would be of great value in intelligently operating the patrol. Information on iceberg distributions in Baffin Bay and along the Labrador coast is an important part of understanding the total iceberg problem. It has long been suspected that the number and distribution of icebergs available to drift south from Baffin Bay could be a significant factor in determining the severity of iceberg conditions on the Grand Banks during a given ice season.

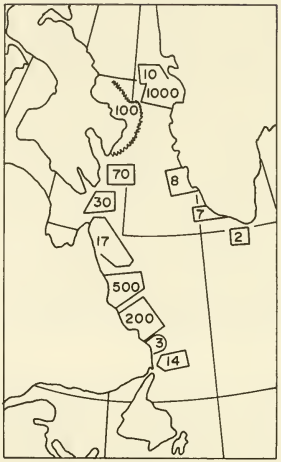
The first attempt to collect information systematically on iceberg distributions north of the Grand Banks was in the summer of 1914 when the U.S. Revenue Cutter *Seneca* sailed as far north as southern Labrador "to observe the origin of the ice which annually appears on the Banks of Newfoundland, and to investigate the agencies by which it is transported from the North." (Johnson, 1915). The next expedition took place 14 years later when the U.S. Coast Guard Cutter *Marion* was dispatched as far north as Disko Island for oceanography and ice observation under the command of Lieutenant Commander (later Rear Admiral) Edward H. "Iceberg" Smith (Smith, 1931). Later cruises and expeditions were made by the ships indicated below.

1931	USCGC *General Greene*---	Southern Greenland and Labrador coast to Hudson Strait.
1933	USCGC *General Greene*---	Southern Greenland and Labrador coast to Hudson Strait.
1934	USCGC *General Greene*---	Southern Greenland and Labrador coast to 54N.
1935	USCGC *General Greene*---	Southern Greenland and Labrador coast to 54N.
1936	USCGC *General Greene*---	Southern Greenland and Labrador coast to 54N.
1938	USCGC *General Greene*---	North to Davis Strait.
1939	USCGC *General Greene*---	Southern Greenland and Labrador coast to 54N.
1940	USCGC *Northland*--------	Baffin Bay.

The cruise of the *Northland* in September of 1940 was the first attempt at a complete survey of the icebergs in Baffin Bay. The results of the iceberg surveys conducted by the *Marion* in 1928 and the *Northland* in 1940 are shown in figure 22. The cruises by these two ships were important because they provided the first systematic information about iceberg conditions in the Labrador Sea and Baffin Bay. Although these two efforts at surveying were necessarily limited by the speed and visibility from the ships, the results established iceberg distribution patterns which have been affirmed by later aerial surveys.

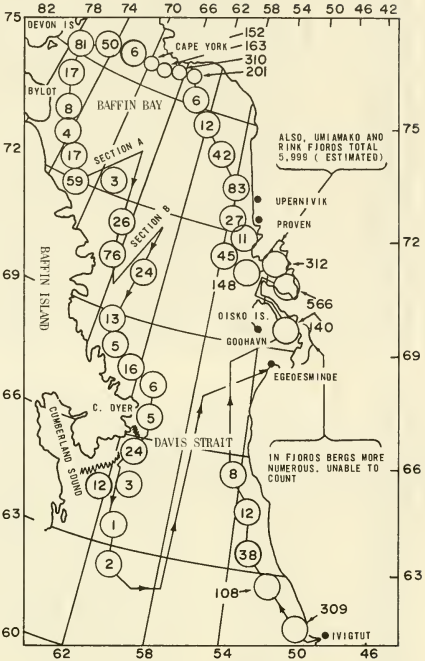
The cruise of the *Northland* was the last use of a ship for the purpose of trying to survey large areas of Baffin Bay or the Labrador coast for icebergs. The cruise of the *Northland* had actually been the first of a series of three annual summer cruises recommended in December 1939. The Second World War resulted in the discontinuation of the series. Following the war, in July 1948, a Coast Guard PB1G Flying Fortress patrol aircraft made the first aerial iceberg survey of Baffin Bay. The aircraft was equipped with an aerial camera, and many of the glaciers and fjords of western Greenland were photographed. The following year, in August 1949, a second survey was made, this time utilizing two PB1G aircraft. Over 1800 aerial photogrpahs were taken on the second survey and used in determining the number of icebergs present along the west coast of Greenland. In accordance with the recommendations of 1939 a third survey was planned to complete the series in 1950. Unfortunately the partial closing of one of the airfields from which the surveys were conducted led to the abandonment of the 1950 survey. Although interest remained in the northern iceberg surveys, 14 years were to pass before they recommenced. However preseason iceberg reconnaissance flights to guard against an unexpected intrusion of icebergs onto the Grand Banks were routinely made as far north as Belle Isle Strait during this period.

In November 1961 and November 1962 the Canadian Department of Transport collected data on iceberg distribution in the course of sea ice surveys in Baffin Bay. The data was provided by the International Ice Patrol, and it was used in analyzing iceberg conditions on the Grand Banks in 1962 and 1963. The Coast Guard recommenced northern iceberg surveys in January 1963 when a SC–130 Hercules patrol aircraft surveyed as far north as southern Baffin Island. Since then surveys at least as far north as Hudson Strait have been made during the periods shown in figure 23. The results of most of these survey flights are given in the Reports of the International Ice Patrol Service in the North Atlantic Ocean for the years 1963 through 1970 (Corwin *et al.* 1964; Lenczyk, 1965a; Lenczyk, 1965b; Murray, 1969a; Murray, 1969b; Murray, 1969c; Kelly and Morgan, 1970. Lenczyk (Corwin *et al.* 1964; 1965a; 1965b) analyzed the 1963, 1964, and 1965 data for the size distribution and travel times of icebergs along the Baffin Island and Labrador coasts. A notable series of surveys were made in 1965 when flights as far north as Hudson Strait were carried out each month of the year, thus giving some indication of the annual iceberg cycle along the Labrador coast. In September 1968 the first complete survey of Baffin Bay since 1949 was made, the surveys between 1964 and 1967 having covered only the western part of the bay. Also in 1968, during August, the U.S. Coast Guard Oceanographic Unit made a photographic survey of West Greenland glacier fronts between 69N and 79N. Similar aerial surveys of Baffin Bay and photographic surveys of the glacier fronts were conducted in the fall of 1969, and are planned for the fall of 1970. When the 1970 surveys are completed they will accomplish the goal set in 1939 of surveys for 3 consecutive years.



ICEBERGS

1928



1940

Figure 22.—Distribution of Icebergs as Observed the Summer of 1928 and September 5-23, 1940.

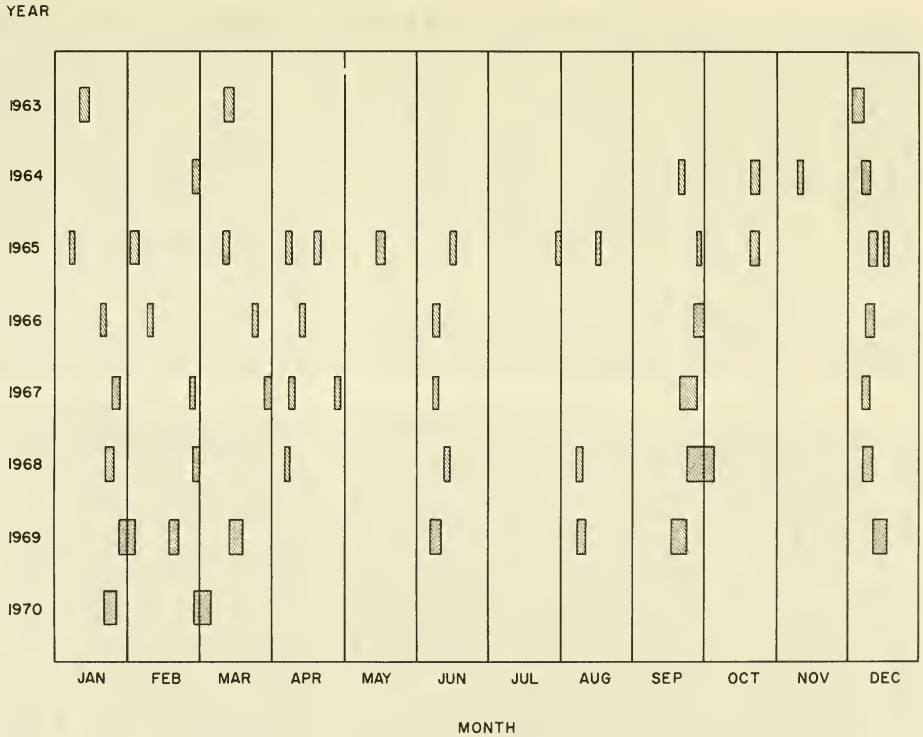


Figure 23.—Monthly Distribution of Northern Icebergs Surveys 1963-70.

Techniques of Preseason Aerial Iceberg Observation

The precise technique used in iceberg observation has varied somewhat from year to year, although generally it is simple and straightforward. In the HC130B Hercules aircraft the ice observers usually sit on stools behind the pilot and copilot where they can see the doppler navigational instruments. One of the ice observers has a chart of the area on a portable plotting board. As the aircraft flies along on its planned tracks, which are normally 25 to 30 miles apart, the ice observers count icebergs as they pass abeam out as far as approximately 15 miles. At the end of a convenient interval, 5 or 10 miles, the number of icebergs counted is plotted on the chart. If the concentration of icebergs is not too large the counts are broken down into small, medium, and large icebergs. Another technique is to record the individual icebergs or groups of icebergs as they pass abeam. In large concentrations this technique requires a third man just to handle the plotting. A third technique is for the observer to pick out mentally an area marked by a few "landmark" icebergs, count the icebergs in that area, record the count in the corresponding area of the chart, and then shift his attention to a new area. In low visibility radar is used to obtain counts by methods identical to those described above for visual use.

On one occasion, in September 1968, a visual statistical sampling technique was used in place of actual counts covering the entire area. This technique was used along the coast and offshore from 30 to 60 miles between latitudes 77–30N and 75–30N because there were too many icebergs to count individually. From comparisons with the 1949 photographic survey it appears to the author that the statistical method is fairly reliable if the following 3 conditions are met: (1) iceberg concentrations are between about 10 and 200 icebergs per hundred square miles, (2) the results are not extrapolated from more than 20 miles off the aircraft track, and (3) the results are not extrapolated to fjords, small bays, or glacier fronts. In using the statistical technique the ice observers made one minute counts of icebergs abeam the aircraft within 7 miles every 3 minutes. The ratio of iceberg concentration beyond 7 miles to that within was also estimated. The miles to go to the next turn point was noted on the doppler navigational readout at the end of each 1 minute count. In the analysis of the data the areas in which counts were made were plotted on a chart, and then the data were interpolated or extrapolated for other areas using the concentration factors.

All of the iceberg surveys since 1963, with the exception of the glacier front surveys, have been visual surveys, supplemented where necessary by radar information. Due to the relative scarcity of shipping in Baffin Bay all radar targets can be presumed to be icebergs. In areas away from the West Greenland coast, probably 90 to 95% of the area of Baffin Bay, visual/radar iceberg observation appears to be adequate for the purpose of determining the general iceberg distribution and approximate count. However, there is a definite psychological tendency for iceberg observers, as they progress northward into Baffin Bay, to disregard an increasing number of smaller size icebergs because they tend to appear as mere growlers or berg bits in the presence of the greater number of very large icebergs found farther north.

The problem of accurate counts within a few miles of the West Greenland coast is much more complicated. Here there are icebergs which may be aground more or less permanently; there are icebergs which may be trapped within a fjord due to a shallow sill; there are icebergs out of sight from Baffin Bay tens of miles up a narrow twisting fjord; there are icebergs so densely concentrated along the front of a glacier that it is impossible to tell from the air where the icebergs stop and the glacier begins; and there are swarms of smaller pieces of ice within the fjords or just outside them which defy consistency in deciding whether they should or should not be included in the count. Visual estimates of the number of icebergs in this area can easily be off by 100% or even more when made from even slow flying aircraft. It is interesting to compare the comments of iceberg observers regarding this area. In a 1949 report it was stated that "Especially in the fjords and along the glacier fronts, the photograph was so full of ice that it staggered the imagination to distinguish bergs from growlers or brash." Using a similar expression a 1968 report notes that "Concentrations of icebergs in some areas in the vicinity of the Greenland coast were so dense that they completely staggered human ability to count the individual icebergs." An iceberg observer once commented orally that

the number of icebergs in the fjords along some glacier fronts will completely "blow your mind." In these areas camera surveys should be used for counts approaching an acceptable accuracy. Even with photographs available the problem of deciding which pieces of ice to count is very difficult in an ice choked area in which there is almost a continuum of pieces of ice covering the spectrum from brash to enormous pieces of glacial ice a mile or more in length. Possibly the best way of evaluating iceberg conditions in the near shore and estuarine area is by the comparison of photographs.

An analysis of the difference between visual and photographic surveys was made of the 1949 data by Soule (1951). Considering the three areas A, B, and C shown in figure 24, Soule found that the ratio between photographic and visual counts for area A was 2.4, for area B was 1.8, and for area C was about 1.0. The high ratio in area A was influenced by the large number of icebergs present in the fjords of West Greenland. The high ratio in area B is probably due to the large number of icebergs which typically congregate between Cape York and Devon Island. The close agreement between photographic and visual counts in area C indicates that visual methods are probably satisfactory for all areas away from the Greenland coast.

Fall Iceberg Surveys

The fall northern iceberg surveys of Baffin Bay include July or August surveys made in 1948 and 1949, and September or October surveys made each year from 1964 to the present. The results of the surveys, in terms of icebergs per two square degrees, are shown in figures 25 through 31. The charts were constructed by plotting the iceberg count for each two square degree areas in the center of the area, and then contouring the resulting chart. The two square degree areas used for plotting were rectangles measuring one degree latitude by two degrees longitude. Thus rectangles were 60 miles in latitude and varied from about 30 to 50 miles in longitude. For features on the contoured chart to be significant they should generally be at least 60 miles in size. Because of the unreliability of nearshore and estuarine counts the contours were not extended into these areas. In general the heavy iceberg concentrations shown off the West Greenland coast appear somewhat farther to seaward than they actually are. This is because the data were plotted in the center of each two square degree area, and the heavy iceberg concentrations usually fall off rapidly away from the coast. The validity of the method of presenting the data may be questioned because of the use of continuous contouring to represent counts of discrete icebergs which are locally random in their distribution. The method appears justified in its results; the contoured distributions are reasonable, and they show a marked similarity from year to year.

Figure 32 is a composite average of all comparable data between 1948 and 1969, and an average of only the September/October data.

The average charts and the charts for the various years show several interesting features which appear to be the normal pattern for summer and fall iceberg distributions in Baffin Bay. It is readily apparent that, with few exceptions, icebergs are concentrated around the periphery of Baffin Bay, with the heaviest concentrations found in eastern Baffin Bay along the Greenland coast. This agrees with Smith's finding (1940) that "bergs were numerous within a coastal zone of 15 miles; farther offshore they became quite scattered to sparse, and farther than 40 miles out they were only occasional. It would appear, from our observations, that in the central portions of Davis Strait and Baffin Bay bergs were very infrequent."

Tongues of icebergs extending westward or southwestward into Baffin Bay from the Greenland coast are commonly found at Disko Bay, Northeast Bay, and between 73N and 75N. If it is inferred that these tongues represent icebergs drifting directly across Baffin Bay, then this path appears to be an important route, in some years possibly more important than the generally accepted route through Melville Bay and then south along Devon, Bylot, and Baffin Island. A comparison of these two routes in 1948, 1949, 1968, and 1969 indicates that each route appears to have contributed approximately the input shown below.

Year	*Percent of input going through Melville Bay*	*Percent of input going directly across Baffin Bay*
1948	64	36
1949	31	69
1968	73	27
1969	55	45

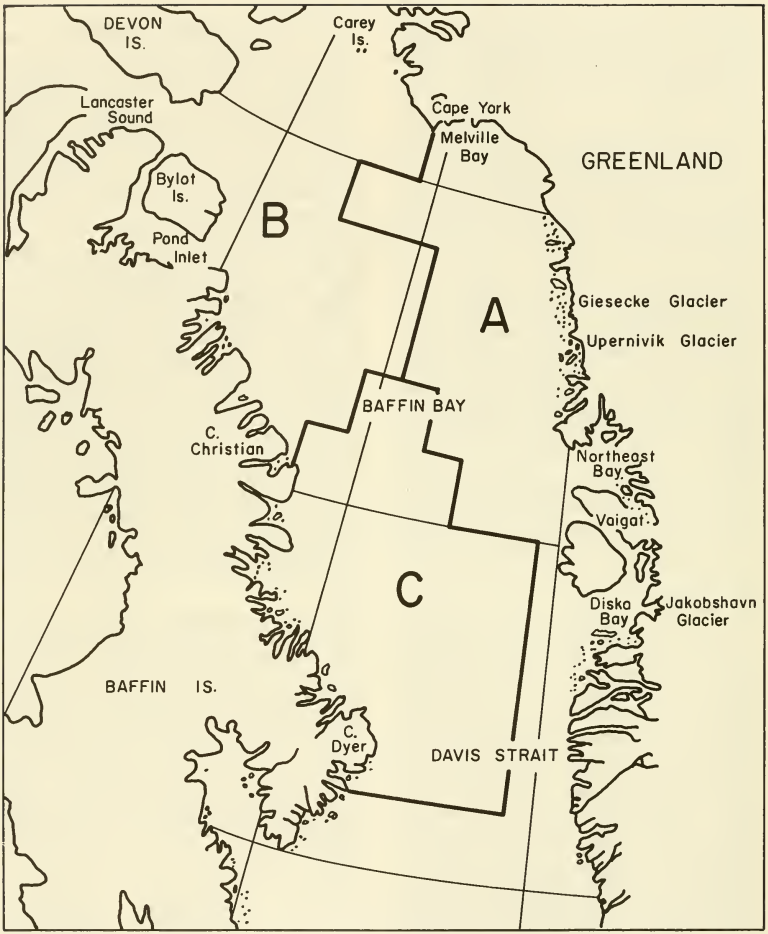


Figure 24.—Locator Chart for Areas A, B, C.

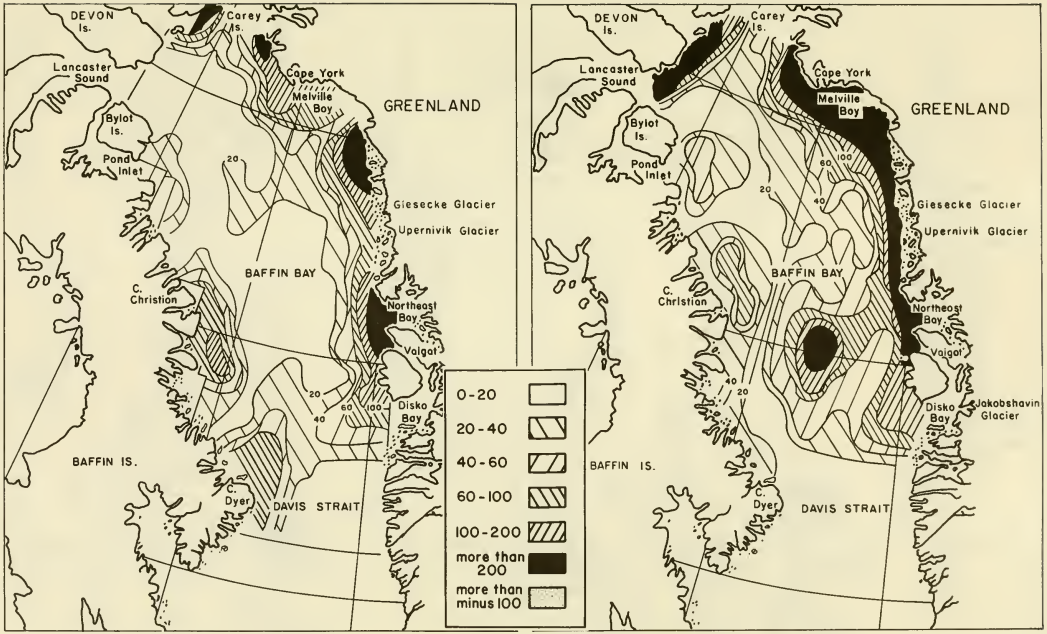


Figure 25.—Iceberg Concentration, 11-30 July 1948 and 10-18 August 1949.

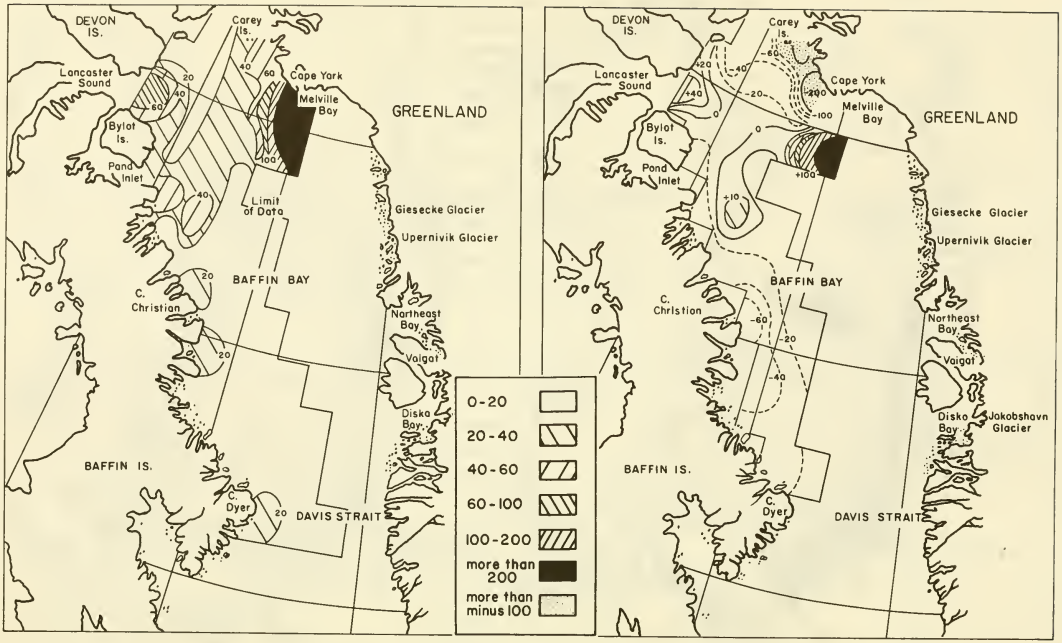


Figure 26.—Iceberg Concentration, 21-23 October 1964, and Anomaly From 1964-69 Average.

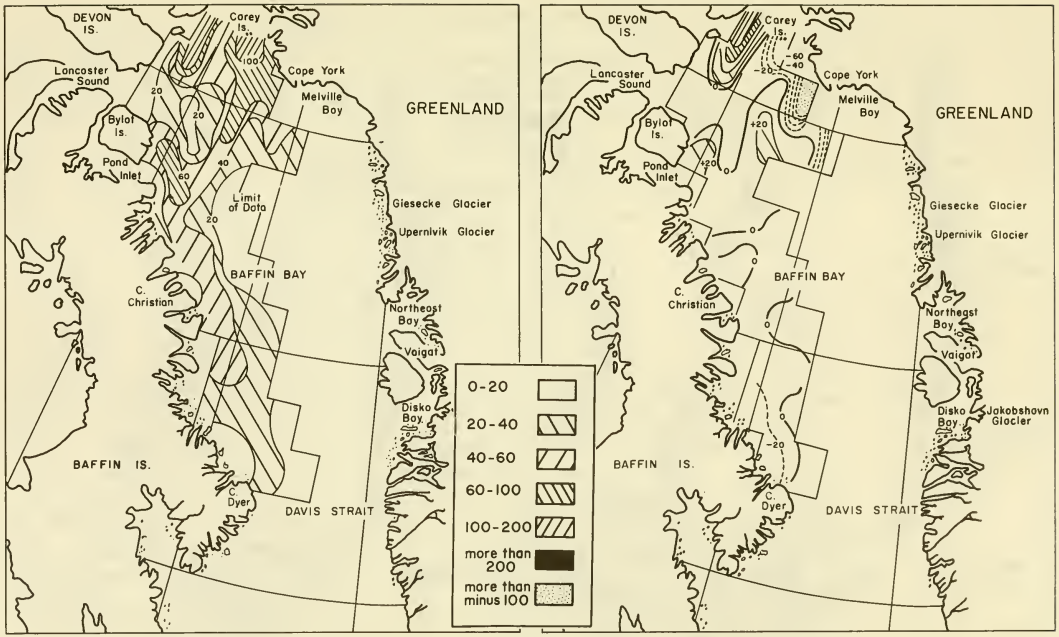


Figure 27.—Iceberg Concentration, 20-22 October 1965, and Anomaly From 1964-69 Average.

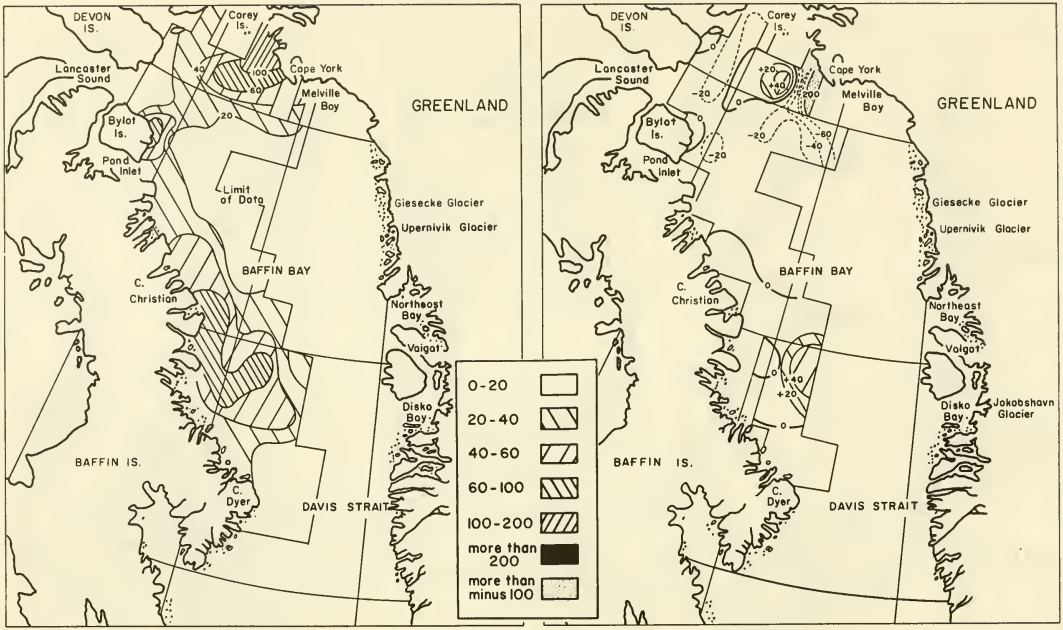


Figure 28.—Iceberg Concentration, 26-30 October 1966, and Anomaly From 1964-69 Average.

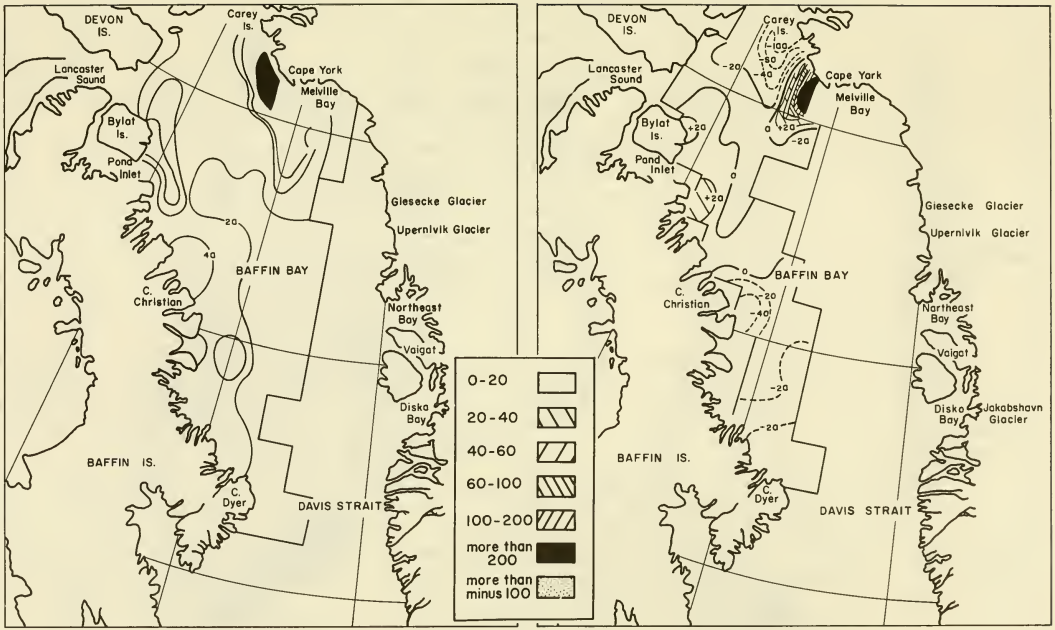


Figure 29.—Iceberg Concentration, 21-28 September and Anomaly From 1964-69 Average.

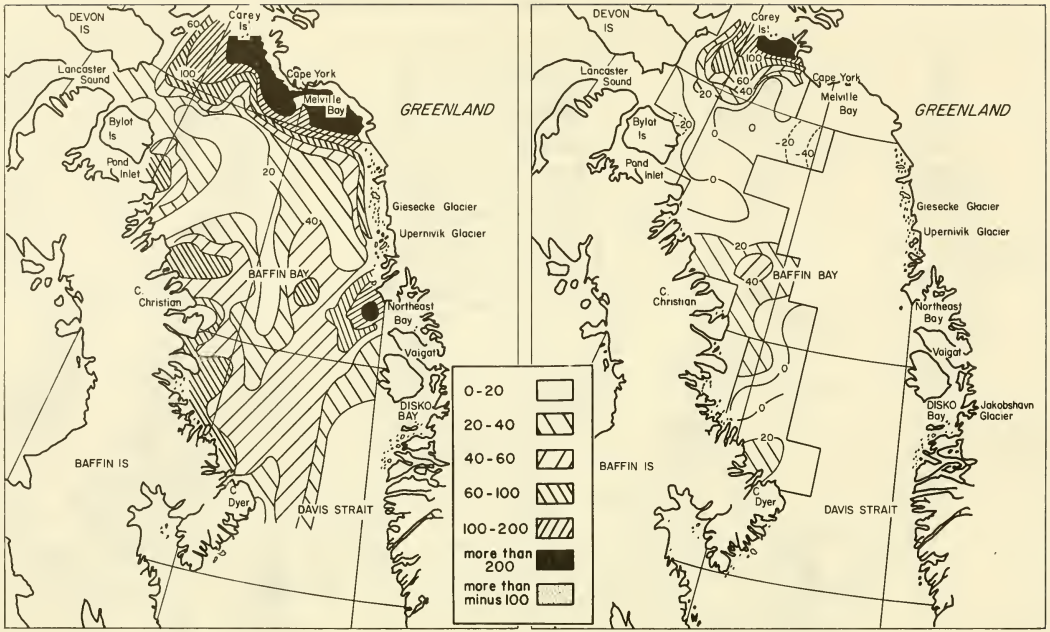


Figure 30.—Iceberg Concentration, 24 September 4 October 1968, and Anomaly From 1964-69 Average.

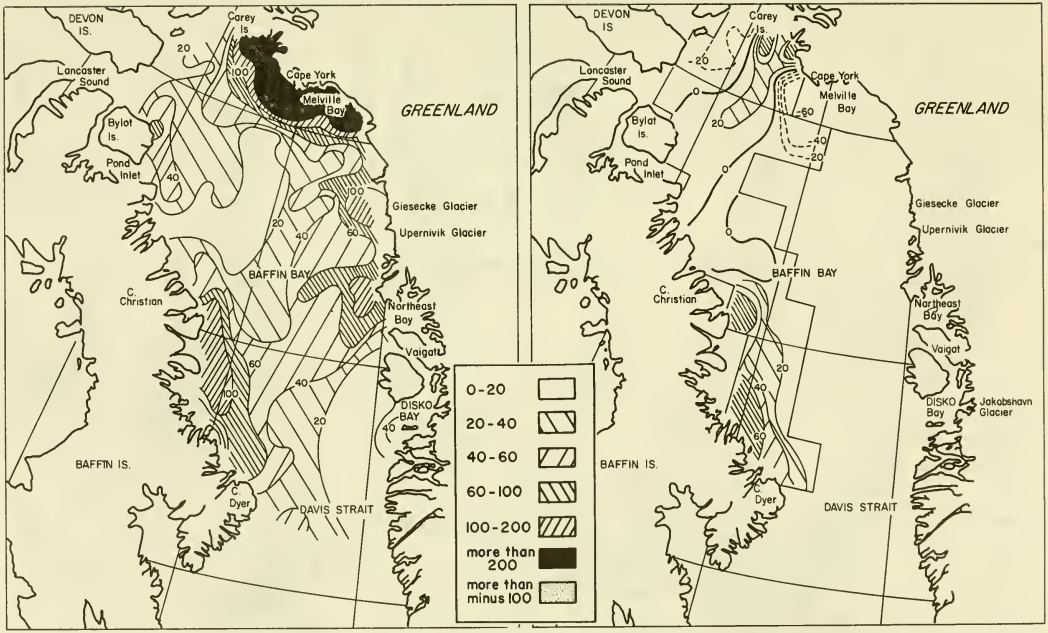


Figure 31.—Iceberg Concentration, 18-23 September 1969, and Anomaly From 1964-69 Average.

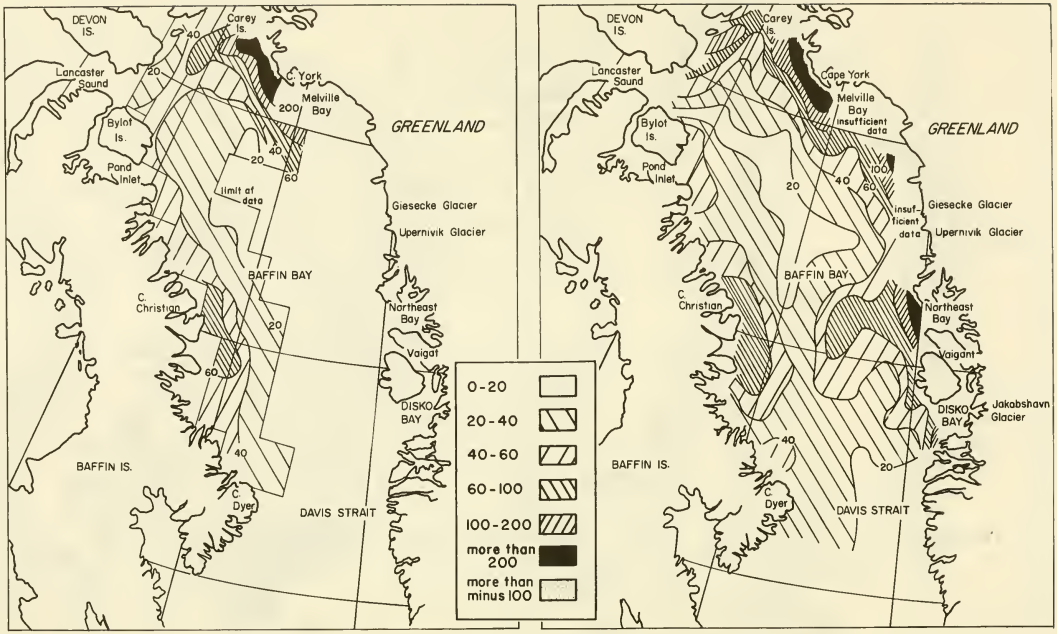


Figure 32.—Average September/October Iceberg Concentration 1964-69 and Composite Average July, August, September, October 1948, 1949, 1964-69.

The July chart for 1948 shows a well developed tongue extending from Disko Bay, and little if any indication of a tongue from Northeast Bay. The August chart for 1949 and the September charts for 1968 and 1969 show well developed tongues from Northeast Bay, with no indication of a tongue from Disko Bay in 1968, and small tongues in 1949 and 1969. It appears that the difference between the July and the August or September charts may be a normal seasonal phenomenon. According to the *Ice Atlas for the Northern Hemisphere* (U.S. Hydrographic Office, 1955), sea ice normally clears from Disko Bay in June or July and from Northeast Bay in July. Thus icebergs calved in Disko Bay are released from sea ice sooner than those calved farther north in Northeast Bay. This would result in the season's production of icebergs from Disko Bay appearing as a tongue in July and then dissipating in August or September as they drifted northward or westward. Meanwhile another tongue would be formed off Northeast Bay as the icebergs were released from the sea ice in that area.

Indications of southwestward tending tongues between 73N and 75N are found on the charts for July 1948, August 1949, and September 1969.

Very heavy concentrations of icebergs are usually found in northern Melville Bay, along the Greenland coast in the vicinity of Cape York, and around the Carey Islands. Many of the icebergs found in these areas drift there in the north-flowing West Greenland current. In some years the heavy iceberg concentrations continue across northern Baffin Bay to Ellesmere and Devon Islands on the Canadian side of Baffin Bay. Off Baffin Island heavy iceberg concentrations are typically found in the general vicinity of Pond Inlet, off Cape Christian, and north of Cape Dyer. The largest concentrations are found off Cape Christian, probably due to the shallow area which extends off-shore in this area, and the confluence of the two iceberg routes mentioned previously, directly across Baffin Bay and north through Belville Bay. As an example of the grounding of icebergs in the shallow water off Cape Christian, a large iceberg was grounded a short distance from the beach there for 2 years. The iceberg concentration north of Cape Dyer appears most prominent in July and August, rather than September or October, indicating that the concentrations may be at least partially due to the confluence of icebergs drifting north through Melville Bay and those coming directly across Baffin Bay from Disko Bay in the summer.

Deviations from the average 1964–69 iceberg distribution shown in figures 28 through 31 document an interesting progression of positive anomalies in northern Baffin Bay during the period 1966 through 1969. In September 1966 there was a deficiency of icebergs in northern Baffin Bay near Cape York. September 1967 found large numbers of icebergs extending westward past Cape York in a broad band. By September 1968 the center of the large excess of icebergs had moved northwest to the vicinity of the Carey Islands. Finally in September 1969 it appears that the excess of icebergs in the area began to dissipate. Apparently the iceberg excess was released into Baffin Bay in the summer of 1966 when the average August air temperature at Upernavik was 18°C above normal. The icebergs had probably not drifted as a group to the vicinity of Cape York in time to be observed on the September flight. However they were beginning to show up south of Cape Christian as can be inferred from the positive anomaly in that area in September. 1967 was a very heavy iceberg season on the Grand Banks; apparently the potential for the heavy season was due to the excess of icebergs which moved directly across Baffin Bay during the late summer and fall of 1966. The icebergs which moved northwest toward Melville Bay evidently were not a major threat to the Grand Banks until 1970, 3 years later. However in 1970 weather conditions were unfavorable for a heavy iceberg season and a light season was recorded.

The above data seem to indicate that the iceberg danger on the Grand Banks can come about by two routes. One, icebergs drift directly across Baffin Bay and threaten the Grand Banks the following year; and two, icebergs drift north into Melville Bay to threaten the Grand Banks during the next several years. Which route the icebergs will take probably is quite dependent on wind and ocean current conditions as they move from glacier fronts into or through the West Greenland Current. It is quite possible that in a given group of icebergs some will follow the northern route and others will follow the direct route. It is possible that the potential for very large iceberg seasons on the Grand Banks is a result of large numbers of icebergs from both routes coinciding in their time of exiting Baffin Bay to drift south.

In any event it appears that the direct route across Baffin Bay is a very important one for icebergs, and one which can provide a late and rapidly developing threat to the Grand Banks.

December Northern Iceberg Surveys

December iceberg survey flights along the Labrador and Baffin Island coasts have been made during the years 1963 through 1969. The timing of the December flights has been remarkably consistent, all having taken place the first part of December. December flights do not extent farther off-shore from the Labrador coast than 200 miles. Therefore the data does not cover the central Labrador Sea or the west Greenland coast south of 66N. The results of the individual surveys are shown in figures 33 through 39 in terms of icebergs per two square degrees. The methods used in plotting and contouring the data are the same as for the fall flights. Figure 40 shows average iceberg conditions based on 4 to 7 year's data.

The largest iceberg concentration in December is found in the vicinity of Cape Christian, as was the case for the fall surveys. There is some indication that the concentration off Cape Christian increases slightly between fall and winter. As was the case in the fall surveys there is a tendency for icebergs to concentrate north of Cape Dyer. Movement of icebergs directly across Baffin Bay is only slightly discernable in the average chart, however it shows up more clearly in the individual charts, particularly the one for 1969. Continuing southward the next major iceberg concentrating area is the hook-like peninsula between Cumberland Sound and Frobisher Bay. In the entrance to Hudson Strait there normally appears to be a slight break in iceberg concentration. This is probably related to the flow of currents in and out of the Strait. South of Hudson Strait icebergs again tend to concentrate, probably because of shallow areas extending well off-shore between the Strait and Hopedale.

January Preseason Iceberg Surveys

The purpose of the January flights has been to monitor the progress of the icebergs as they drift south toward the Grand Banks, and to estimate how heavy the iceberg season will be. Figures 41 through 47 show January iceberg distributions for the various years 1963 and 1965 through 1970 in icebergs per two square degrees along the Baffin Island and Labrador coasts. As was the case in the December flights the coverage does not extend offshore more than about 200 miles at most. Figure 48 based on 4 to 7 years data, represents average January iceberg conditions in this area. The general pattern of iceberg concentrations is similar to the December pattern with accumulations of icebergs found between Cumberland Sound and Frobisher Bay, and along the northern Labrador coast. However, the average total iceberg count south of Cumberland Sound increases by a factor of about 2 between December and mid-January. The average southern limit of icebergs in both December and January is about 53N.

The correlation between the number of icebergs in January south of 60N, as far north as coverage has been uniform, and the number of icebergs which drift south of 48N into trans-Atlantic shipping routes during March through July is low, as is shown by figure 58. The correlation coefficient is only 0.19 using a least squares fit between the two variables. Use of data north to 64N, for the years in which it was available, did not improve the correlation. This low correlation between January iceberg potential along the Labrador coast and iceberg severity on the Grand Banks in the following months emphasizes the importance of other factors in January, primarily winter winds, in determining the severity of the iceberg season on the Grand Banks.

February Preseason Iceberg Surveys

The preseason iceberg surveys carried out in February are the most important preseason Ice Patrol activities of the U.S. Coast Guard. The February surveys are directly related to the operation of the Ice Patrol in that during a number of years icebergs have begun to threaten the Grand Banks in February. Also the results of the February flights are a major factor in deciding when to start routine iceberg patrols of the Grand Banks and daily broadcasts of iceberg positions.

Unfortunately the so-called February flights have not all been made at the same time each years. In fact there have been years in which flights have not been made in February, but rather were made in early March instead. In order to analyse these surveys more uniformly they have all been adjusted to a common date of 25 February. This was done by "drifting" the icebergs sighted on the various surveys forward or

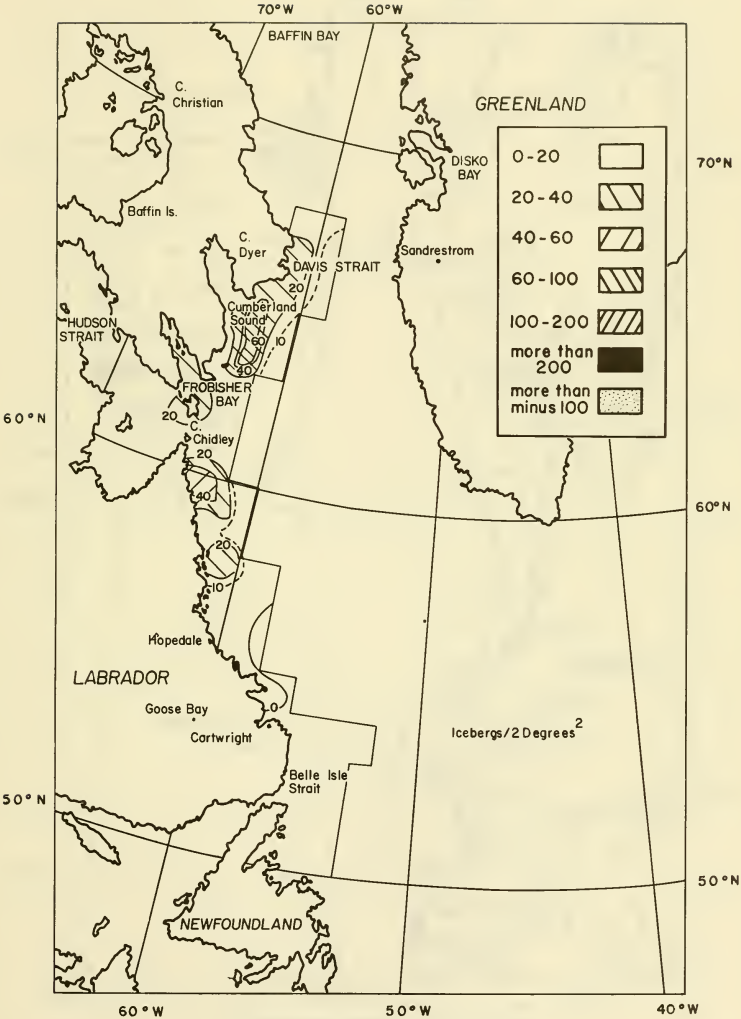


Figure 33.—Iceberg Concentration, 3-5 December 1963.

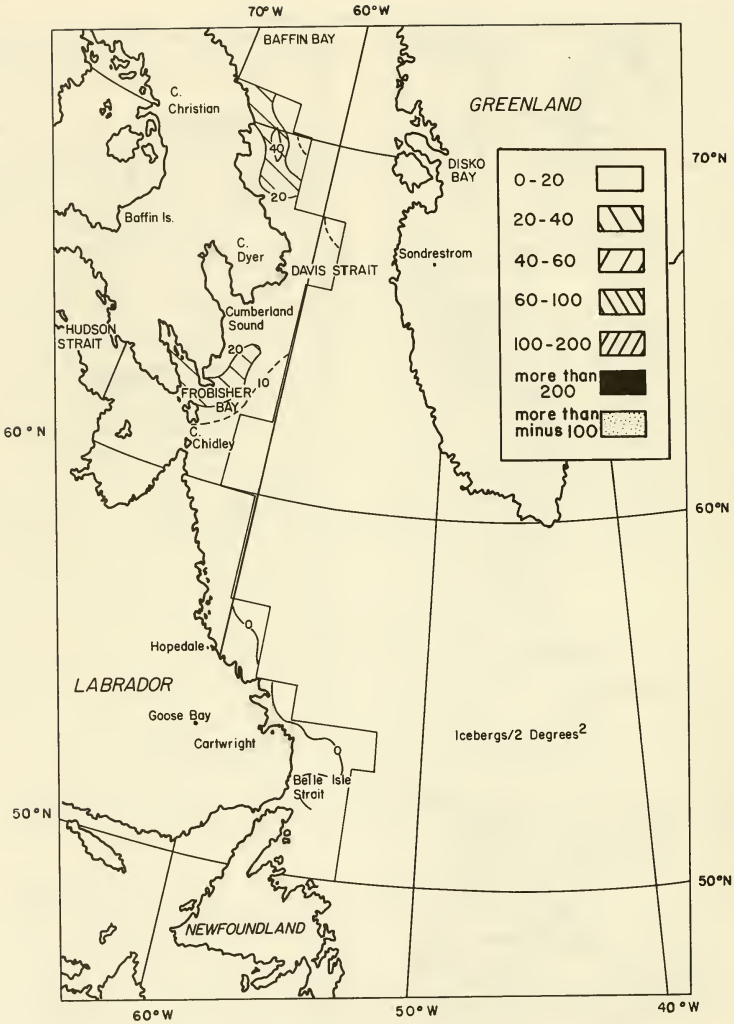


Figure 34.—Iceberg Concentration, 6-8 December 1964.

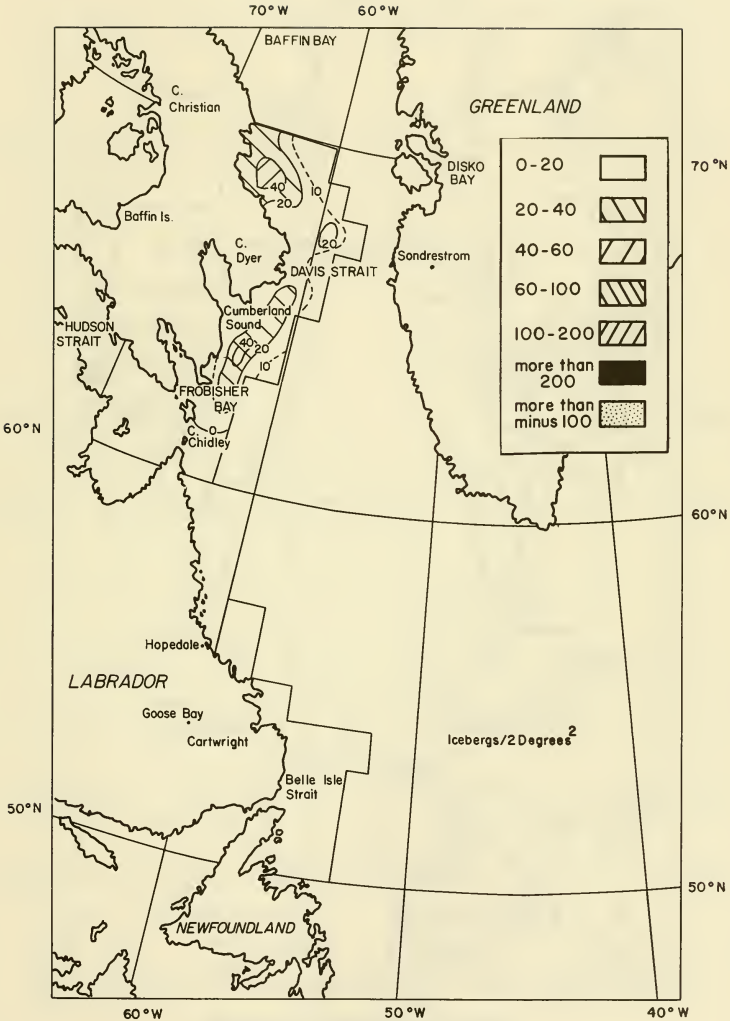


Figure 35.—Iceberg Concentration, 9-11 December 1965.

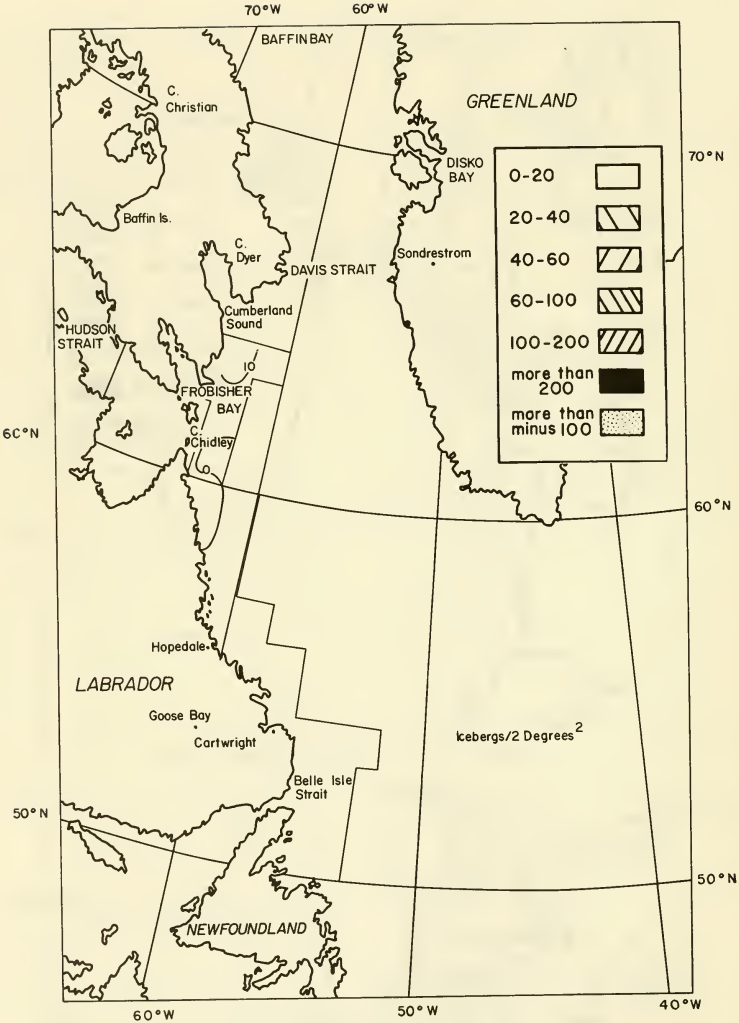


Figure 36.—Iceberg Concentration, 8-9 December 1966.

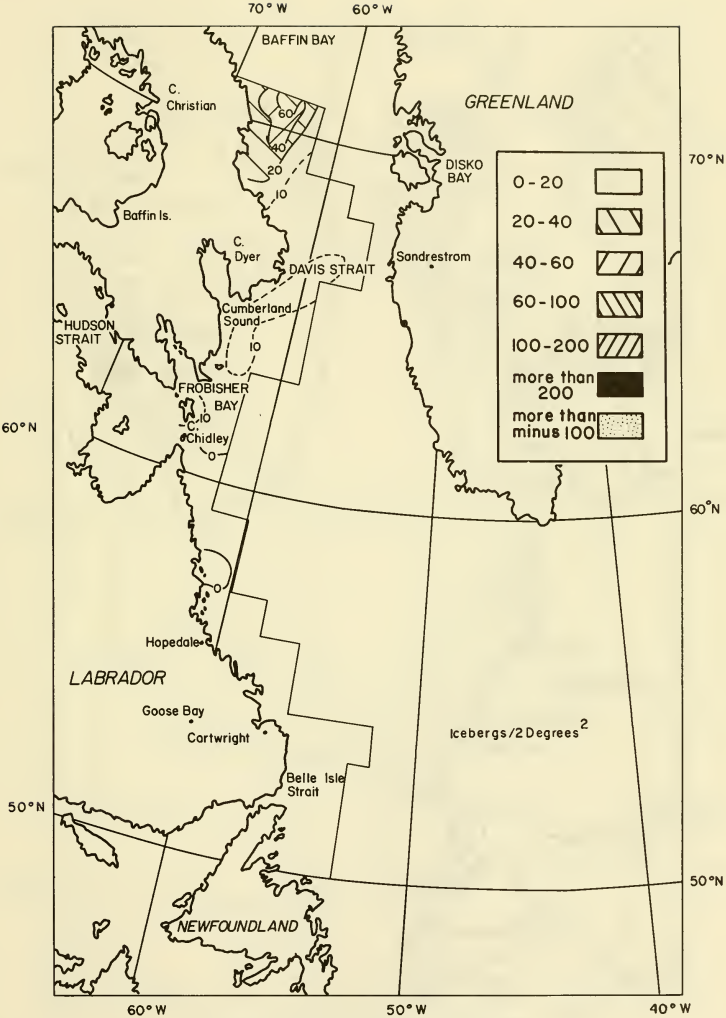


Figure 37.—Iceberg Concentration, 6-9 December 1967.

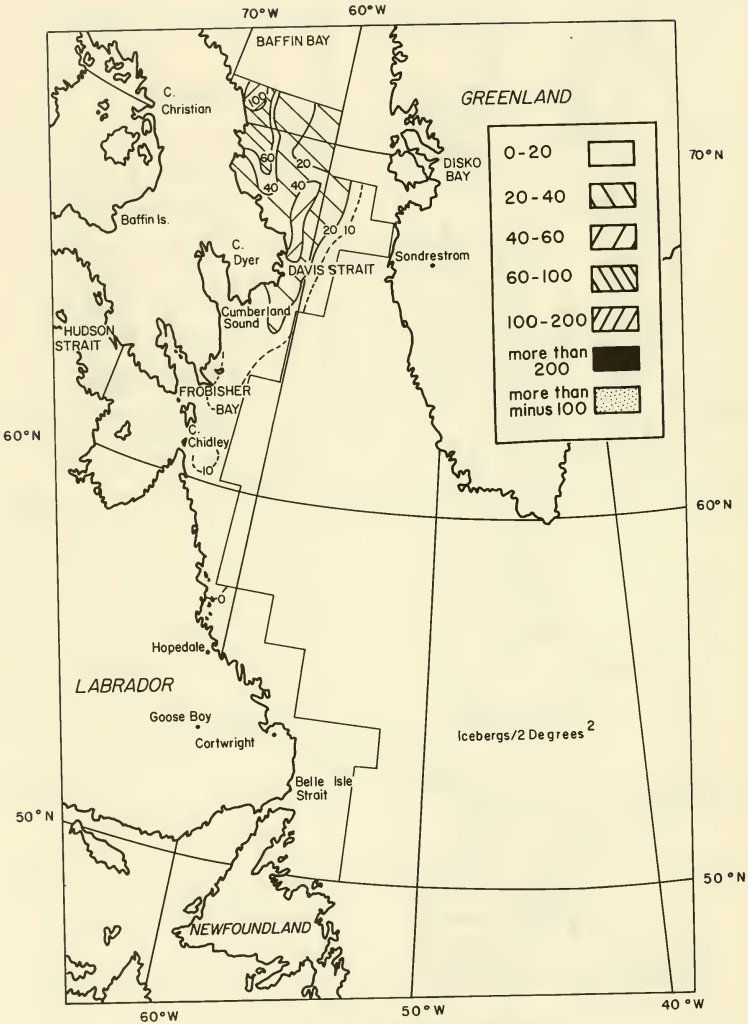


Figure 38.—Iceberg Concentration, 5-10 December 1968.

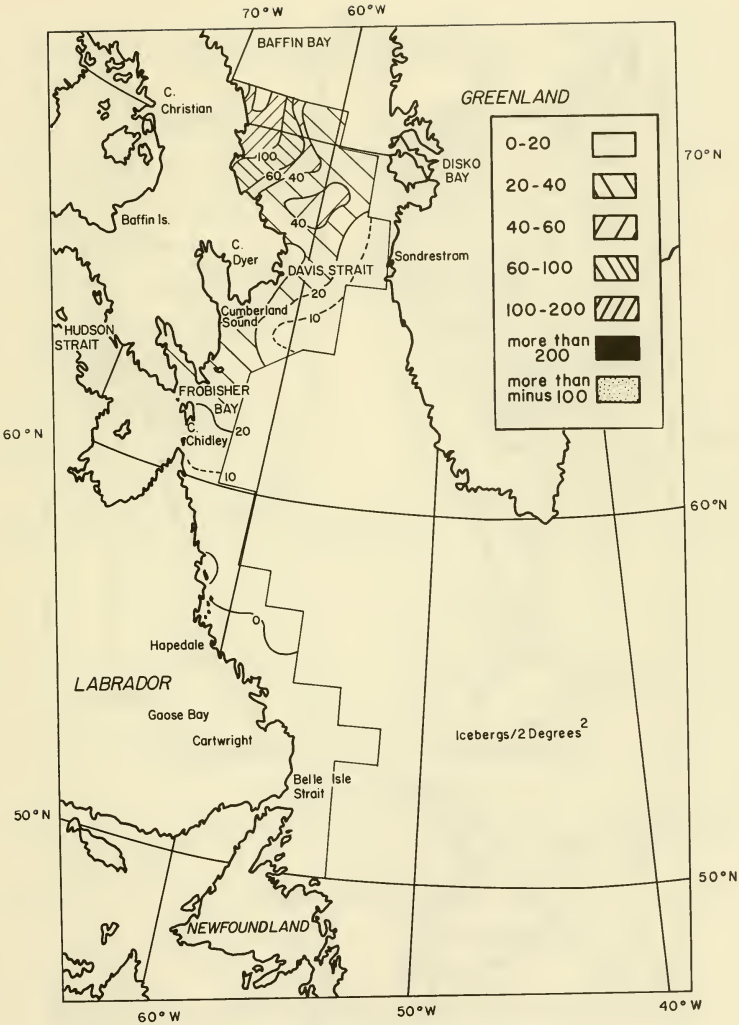


Figure 39.—Iceberg Concentration, 11-16 December 1969.

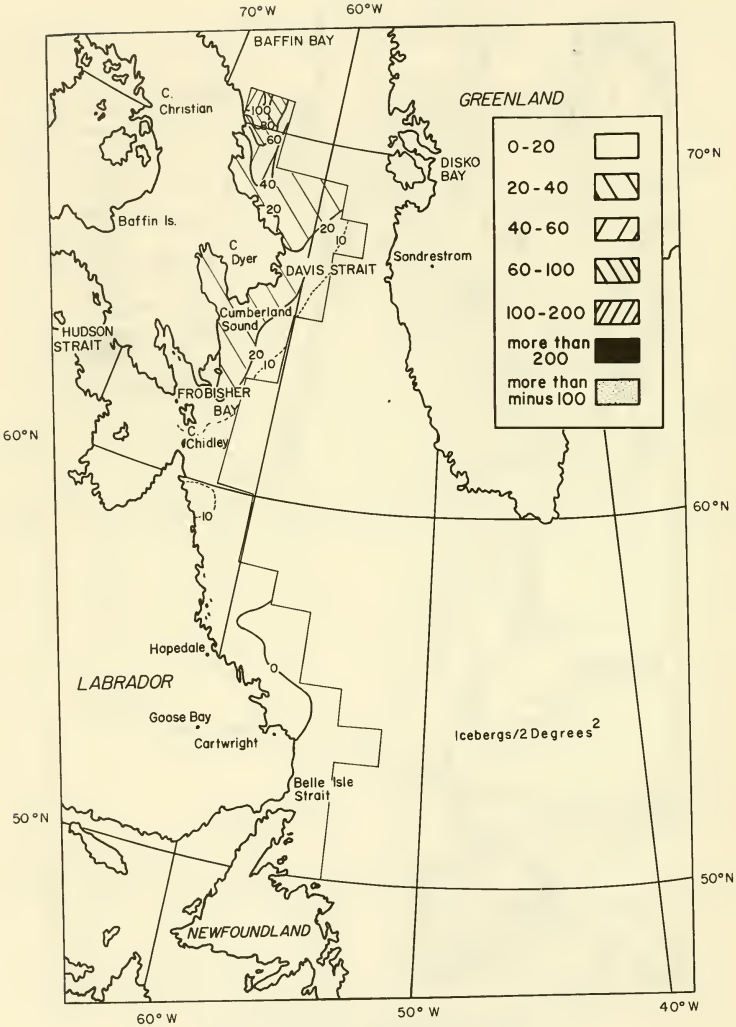


Figure 40.—Iceberg Concentration, December Average 1963-69.

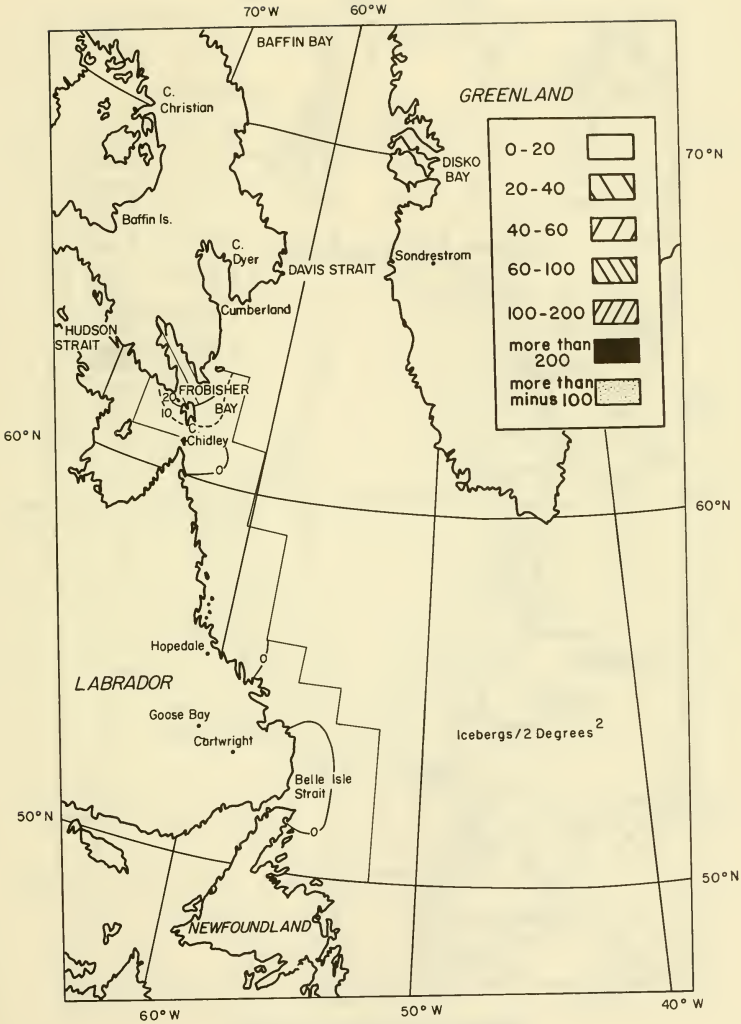


Figure 41.—Iceberg Concentration, 13-14 January 1963.

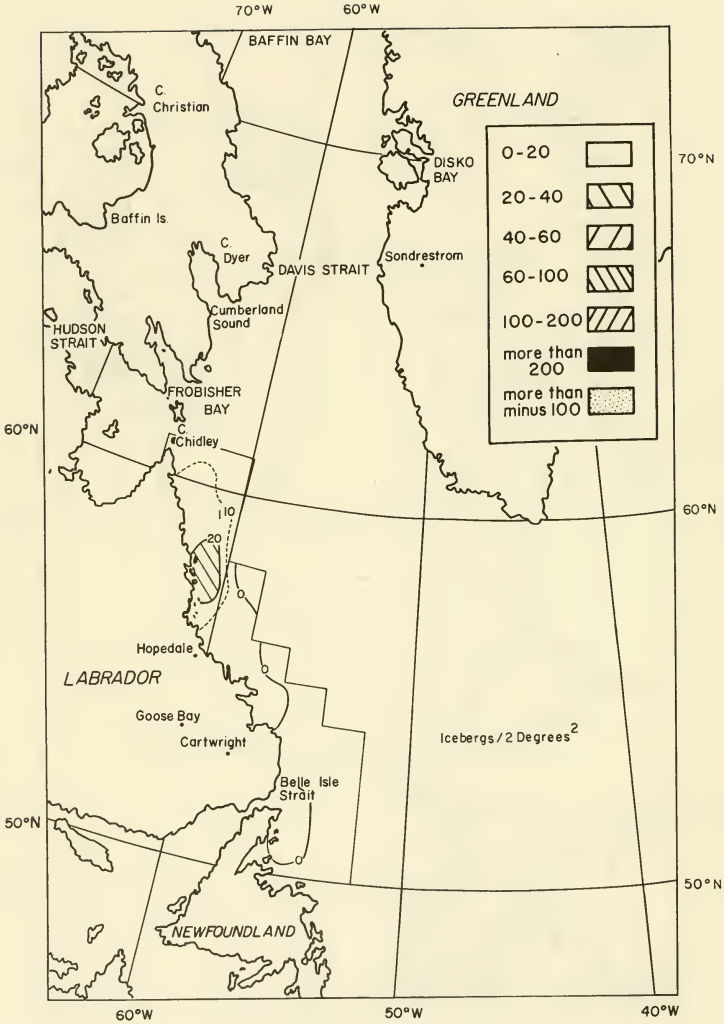


Figure 42.—Iceberg Concentration, 7 January 1965.

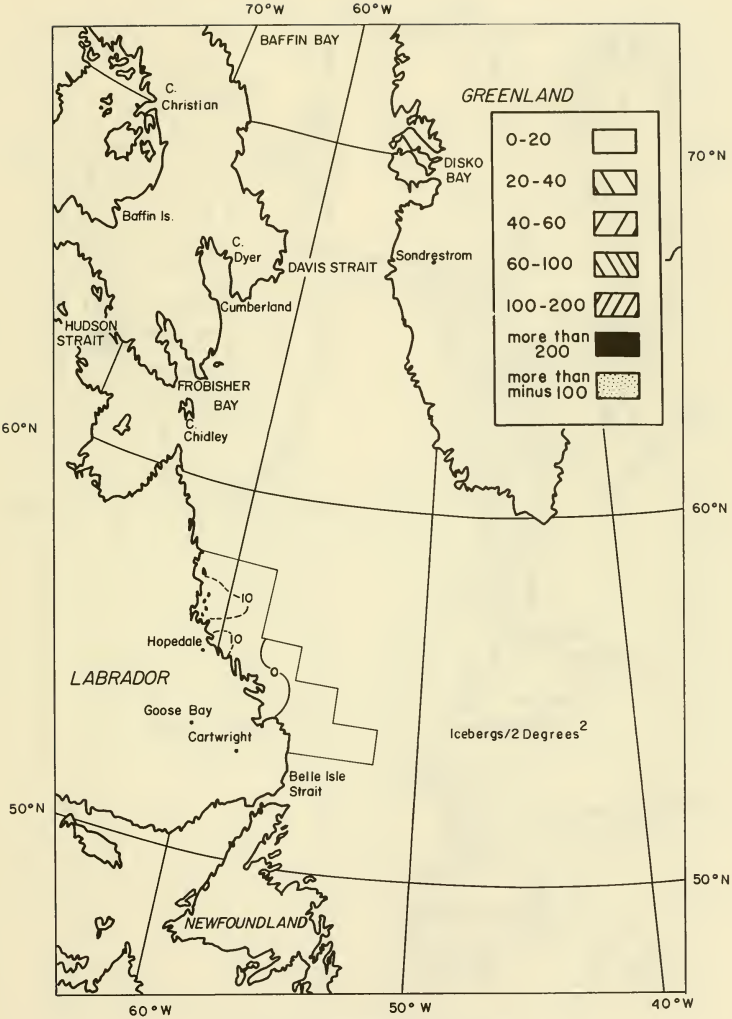


Figure 43.—Iceberg Concentration, 20 January 1966.

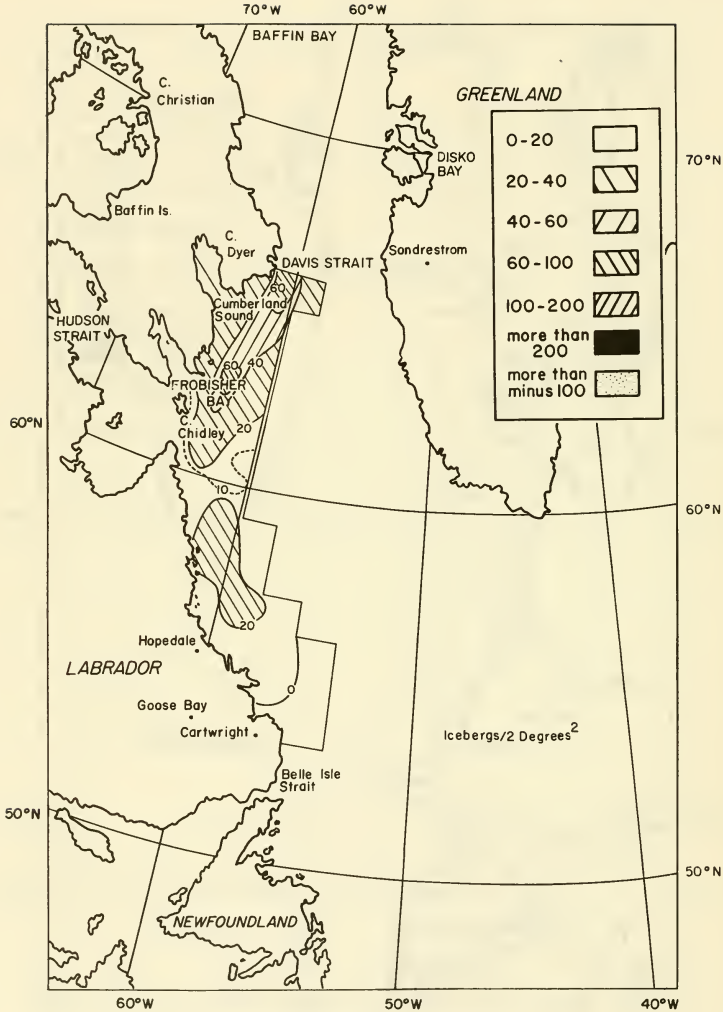


Figure 44.—Iceberg Concentration, 25-26 January 1967.

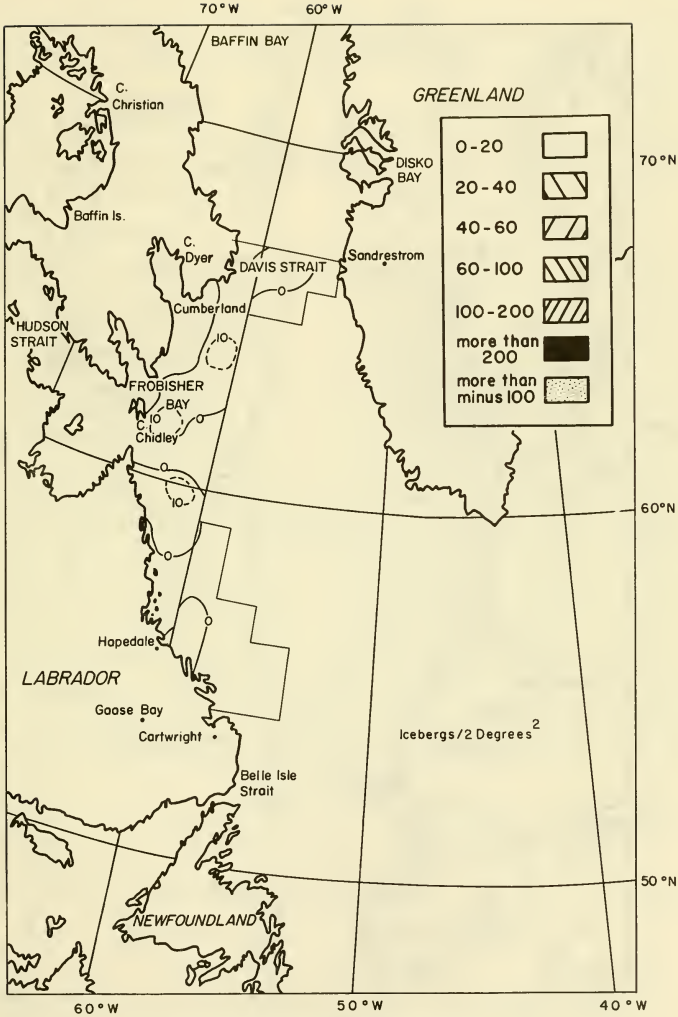


Figure 45.—Iceberg Concentration, 22-25, January 1968.

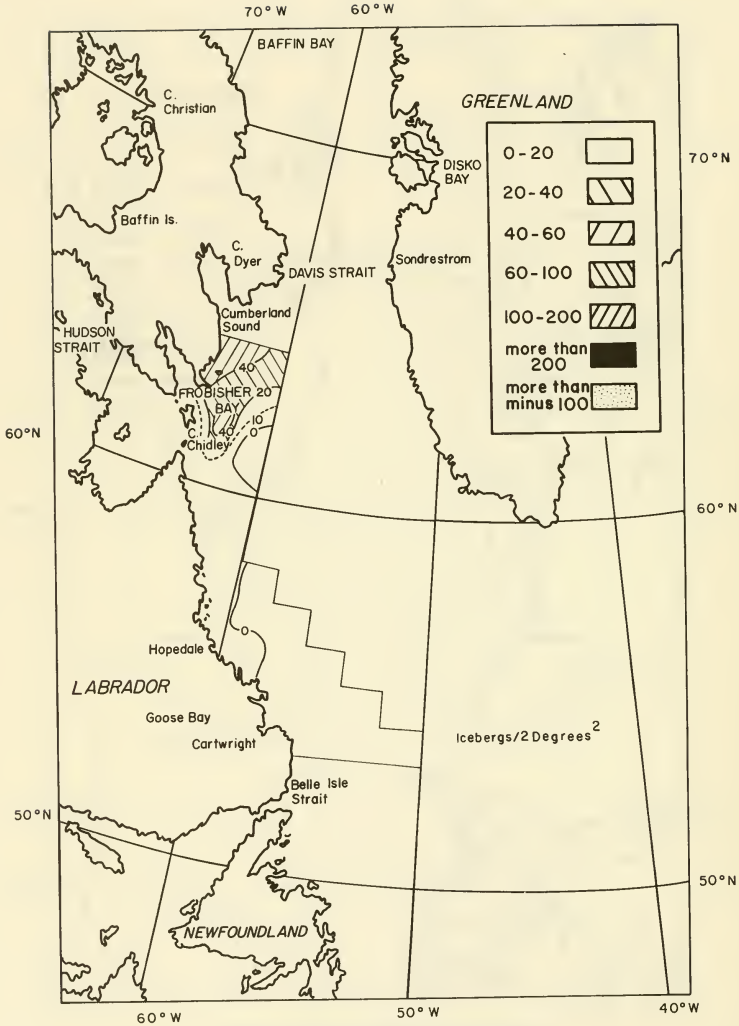


Figure 46.—Iceberg Concentration, 27 January-2 February.

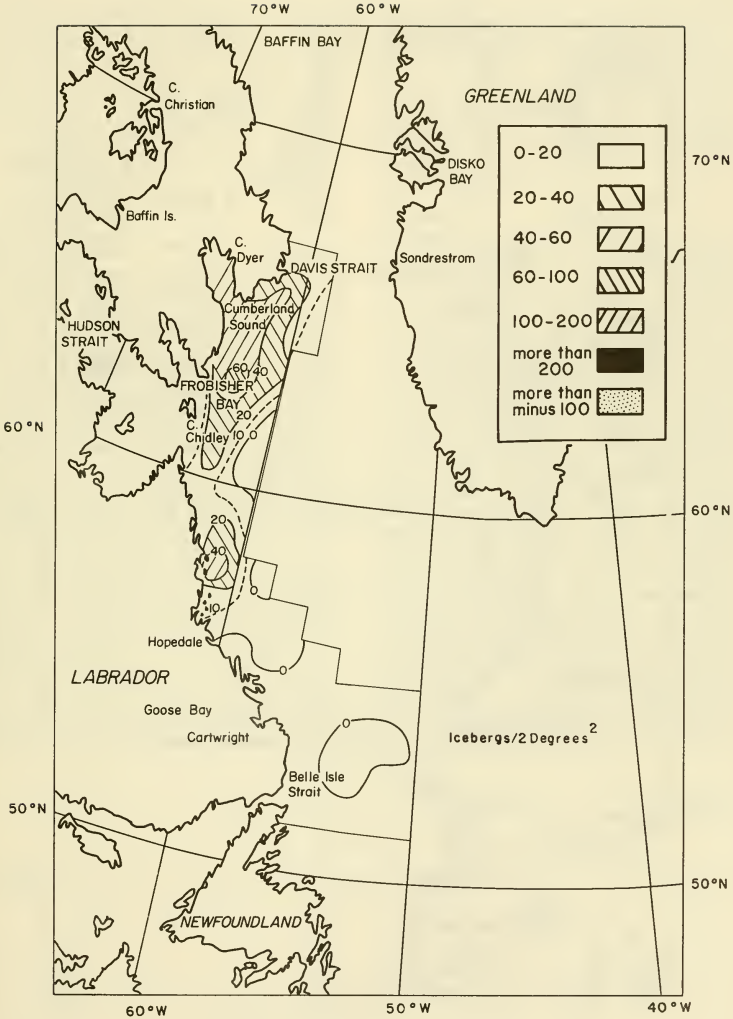


Figure 47.—Iceberg Concentration, 20-24 January 1970.

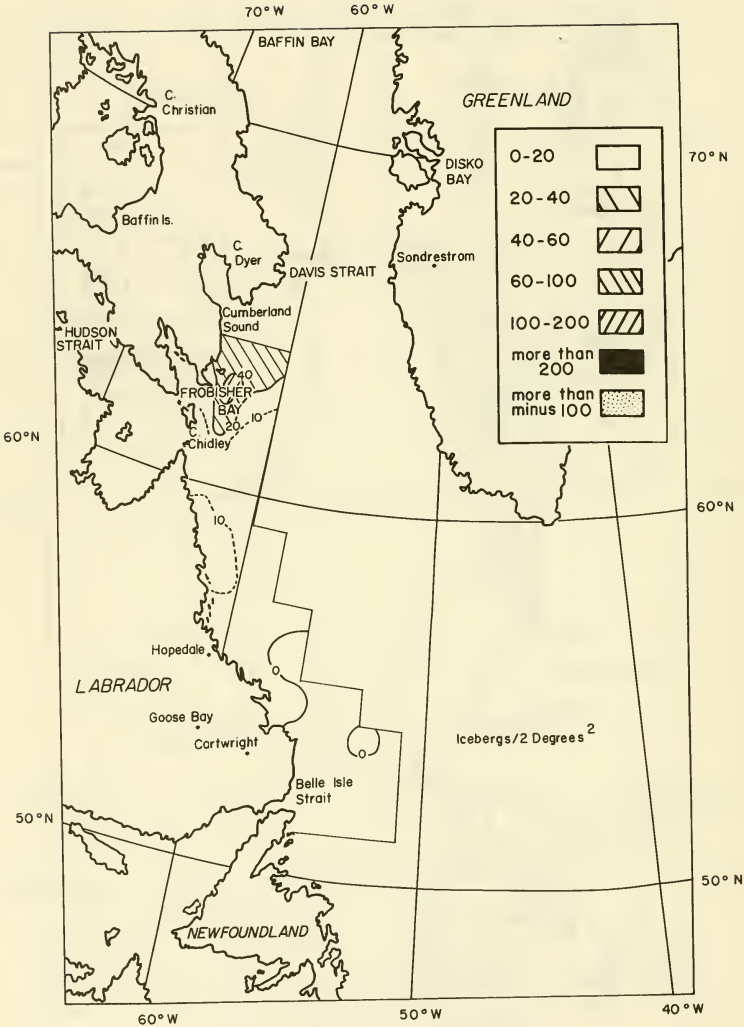


Figure 48.—Iceberg Concentration, January Average, 1963-70.

backward in the Labrador Current at a rate of 7 miles per day (selected as the best average of several estimates of the drift rate of icebergs along the Labrador coast reported in the various Reports of the International Ice Patrol Service in the North Atlantic Ocean). The actual dates of the "February" survey are given below:

27 February–4 March 1970
19–20 February 1969
27–28 February 1968
25–27 February 1967
9–10 February 1966
11 March 1965
26–28 February 1964
13–14 March 1963

February iceberg concentrations along the Labrador coast for the years 1963 through 1970 are shown in figures 49 through 56 in icebergs per two square degrees. Average iceberg concentrations for February are shown in figure 57. The average chart and the charts for the various years indicate that icebergs extend as a band down the Labrador coast with concentrations frequently occuring near 57N to 58N, near 55N to 56N, and near the Strait of Belle Isle. The average total iceberg count south of Hudson Strait increases by a factor of about 4 between mid-January and late February, and by a factor of about 10 between early December and late February.

The correlation between the number of icebergs south of 61N on the February survey and the number of icebergs drifting south of 48N is fair, as shown in figure 58. The actual correlation coefficient is 0.61 using a least squares fit between the two variables.

The correlation between the northern boundary of the southernmost one degree latitude interval containing 10 icebergs on the February survey and the date the first group of icebergs drift south of 48N is also given in figure 58. As indicated by a correlation coefficient of 0.77 there is a fairly good relationship between the southern extent of icebergs on the February flights and when the icebergs will begin to drift south of 48N. The average rate of drift which can be derived from this relationship, based on a reasonable path of iceberg drift, is 6.25 miles per day, a value in fair agreement with the drift rate of 7 miles per day estimated previously.

Conclusion

The primary purpose of this report has been to present an analysis of the geographical distribution of icebergs in certain areas in the fall and winter during the period 1963–70. Admittedly the length of the record is quite short for such an analysis. However it can be noted that the average number of icebergs drifting south of 48°N onto the Grand Banks during the period 1963–70 is about 180 per season, not greatly below the 1946–70 average of 229. Also the 1963–70 period has included a very heavy (441 icebergs) and a very light (0 icebergs) season. In the course of analyzing fall and winter iceberg distributions, fair to good correlations between January and February distributions and subsequent iceberg conditions on the Grand Banks have been noted. Further research should be directed toward analysis of these January and February distributions in connection with other environmental parameters such as wind, temperature, and ocean currents with a goal of developing accurate methods of forecasting the beginning, duration, and severity of the iceberg season on the Grand Banks. Meanwhile iceberg data collection in January and February should continue with the dates of the surveys being stabilized, preferably centered on 15 January and 25 February.

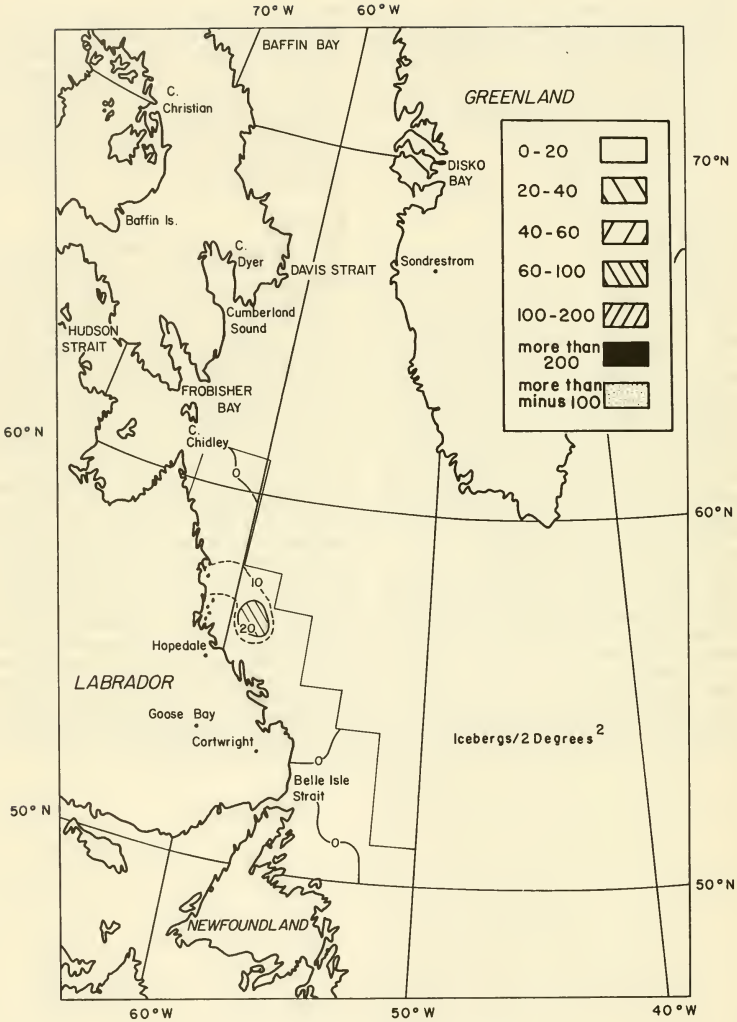


Figure 49.—Iceberg Concentration, February 1963.

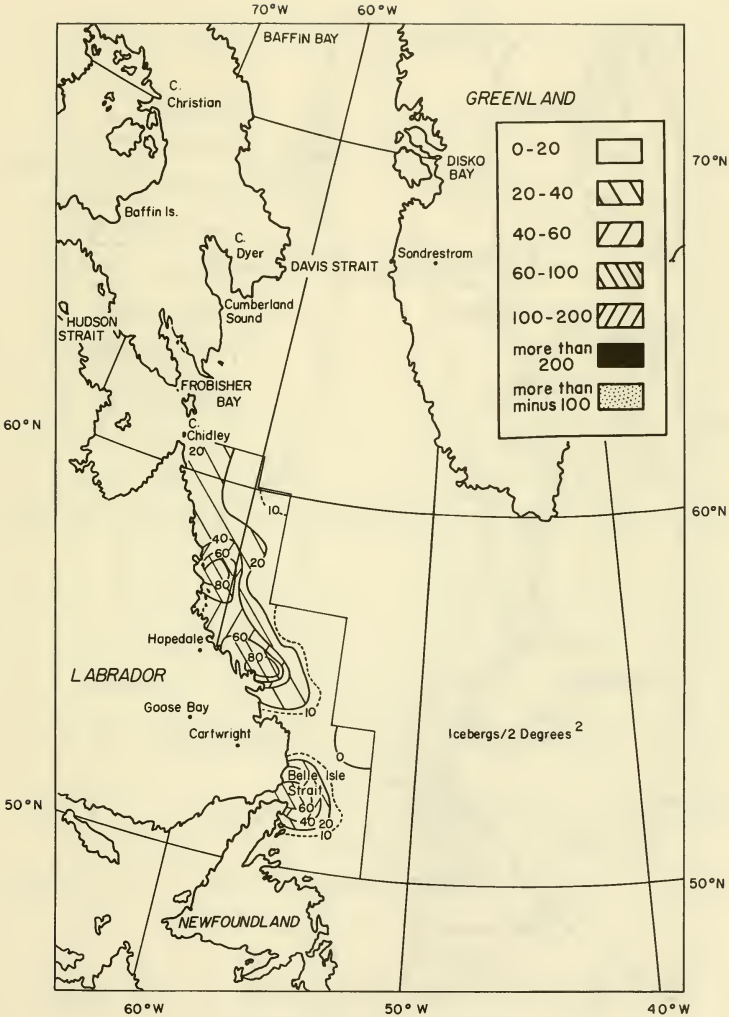


Figure 50.—Iceberg Concentration, February 1964.

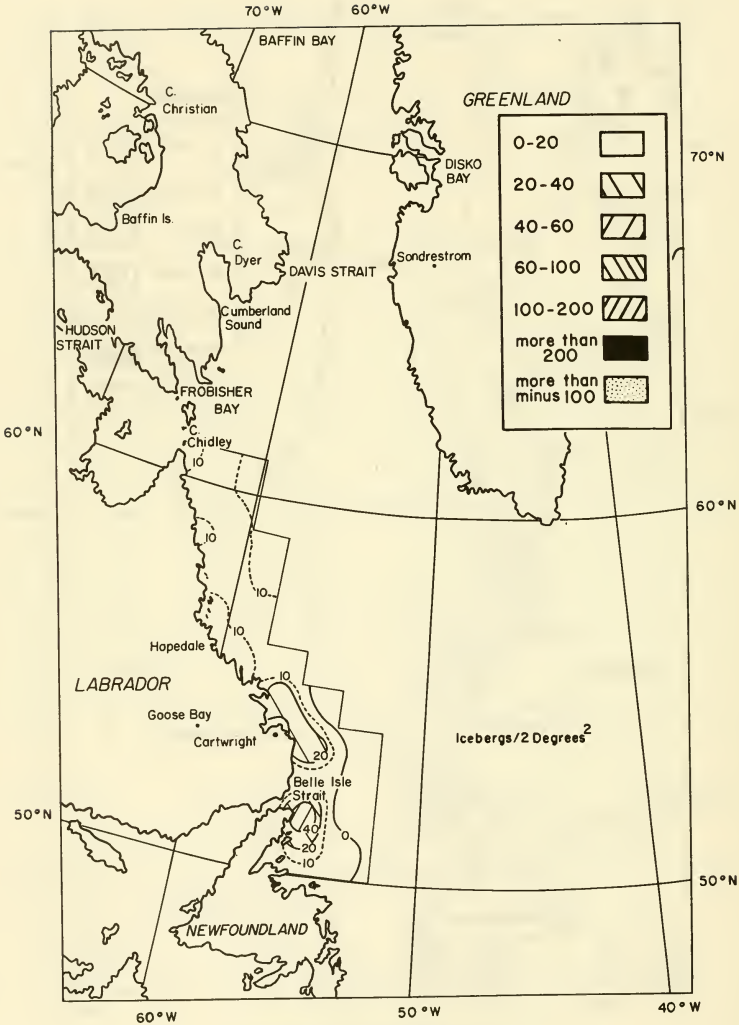


Figure 51.—Iceberg Concentration, February 1965.

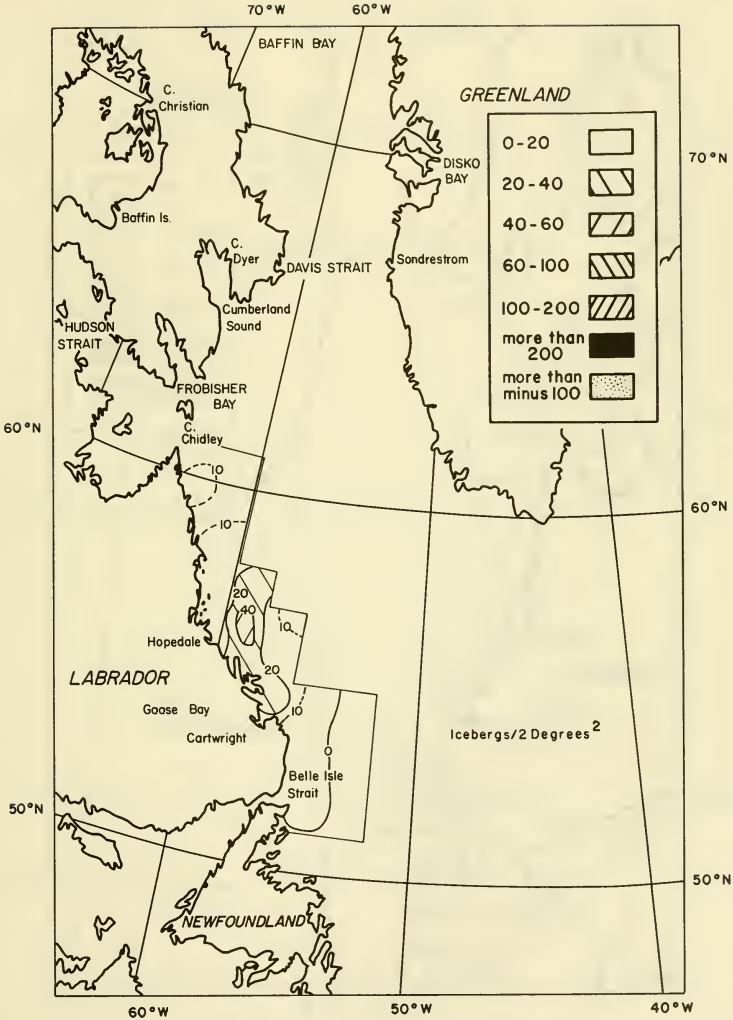


Figure 52.—Iceberg Concentration, February 1966.

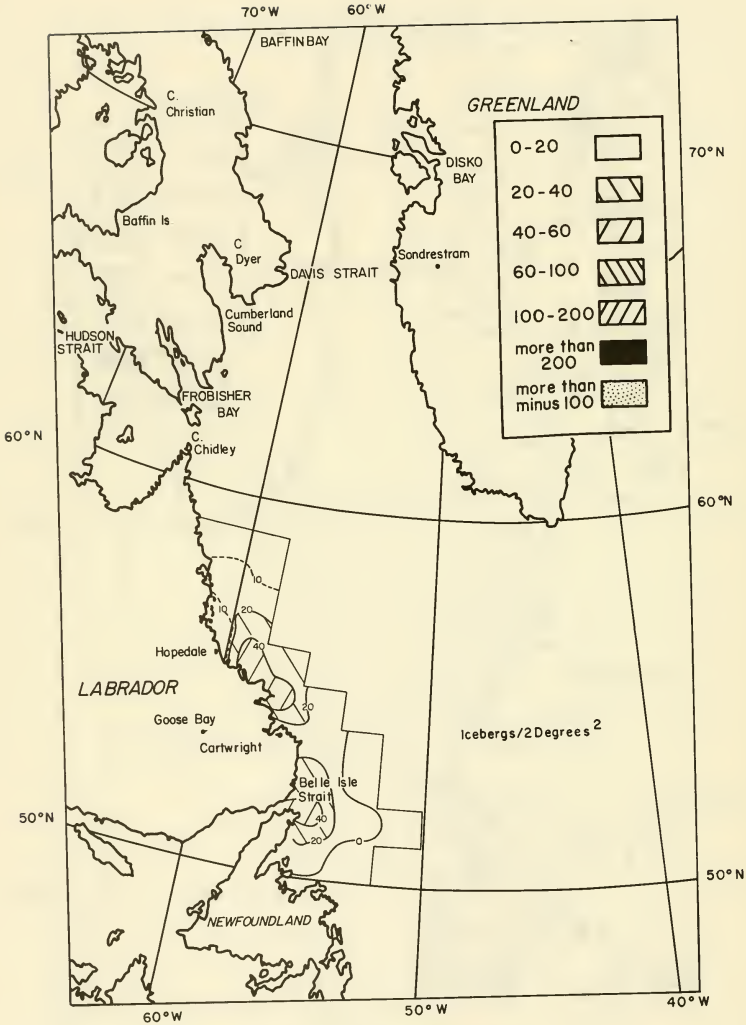


Figure 53.—Iceberg Concentration, February 1967.

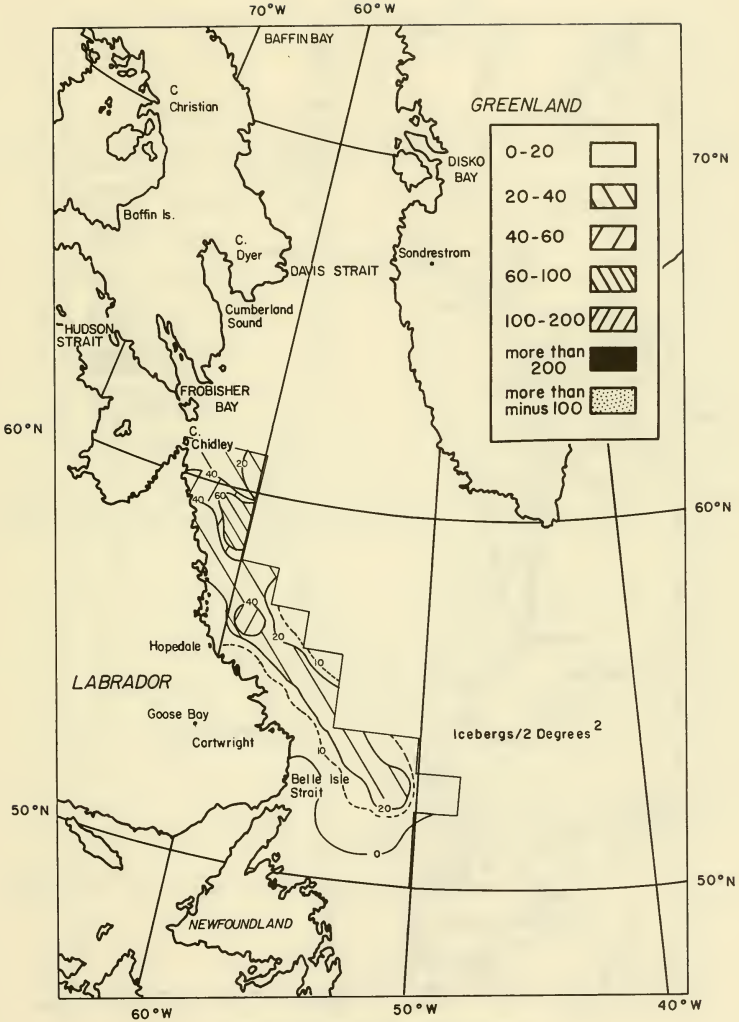


Figure 54.—Iceberg Concentration, February 1968.

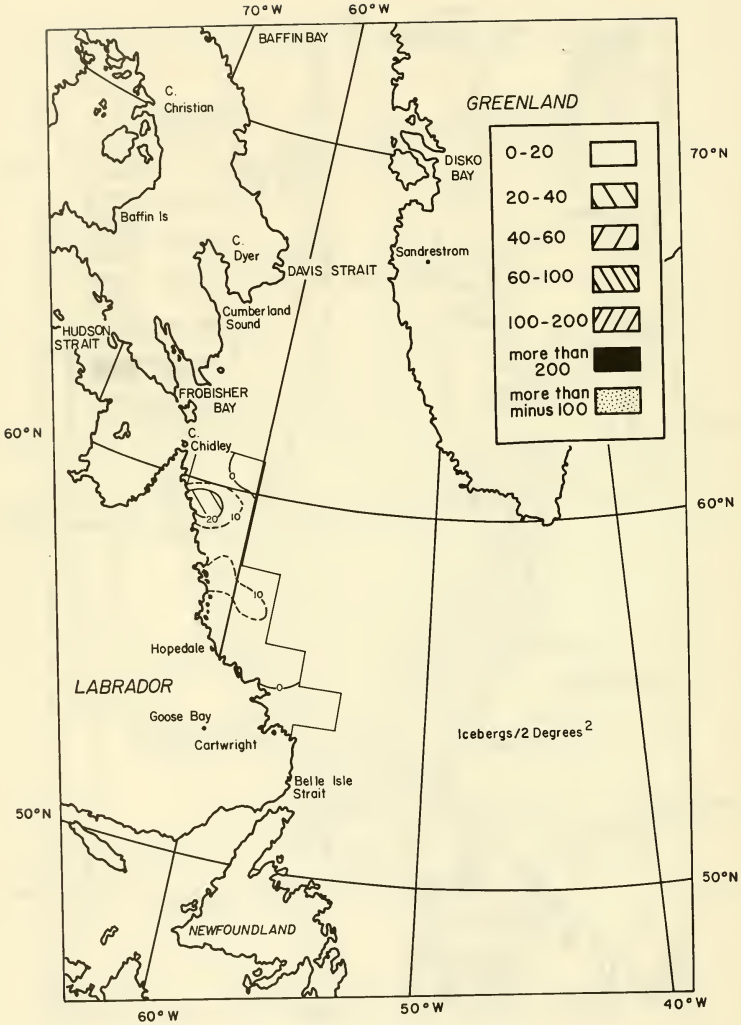


Figure 55.—Iceberg Concentration, February 1969.

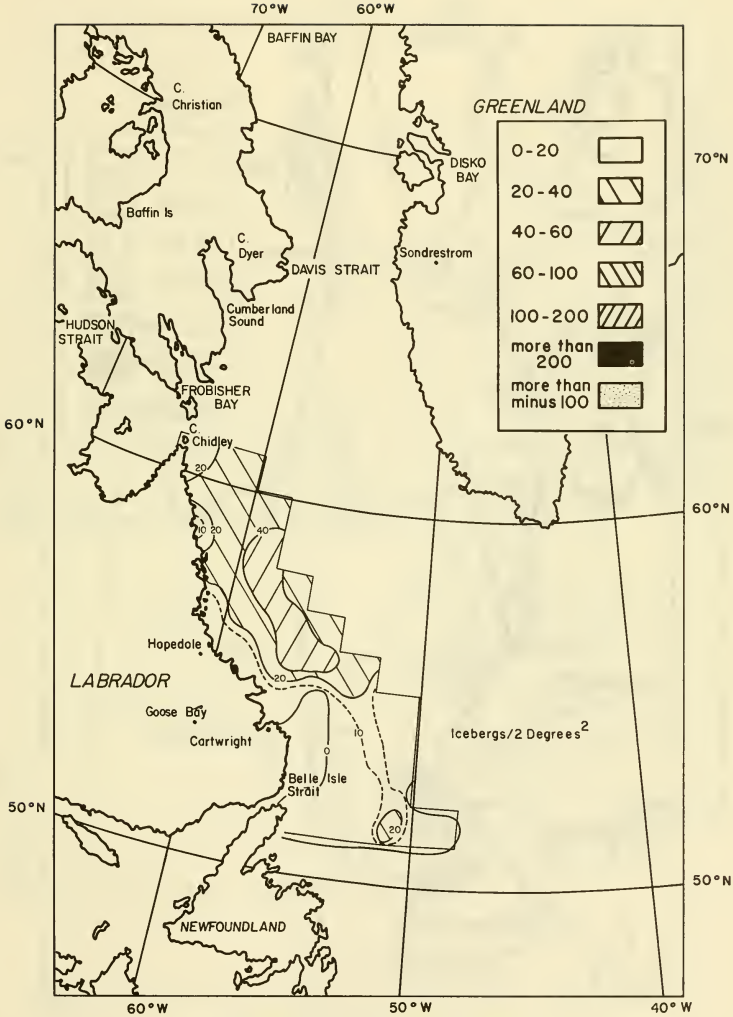


Figure 56.—Iceberg Concentration, February 1970.

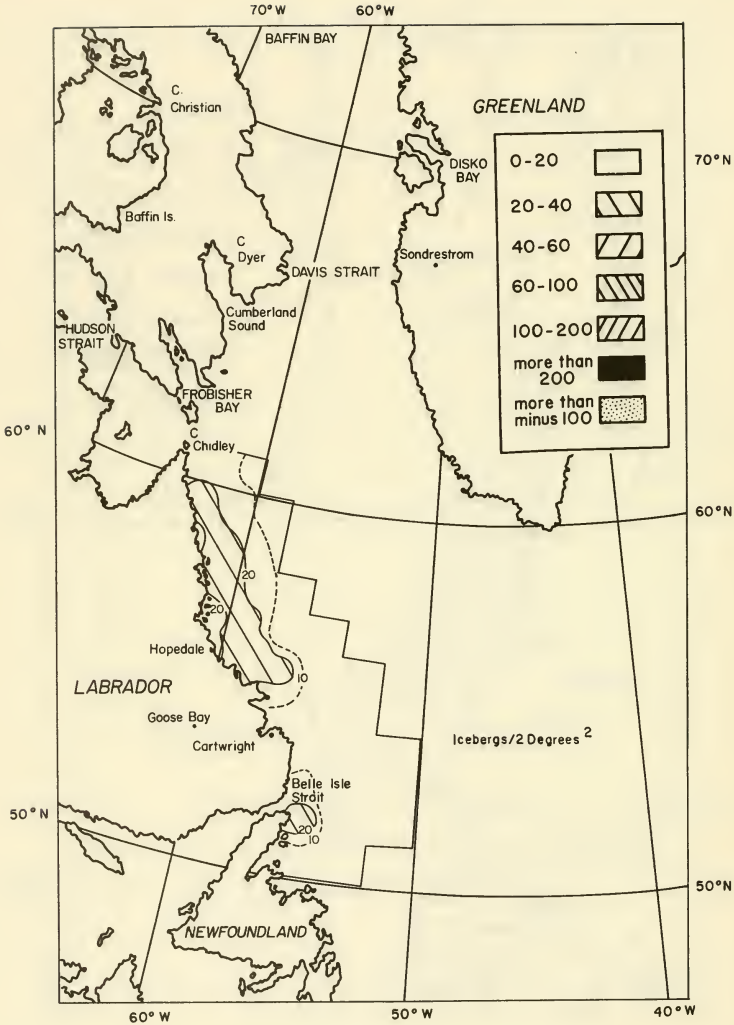


Figure 57.—Iceberg Concentration, February Average, 1963-70.

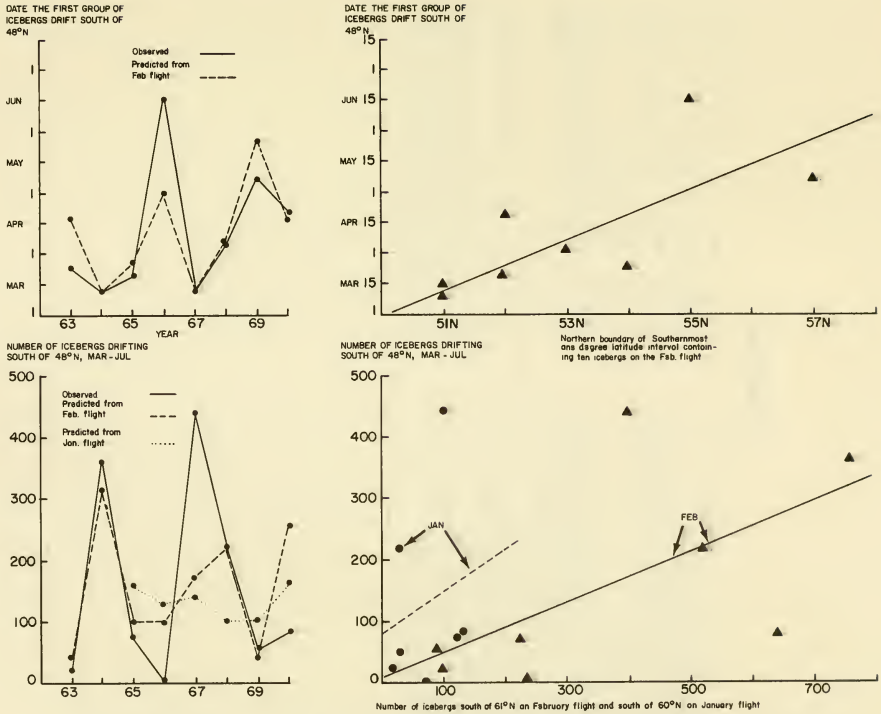


Figure 58.—Correlation of Iceberg Severity and Arrival Dates on the Grand Banks With Preseason Flights in January and February.

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