C. J. Stevenson

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GEOGRAPHICAL PAPER No. 27

A Report on Sea Ice Conditions in the Eastern Arctic, Summer 1960

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Ice that passes through Hell Gate Passage into Jones Sound is generally reduced to block and small floes. View facing North Kent Island, August 21, 1960.

P R E F A C E

This is a report of the fourth ice reconnaissance survey of the Eastern Arctic carried out during the summer of 1960 when the northern supply ship C.M.S. d'Iberville made her annual voyage to those waters.

It is published to provide a picture of the nature, conditions, and distribution of the ice encountered by Canadian Government ships on annual re-supply missions. Its purpose is to record the special problems that ice presents to the ships engaged in this work in Canada's Eastern Arctic waters.

N.L. Nicholson
Director
Geographical Branch

ROGER DUHAMEL, F.R.S.C.
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OTTAWA, 1961

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A REPORT ON SEA ICE CONDITIONS IN THE EASTERN ARCTIC, SUMMER 1960

INTRODUCTION AND ACKNOWLEDGMENTS

This report describes the sea ice conditions encountered by the Canadian government ship, the C.M.S. d'Iberville, on her annual resupply mission to Resolute and to Eureka in northern Ellesmere Island in August, 1960. It also outlines the relationship of ice conditions to the prevailing climatic conditions that were experienced during the voyage in the Eastern Canadian Arctic.

Ship-board ice reconnaissance was supplemented by aerial ice reports issued over the Mufax system by the Meteorological Branch, Department of Transport. The ship's helicopters were used at Resolute, Norwegian Bay and Slidre Fiord to examine local ice conditions.

The writer wishes to acknowledge the cooperation given by Captain C.A. Caron, J.M. DesRosiers, first mate, and other officers of the C.M.S. d'Iberville, by the crew of the ship's helicopters, and also by the ice observers of the Meteorological Branch.

In this survey, Cape Chidley marks the southern limits of the area. The ship's course to and from Resolute and Eureka is shown on Figures 5, 7, 10 and 11. The report is divided into the following sections: regional climate and general ice conditions; regional ice conditions and factors affecting the distribution, and distribution of icebergs. The symbols and main outline of ice classification used are based on those followed by the United States Navy Hydrographic office.

PART I

REGIONAL CLIMATIC CONDITIONS

Mean monthly temperatures for parts of the Eastern Arctic are given in Table 1. Thawing conditions were well advanced in June, but in the previous month low freezing temperatures prevailed throughout the Arctic region. By the end of June, surface puddling reached as much as 4/10 of the ice surface. Temperatures in July rose well into the 40's, with deterioration and break-up of the sea ice advancing rapidly, particularly in the sounds adjacent to Baffin Bay. August temperatures, somewhat lower than those of July, brought a sustained reduction of the icefields that continued into the first half of September. Then, with rapid fall in minimum temperatures to zero levels, ice forming and growth processes advanced rapidly in the latter part of the month.

TABLE 1

Mean Monthly Temperatures (F.°)

Area	June Mean-Normal	July Mean-Normal	August Mean-Normal	September Mean-Normal
Eureka Sound	40 - 37	44 - 42	43 - 38	23 - 19
Queen Elizabeth Is. (W.)	34 - 31	39 - 38	37 - 34	20 - 18
Parry Channel (E.)	36 - 34	43 - 41	41 - 39	26 - 26
Baffin Bay	36 - 35	45 - 41	42 - 40	34 - 32
Monthly Average	36.5 - 34.2	42.7 - 40.5	40.8 - 37.7	25.8 - 23.7

In the Eastern Arctic, air temperatures from May to September were from 2 to 4 degrees above normal (Table 1). In Baffin Bay, temperatures were 1 degree above normal for June, 4 degrees for July, 2 to 3 for August and 2 for September. Above normal temperatures in the Queen Elizabeth Islands were also high, being 4 degrees above normal for May, 3 for June, 1 for July, 3 for August and 2 for September. As above normal temperatures provide an earlier break-up of the arctic icefields, the season was estimated to be about 2 weeks ahead of normal spring break-up; an early break-up initiates a longer navigation season.

The general NW - SE trend of the June isotherms showed that the Queen Elizabeth Islands and Baffin Bay tended to have similar temperatures; the 35-degree isotherm paralleled Parry Channel* and the east coast of Baffin Island. The Eureka Sound area recorded temperatures that were 5 to 8 degrees higher than those of the surrounding region. By July the isotherms trended in a general E - W direction. The 40-degree isotherm extended across the southern tier of islands, north of the Canadian mainland; the 35-degree isotherm was interpolated to lie northwest of the Queen Elizabeth Islands. Parry Channel temperatures were from 5 to 7 degrees lower than Davis Strait. The Eureka Sound area recorded temperatures that were 2 to 6 degrees higher than elsewhere in the arctic archipeligo north of 70 degrees latitude. The trend of the August isotherms was similar to July; however, the 40-degree line had pushed north to parallel Barrow Strait, Lancaster Sound and the northeast coast of Baffin Island; Eureka Sound was about 5 degrees higher than elsewhere in the Queen Elizabeth Islands. By September, the 30-degree isotherm extended from Bylot Island across the northern edge of the Canadian mainland and the 20-degree isotherm extended NE to SW across the Queen Elizabeth Islands.

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*Parry Channel comprises Lancaster Sound, Barrow Strait, Viscount Melville Sound and M'Clure Strait.

During the summer there was a gradation in temperatures between the eastern and western areas of the Queen Elizabeth Islands. This variation was much more pronounced in July than in June. In July and August, the difference was from 2 to 6 degrees and about 4 degrees for September. This range in temperatures coincided with the prevailing ice conditions existing in the area. In August, light ice cover and open water occupied Eureka Sound and the eastern areas of Norwegian Bay; whereas, in the western parts of the channels of the Queen Elizabeth Islands ice coverage reached 9/10 concentration. September temperatures indicate that the ice accumulation expands from west to east with declining temperatures; the difference in temperatures between the western and eastern parts of the Arctic islands is from 7 to 10 degrees (Mould Bay recorded 21.6°F, Isachsen 18.1°F and Arctic Bay 28.2°F).

The drop in temperatures between July and August for the Queen Elizabeth Islands was from 1 to 3 degrees, but for the east coast of Baffin Island it ranged from 2 to 6 degrees. By September, mean temperatures had fallen 15 to 20 degrees from August levels.

Associated with the period of maximum temperatures were long hours of sunlight. For example, at Resolute, sunlight accounted for 25 per cent of the hours of May, 26 per cent for June, 27 per cent for July, 8 per cent for August and 4 per cent for September. The long hours of sunlight in July were a major factor in causing a reduction of the icefields. Throughout the period of the C.M.S. d'Iberville's voyage in arctic waters from August 7 to September 4, sunlight accounted for 17 per cent of the hours, dense fog 37 per cent and cloud-covered skies 46 per cent. Sunny skies were most prevalent in the Eureka Sound-Norwegian Bay area, and fog in the Davis Strait-Baffin Bay-Lancaster and Jones sounds area. Winds during the period were mainly from an easterly quadrant (NE-E-SE) accounting for 47 per cent of the direction frequencies; SW-W-NW winds accounted for 24 per cent, and calms for 16 per cent. In terms of wind mileage,* easterly winds accounted for 70 per cent and westerly winds 19 per cent. Wind speeds from the easterly quadrant averaged 17 mph; east wind speeds averaged 25 mph. The east winds of this easterly quadrant provided 40.2 per cent of the wind mileage. Westerly sector wind speeds averaged 9.1 mph, with west speeds providing the greatest velocity, averaging 11.4 mph. The major effect of the mild, maritime easterly winds was a rapid reduction of the icefields progressing in an E-W direction from Baffin Bay westward along Parry Channel and Jones Sound.

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*Wind mileage is the distance that the wind travels in miles in any given direction.

GENERAL ICE CONDITIONS

(Figures 1, 2, 3, 4)

Ice conditions throughout the re-supply mission area were variable, the area of the ice cover decreasing with the advance of the season. At the beginning of August, Baffin Bay ice lay to the south of Pond Inlet and extended about 120 nautical miles east of the coast (Figure 1A). Although only comparatively small areas of the ice cover were actually observed, concentrations seemed to consist mainly of 6/10 to 8/10. By mid-August the Baffin fields were substantially reduced and extended from Clyde Inlet to Frobisher Bay (Figure 1B). The pack was divided into two major areas of ice, one to the north and one to the south of Cape Dyer. By the end of August the Baffin pack, except for a small area of ice near Clyde Inlet, extended from Cape Dyer to Frobisher Bay (Figure 6B). About mid-September the last remnants of Baffin ice disappeared from the entrance to Frobisher Bay and Cumberland Sound.

The 'North Open Water' of Baffin Bay was well advanced by the end of May. By the beginning of August, over three-quarters of Baffin Bay was free of ice, with open water extending westward to Barrow Strait and to Hell Gate Passage (Figures 1A, 3). In Lancaster Sound ice concentrations of 9/10 occupied the bays and the north side of the sound. The 'North Open Water' by mid-August extended well into Smith Sound at the north end of Baffin Bay (Figure 2B, see also Figure 4). Arctic ice drifted southward into Baffin Bay off the Ellesmere Island coast, swept into the entrance of Jones Sound and melted off the east coast of Devon Island. The ice cover, bordering the south coasts of Cornwallis and Devon islands on Parry Channel disappeared between August 13 and 18, except for the ice that was isolated in the bays by strong winds.

Norwegian Bay was covered with landfast ice until July 13, and only in the central part of Eureka Sound was 'working' ice (8/125 to 8/018) in evidence. Slidre Fiord was two-thirds open. Open water extended into the eastern entrance of Cardigan Strait and Hell Gate Passage. By July 25 to 27, landfast ice (10/0010) was limited to the western and northern parts of Norwegian Bay; Eureka Sound was marked by a significant reduction in ice cover (Figure 3). By August 12, the extensive open water area of Eureka Sound was extending south into Norwegian Bay. By August 21, the eastern part of Norwegian Bay was mainly open water or supported a light ice cover (<1/100 - 3/300).

Hell Gate Passage and the western end of Jones Sound was already ice free before July 5. The early opening of the passage provided the means for the ice to escape from Norwegian Bay relatively early in the season.

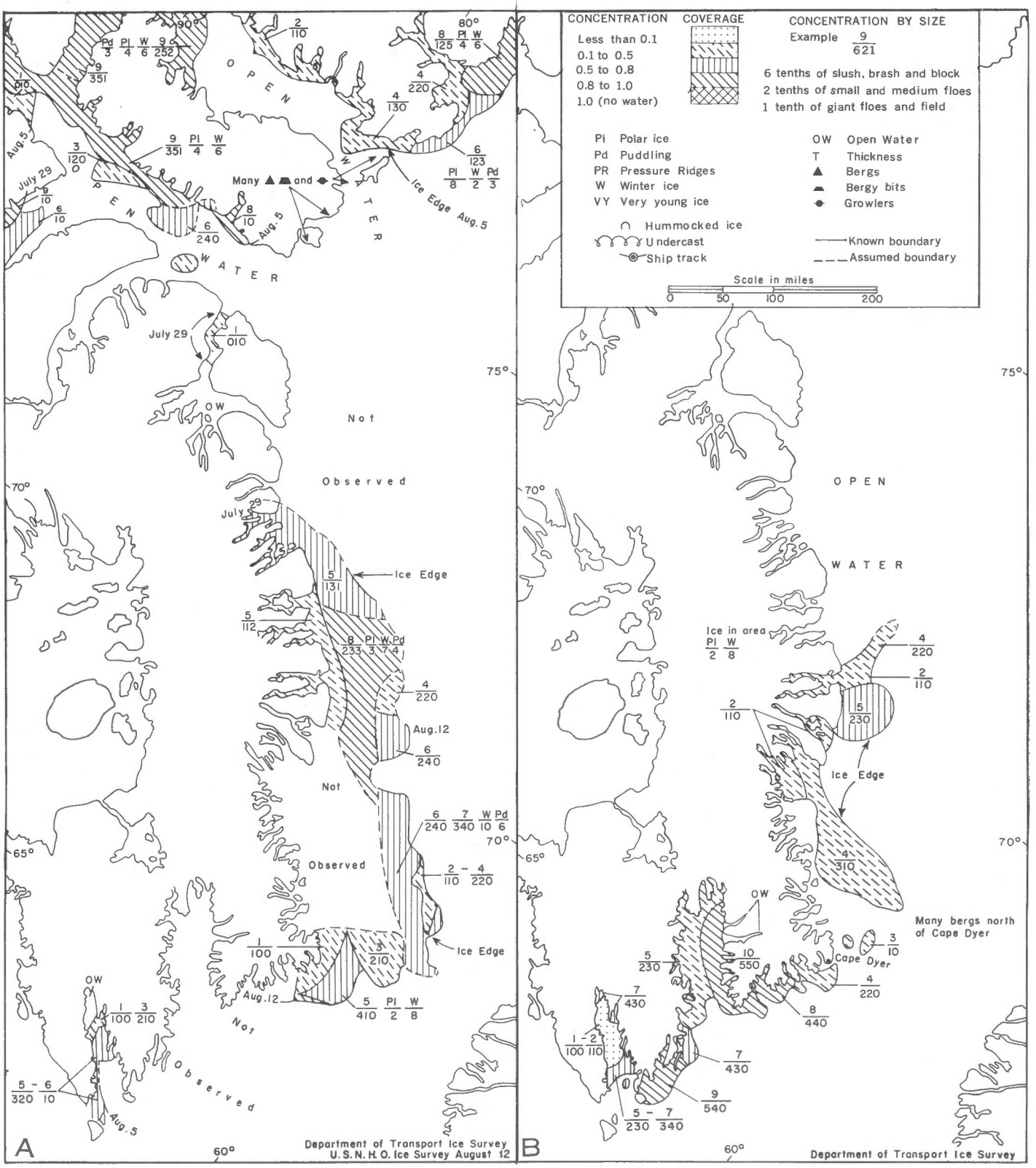

Figure 1 A. Ice distribution, Davis Strait – Baffin Bay, July 29, August 2, 5, 12.
B. Ice distribution, Davis Strait – Baffin Bay, August 16, 18.

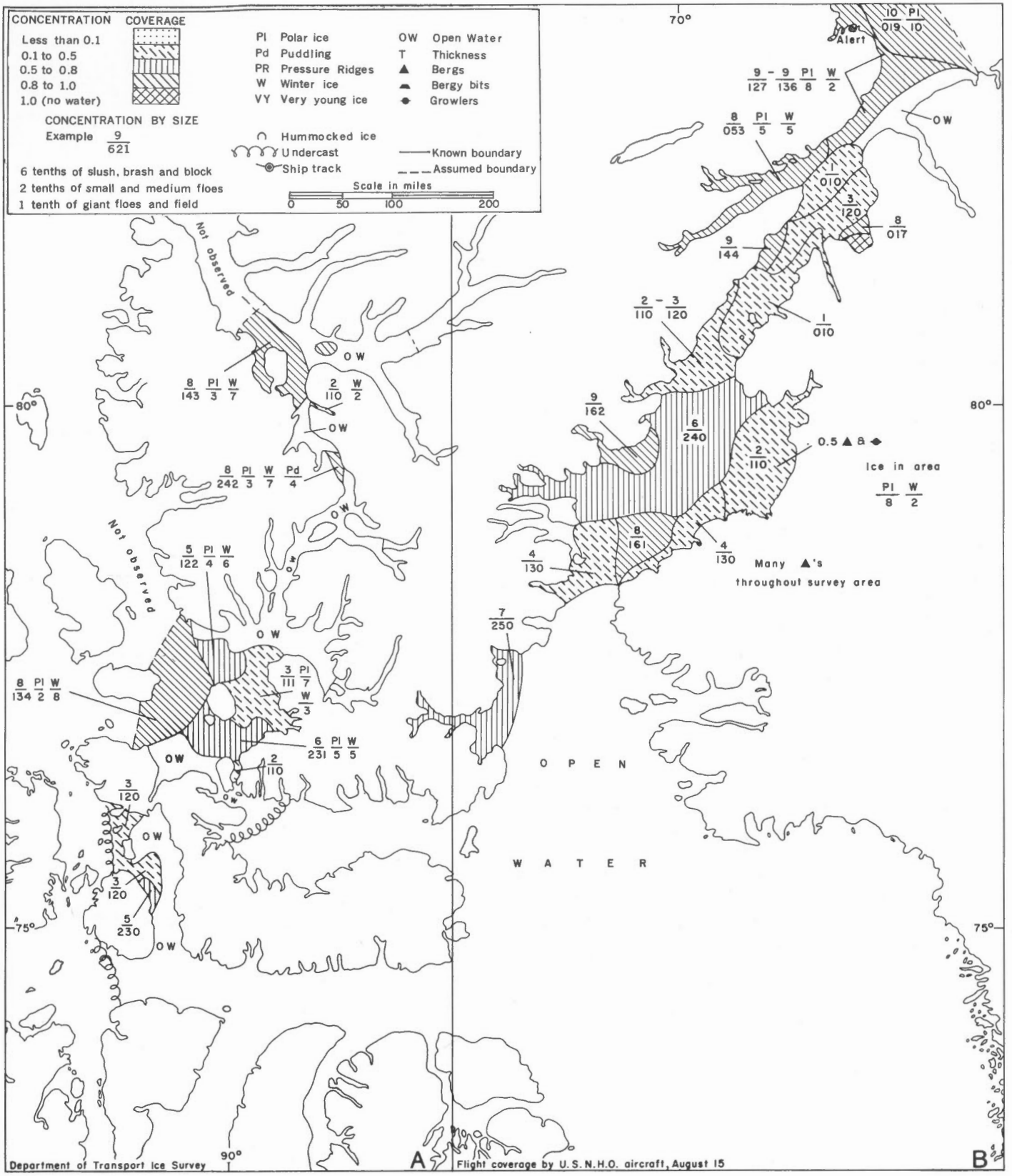

Figure 2 A. Ice distribution, Davis Strait – Baffin Bay, August 20.
B. Ice distribution, Smith Sound – Robeson Channel, August 15.

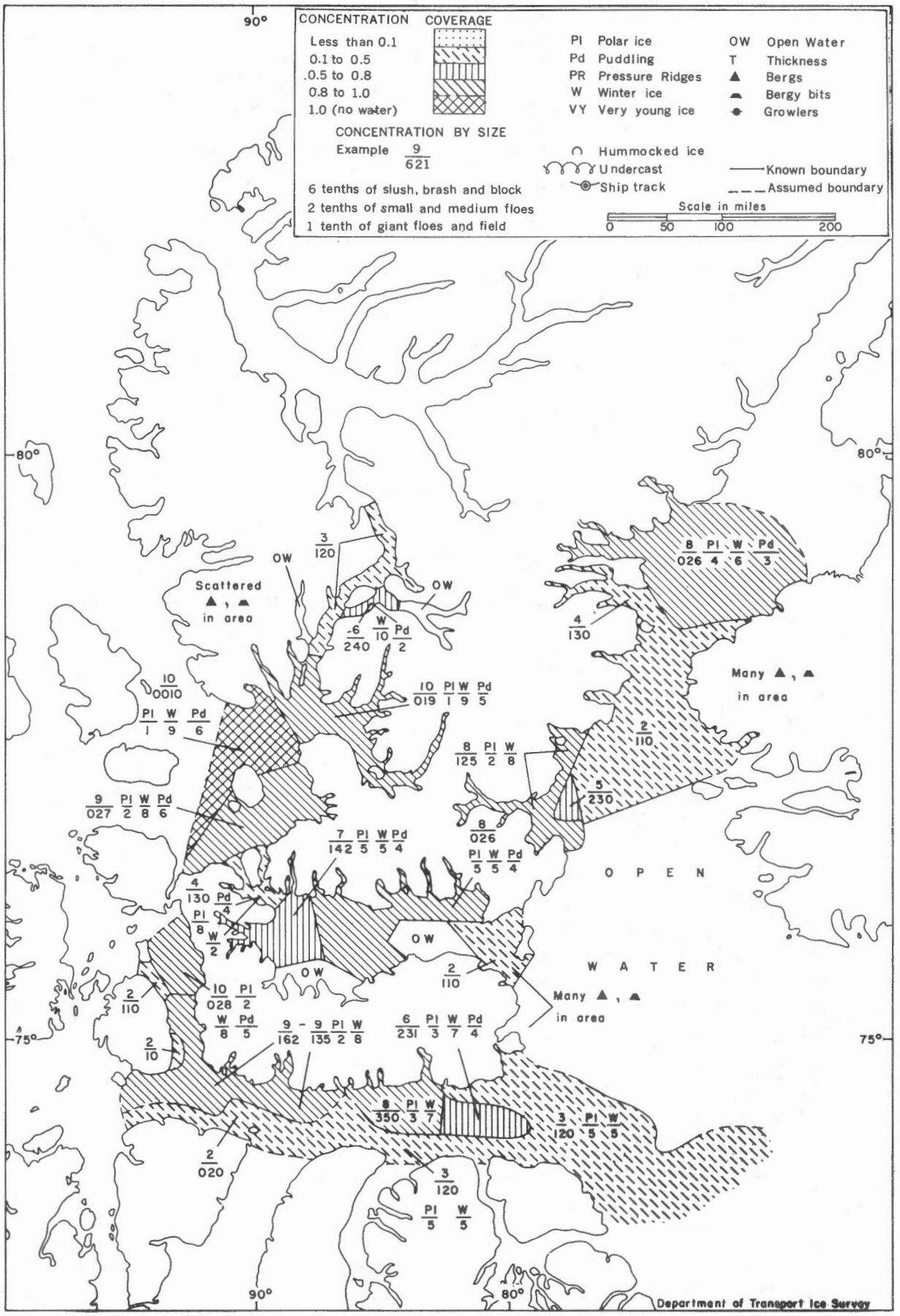

Figure 3 Ice distribution in the central Canadian Arctic, July 25 – 27.

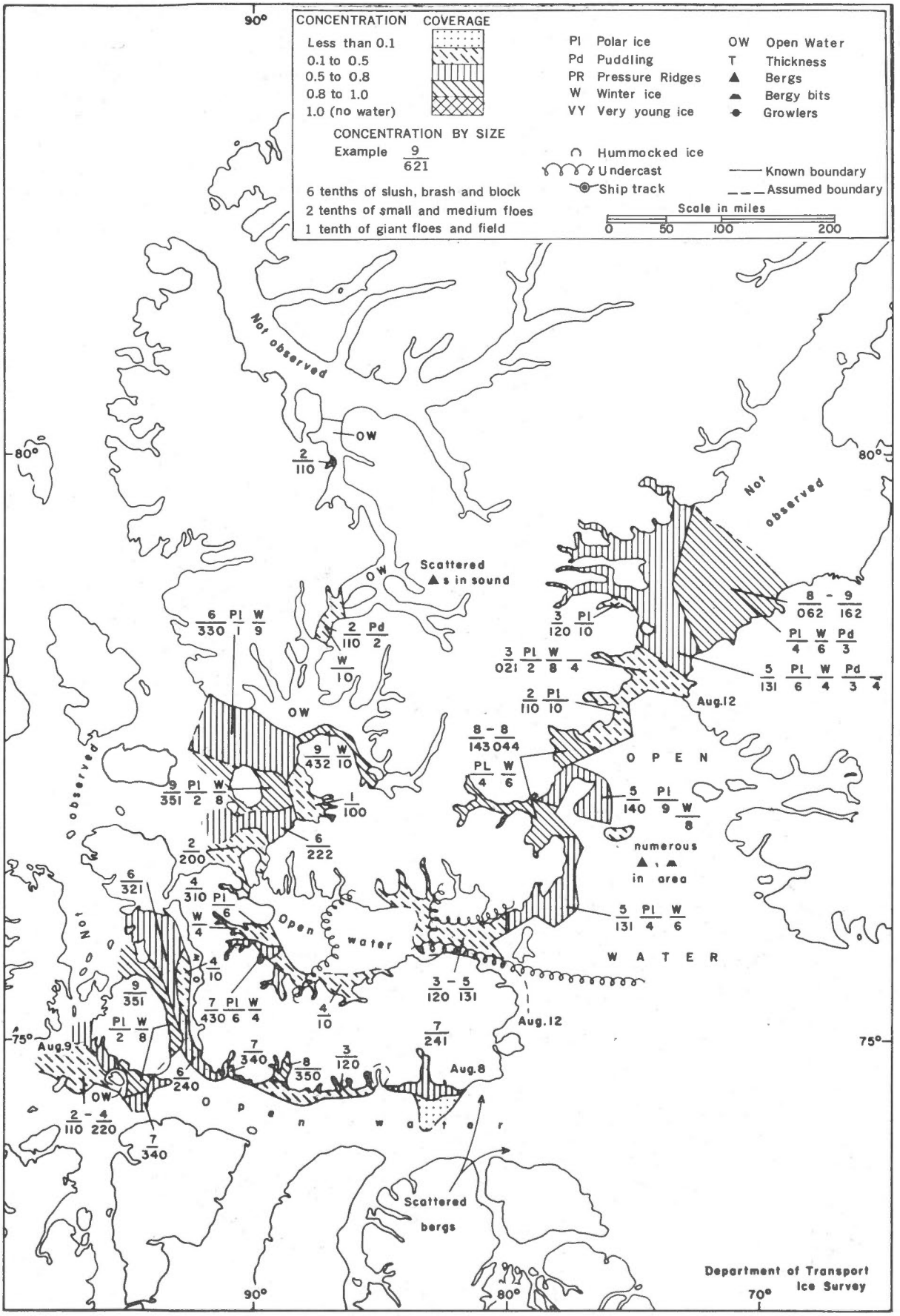

Figure 4 Ice distribution in the central Canadian Artic, August 9, 10, 12.

Ice coverage in Baffin Bay during the 1960 season were considerably less extensive than in 1958. Comparatively little ice entered the bay from Smith Sound. Ice conditions in Lancaster Sound were considerably heavier with similar ice coverage being about 2 weeks later than in 1958. The ice cover in Norwegian Bay was essentially similar to that of 1958.

PART II

ICE CONDITIONS: BAFFIN BAY - DAVIS STRAIT
(Figure 5: August 7-21)
(Figure 6A: August 20, 24; Figure 6B, Aug. 27)
(Figure 7: Sept. 1-5)

Ice Distribution

The ice forecasts for August 6, 8, 10 and 13, are shown on Figure 5, and cover the period when the C.M.S. d'Iberville was enroute to Lancaster Sound. Forecast ice concentrations for these dates ranged from 7/10 to 9/10. The ship's course during the northbound voyage from August 7 to 11 lay in open water to the east of the pack ice. The forecasts coincided closely with observed positions of the ice.

The pack-covered area continued to shrink during August and the forecasts of August 20 and 24 (Figure 6A) showed the main body of the pack to be lying to the east and southeast of Cape Dyer. The actual ice conditions for this area on August 27 are shown on Figure 6B. On the return journey (Figure 7) from September 1 to 5, the ship's course lay close to the Baffin coast. Except for the isolated icefield near Clyde Inlet that the ship passed through on September 2, the return journey was made in open water. On September 3, the Baffin Bay ice was restricted mainly to the coast facing Cumberland Sound and consisted of concentrations of small to medium floes.

Factors Affecting Ice Distribution

The rapid deterioration of the Baffin Bay icefields depended upon air and water temperatures supported by wind and wave action. Movement of the ice is related to the direction of the prevailing winds, tides and currents. The amount of increment from sources of ice supply have a major bearing on the rate of deterioration. Except in the early part of the season when the 'North Open Water' began to penetrate into Parry Channel, Lancaster Sound contributed almost no ice to the Baffin pack; a similar condition was noted in Jones Sound. The release of ice through Smith Sound is sporadic; in 1958 heavy masses of ice had entered Baffin Bay.

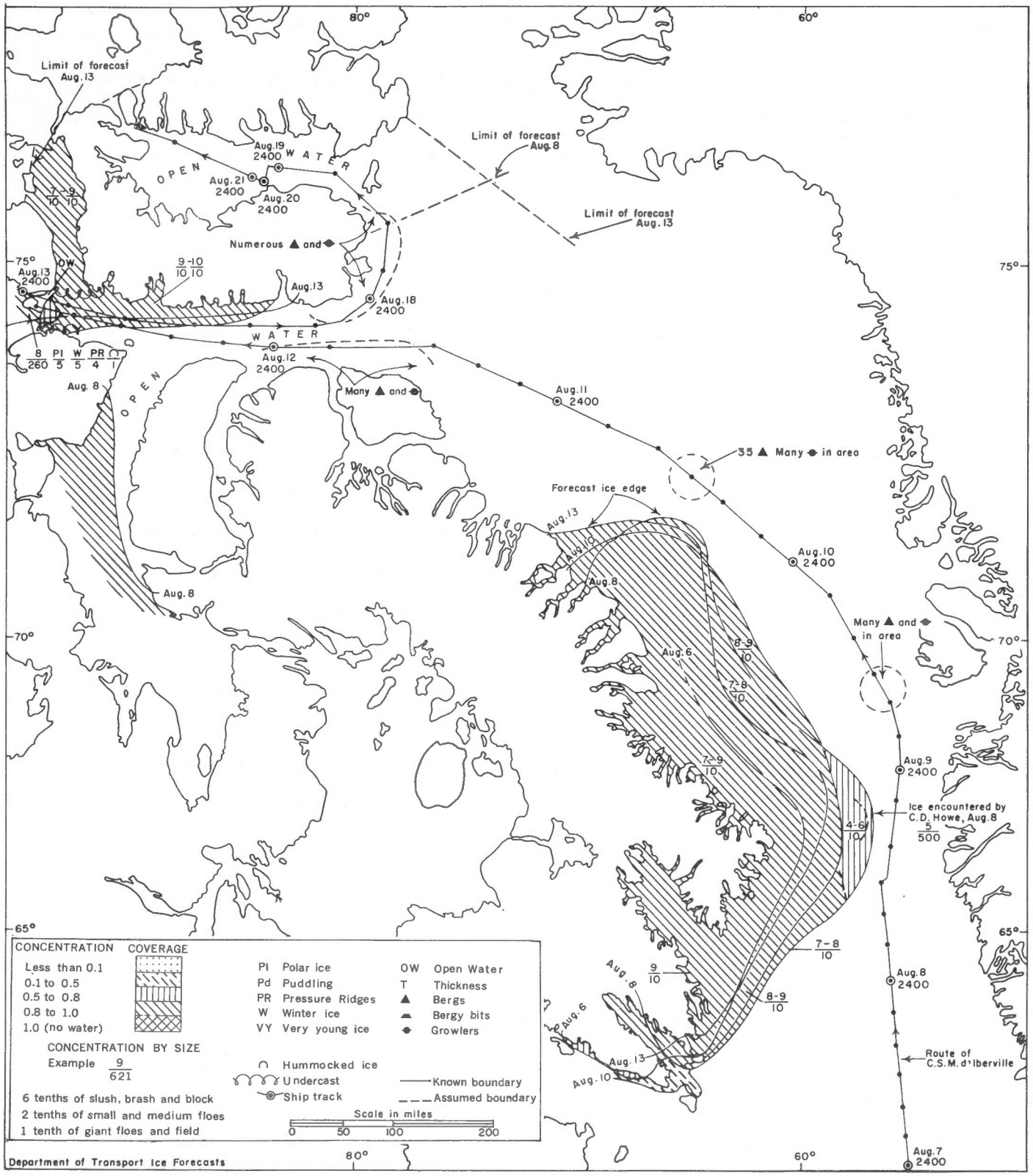

Figure 5 Ice distribution, Davis Strait – Baffin Bay, August 7 – 12; Lancaster Sound – Jones Sound, August 17 – 21.

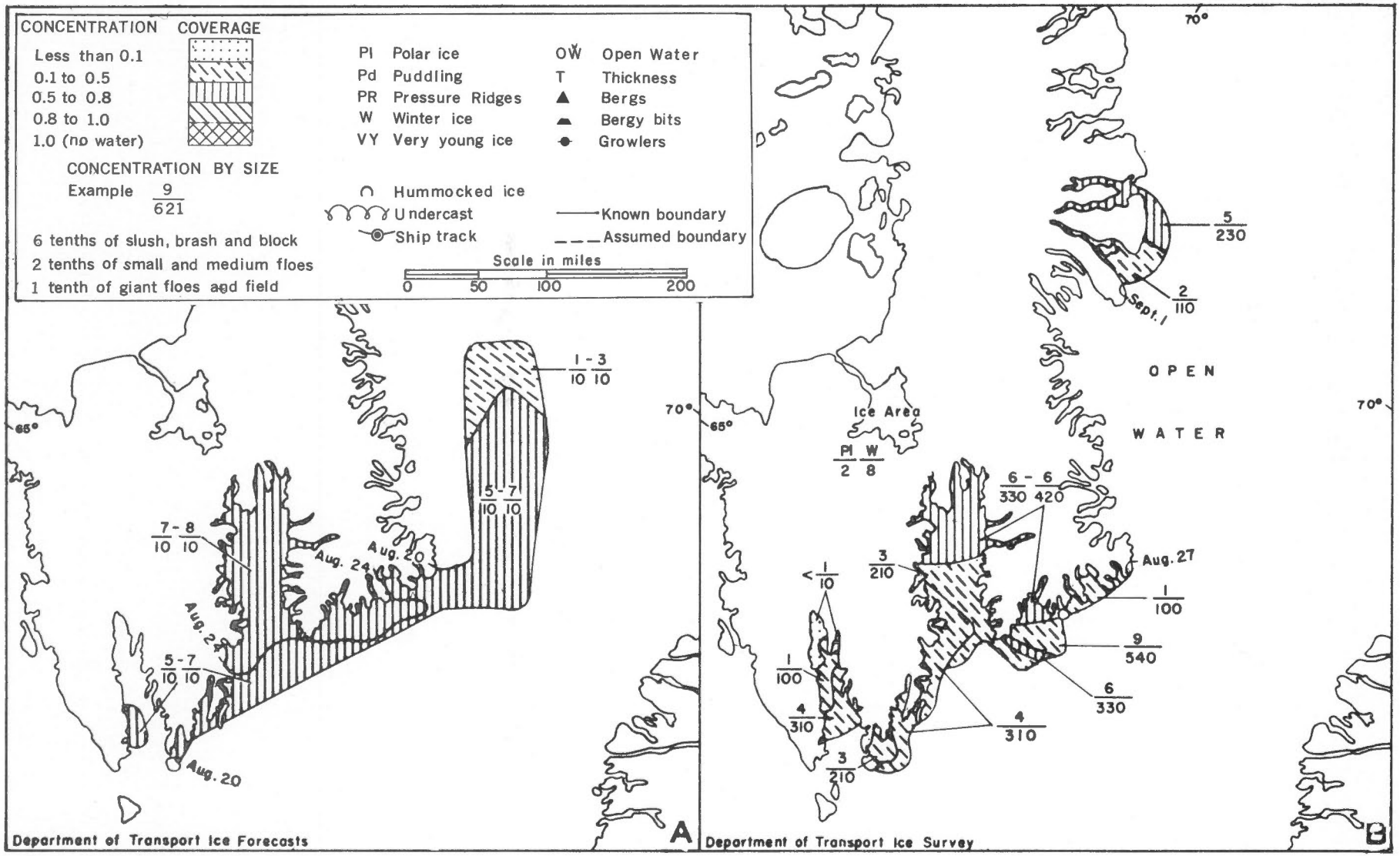

Figure 6 A. Ice distribution, Davis Strait – Baffin Bay, August 20 – 24.

B. Ice distribution, Davis Strait – Baffin Bay, August 29 – September 1.

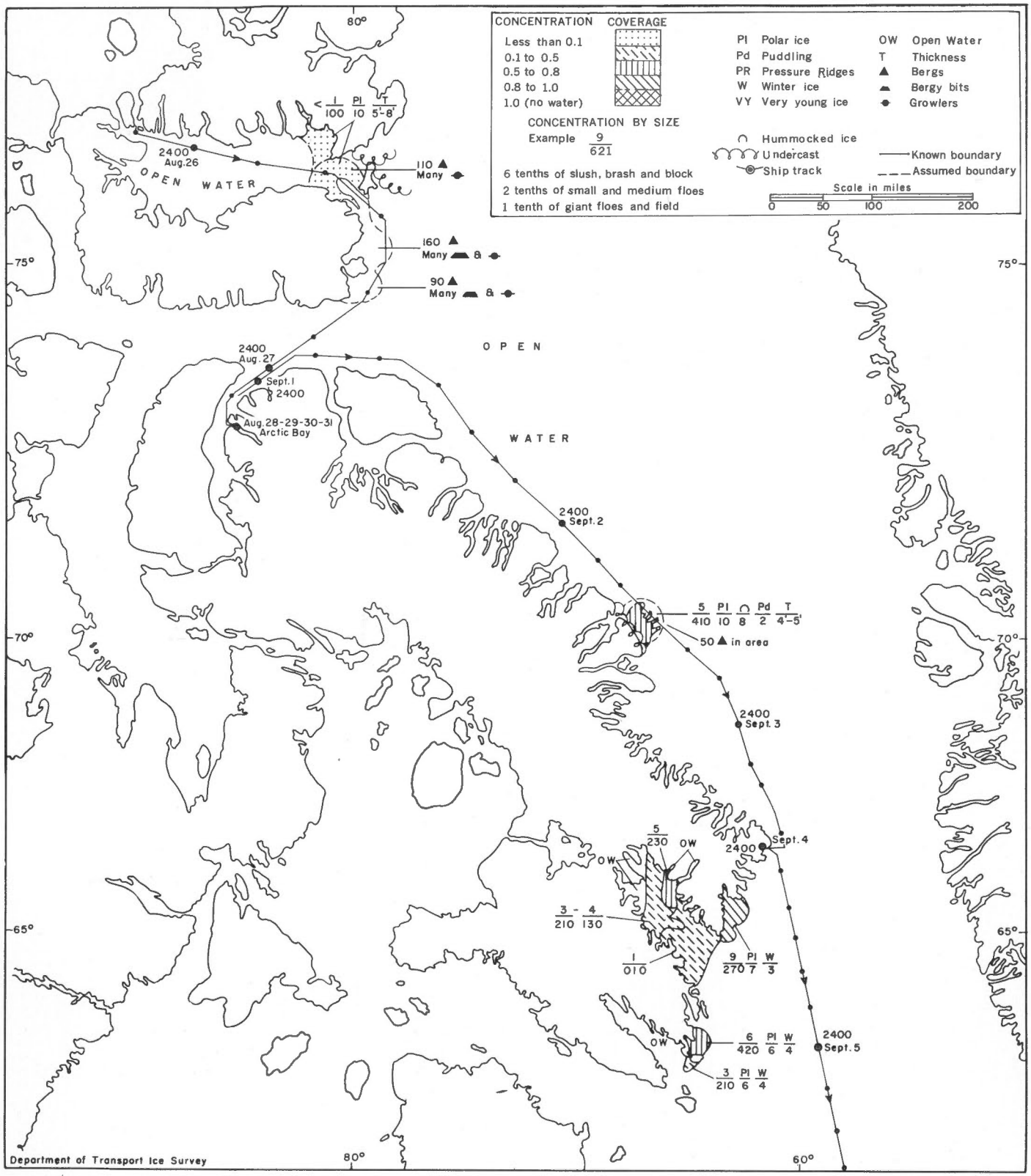

Figure 7 Ice distribution, Jones Sound, Baffin Bay and Davis Strait, August 26 – September 5.

Local weather conditions favoured a slow deterioration of the ice; foggy weather prevailed 49 per cent of the period, and overcast and cloudy weather 42 per cent, thereby reducing the amount of insolation to 9 per cent. Generally, extensive fog and undercast lay over the Baffin coast, particularly over the icefields. Fog over the eastern side of Baffin Bay tended to be considerably less.

Winds either close or open up an icefield. During the voyage through Davis Strait and Baffin Bay easterly quadrant winds (NE-E-SE) accounted for 47 per cent of wind frequencies and for 70 per cent of wind mileage; north winds accounted for 14 per cent and calms 16 per cent of wind direction frequencies. Easterly wind speeds averaged 8 to 13 mph. The major effect of the winds was to hold the ice close to Baffin Island and to permit it to drift southward with the current. The state of the sea also had a bearing on the disintegration of the ice; 67 per cent of the period indicated a sea surface that was calm and glassy; 33 per cent of the sea surface varied from rippled to slightly rough. The state of the sea encouraged a slow disintegration of the Baffin Bay ice.

Air and water temperatures in Baffin Bay and Davis Strait were substantially higher than those recorded in 1958 (Table 2a). Undoubtedly the reduced flow of ice from Smith Sound into Baffin Bay was a major factor, and together with prevailing maritime winds contributed to the high temperatures recorded in this area. Air temperatures stood well above freezing; the average minimum air temperature was 32.2°F., the average maximum 52.1°F., and daily average 44.9°F. Temperatures recorded on the southbound voyage were generally lower than those recorded northbound and may be accounted for by the effect of lower water temperatures and prevailing fog adjacent to the Baffin Island coast. The general air temperatures for the intervening part of August, (August 12 and 31) may be considered similar to those recorded on the north bound and south bound voyages. Of some 54 recordings taken during the 9-day period at 4-hour intervals only two dropped to 32°F. Such high air temperatures led to rapid reduction of the ice cover.

Surface and sub-surface* water temperatures followed a pattern that corresponded closely to air temperatures (Table 2a), and were substantially higher than those recorded during the 1958 voyage. The daily average was 41.1°F. The sub-surface water temperatures were lower. The daily average surface water temperature was 3.8°F.; sub-surface water temperature was 5.8°F. lower than the daily air average. As the daily minimum temperatures stood well above the 29°F.-level, thawing processes were not interrupted by freezing periods. It was considered that the intervening part of August was not interrupted by the

*Sub-surface water temperatures are taken at the ship's intake, located 26 feet below the surface.

TABLE 2

Temperature tables, Baffin Bay - Davis Strait, Aug. 7-11; Sept. 1-4

a. Daily temperatures

Date	Air (F.°)			Surface Water (F.°)			Sub-surface Water (F.°)		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
Aug. 7	43	46	44.8	42	45	43.5	38	44	41.3
Aug. 8	37	52	44.3	37	41	39.1	35	38	36.5
Aug. 9	44	63	54.5	47	49	48.0	44	48	46.0
Aug. 10	43	70	55.3	45	47	46.1	43	46	44.5
Aug. 11	38	44	40.6	34	42	38.5	35	40	37.1
Sept. 1	37	56	41.5	36	42	40.0	35	41	38.0
Sept. 2	37	48	40.3	34	42	40.1	32	41	37.5
Sept. 3	32	46	36.5	34	40	36.0	32	36	33.6
Sept. 4	33	44	39.1	35	42	38.6	34	42	37.8
Daily Average	38.2	52.1	44.9	38.2	43.3	41.1	36.4	41.8	39.1

b. Daily heat accumulative temperatures

Date	Air (F.°)*	Surface Water (F.°)**	Sub-surface Water (F.°)**
Aug. 7	25	29	24
Aug. 8	25	20	15
Aug. 9	45	38	34
Aug. 10	49	34	31
Aug. 11	18	18	17
Sept. 1	29	20	18
Sept. 2	21	18	15
Sept. 3	14	16	10
Sept. 4	13	19	18
Daily Average	26.5	23.5	20.2

*Daily heat accumulation for air is the sum of the difference of minimum and maximum temperatures from 32°F.

**29°F. is used for the calculation of the freezing temperature of sea water.

c. Cumulative mean temperatures (F.°) at 4-hourly intervals

	0400	0800	1200	1600	2000	2400
Air temperatures	39.7	45.0	47.0	50.9	42.0	40.9
Surface water temperatures	41.5	40.4	40.2	41.3	41.9	41.3
Sub-surface water temperatures	39.8	39.0	37.5	39.8	39.8	39.2

freezing of surface waters. However, microthermal temperatures such as occur in enclosed fresh water puddles on the ice surface existed as was shown by the formation of glimmer ice on the icefields encountered on September 2.

Temperature effectiveness for air, surface and sub-surface waters is given in Table 2b. The daily heat accumulative temperature for air was 26.5°F., for surface water 23.5°F. and for sub-surface water 20.2°F. The high positive heat level of these values emphasizes the effectiveness of prevailing temperature conditions to reduce the ice cover. These temperature values are more than three times the 1958 value for air, more than twice that for surface water, and about twice that for sub-surface water.

The cumulative mean temperatures for air, surface-water and sub-surface water are given in Table 2c. Highest air temperatures occurred from 0800 to 2000 hours with the maximum occurring about 1600 hours, and the minimum during the early morning hours. Essentially, the 24-hour daily interval was marked by effective thawing temperatures; the range between the 0400 minimum and the 1600 maximum was 11.2°F. Surface-water temperatures were remarkably uniform, with only 1.7°F. between the minimum and maximum mean values; sub-surface values showed a greater range of 2.3°F. Although the range in water temperatures throughout the 24-hour daily interval tended to be slight the 1200-noon interval showed the lowest water temperatures.

The combined effect of a series of favorable physical conditions that existed during the 1960 summer season was to reduce the extent of the icefields to less than normal levels. Favorable physical conditions consisted of above normal regional air temperatures, high water temperatures, low influx of ice into Baffin Bay from Smith Sound and strong, mild, maritime winds from an easterly quadrant. Less favorable features were the high amount of fog and undercast, and low insolation in conjunction with the smooth state of the sea, especially in the areas occupied by the ice cover.

ICE CONDITIONS: LANCASTER SOUND - BARROW STRAIT

(Figure 3: July 25-27)
(Figure 4: Aug. 9-10)
(Figure 5: Aug. 12-18)
(Figure 8: Aug. 13 and 16)

Ice Distribution

Ice conditions in Lancaster Sound on July 5 varied from 6/10 to 9/10, but west of the 95° meridian concentrations were 10/10. The ice cover that existed in this area on July 25 and 27 is shown on Figure 3,

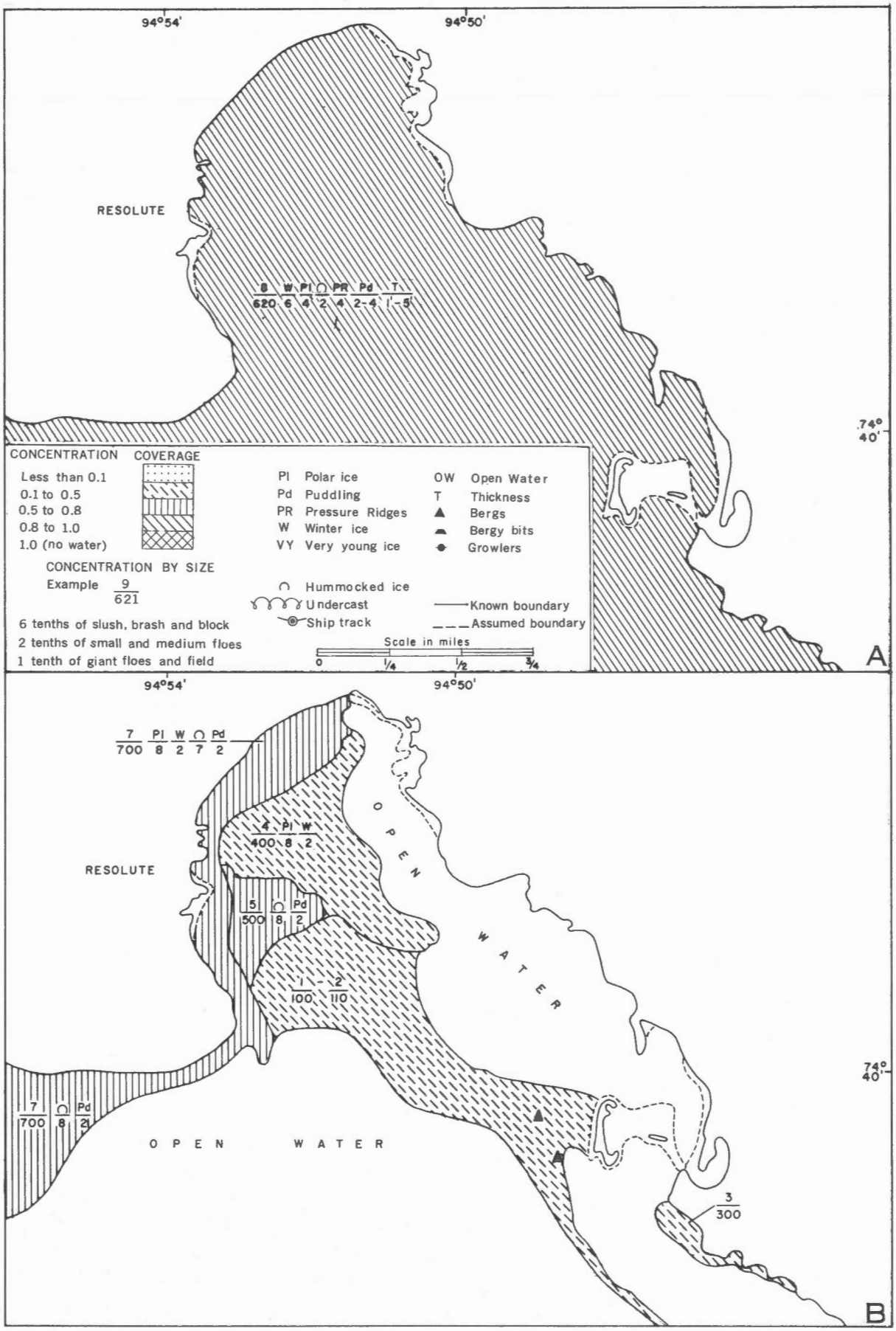

Figure 8 Ice distribution, Resolute Bay, (A) August 13; (B) August 16.

that of August 5 on Figure 1A, and that of August 9 on Figure 4. The ice forecasts for August 8 and 13 appear on Figure 5, and cover the period when the C.M.S. d'Iberville was on Barrow Strait enroute to and from Resolute. The ship's course inbound lay to the south of the forecast location of the icefields.

Although there was a gradual progression of the ice edge westward, the deterioration of the icefields in Parry Channel occurred simultaneously. On August 6, an unbroken reach of open water extended into Barrow Strait to the north of Russell Island, and the ice edge continued to retreat westward. The farthest western limit of open water in Parry Channel is not known. Figure 8 shows the ice conditions in Resolute Bay on August 13 and 16.

Factors Affecting Ice Distribution

The rapid deterioration of the icefields in the eastern half of Parry Channel as in Baffin Bay depended upon air and water temperatures supported by wind and wave action.

Local weather conditions were extremely variable. In the period from August 12 to 17, foggy weather prevailed 72 per cent of the period, cloudy overcast skies 25 per cent, and sunny skies 3 per cent. Later, in the period from August 27 to 31, cloudy overcast skies were prevalent 90 per cent of the period and sunny weather 3 per cent. Generally extensive fogs and undercast extended over Parry Channel during the greater part of August.

During the period August 12 to 17, easterly quadrant (NE-E-SE) winds accounted for 80 per cent of wind frequencies and almost 90 per cent of wind mileage. Easterly winds averaged 14 to 23 mph. On August 13, wind speeds ranged from 20 to 30 mph and on August 17 varied from 20 to 40 mph, with gusts of 45 to 55 mph. The most significant effect of these winds was to cause the icefields to hug the northern coasts of Parry Channel. In the latter part of August easterly quadrant winds were reduced to 25 per cent in frequency, and westerly winds (NW-W-SW) accounted for 30 per cent, and calms 30 per cent. Easterly winds averaged 14 mph and westerly winds 8 mph. In the period August 12 to 17, the condition of the sea showed that 36 per cent of the recordings were calm and glassy; 28 per cent varied from rippled to slightly rough; and 36 per cent recorded sea swells with rippled to moderately rough. In the latter part of the month 57 per cent of the sea recordings were calm and glassy and 43 per cent varied from rippled to slightly rough.

Air and water temperatures in the eastern half of Parry Channel were lower than those recorded in 1958 and lower than those in the Baffin Bay-Davis Strait area (Table 3a). High water and air temperatures reduce the distance that ice drifts before it melts away, thereby reducing the chilling effect of floating ice;

TABLE 3

Temperatures tables, Lancaster Sound - Barrow Strait, Aug. 12-17; 27-31

a. Daily temperatures

Date	Air (F.°) Min.	Max.	Av.	Surface Water (F.°) Min.	Max.	Av.	Sub-surface Water (F.°) Min.	Max.	Av.
Aug. 12	36	39	37.3	31	35	33.5	30	35	32.8
Aug. 13	33	48	37.6	30	32	31.1	29	34	31.1
Aug. 14	31	38	35.3	30	32	31.6	30	32	30.5
Aug. 15	38	41	39.7	31	32	31.8	30	34	32.0
Aug. 16	39	63	45.5	32	34	33.6	30	33	33.3
Aug. 17	37	44	39.3	34	37	35.3	32	35	33.5
Aug. 27	37	50	43.8	36	39	38.1	34	37	35.1
Aug. 28	40	52	44.8	38	39	38.7	34	36	35.1
Aug. 29	38	43	40.5	38	38	38.0	34	35	34.3
Aug. 30	38	51	45.5	37	39	38.0	34	37	35.0
Aug. 31	39	48	44.6	39	39	39.0	35	37	36.0
Daily Average	36.9	47.0	41.3	34.2	36.0	35.3	32.0	35.0	33.5

b. Daily heat accumulative temperatures

Date	Air (F.°)*	Surface Water (F.°)*	Sub-surface Water (F.°)*
Aug. 12	11	8	7
Aug. 13	17	4	5
Aug. 14	5	4	4
Aug. 15	15	5	6
Aug. 16	38	8	5
Aug. 17	17	13	6
Aug. 27	23	17	13
Aug. 28	28	19	12
Aug. 29	17	18	11
Aug. 30	25	18	13
Aug. 31	23	20	14
Daily Average	19.9	12.2	8.7

* See Table 2b

c. Cumulative mean temperatures (F.°) at 4-hourly intervals

	0400	0800	1200	1600	2000	2400
Air temperatures	38.1	39.7	44.8	43.4	42.1	39.5
Surface water temperatures	34.8	35.4	35.7	35.7	35.4	35.1
Sub-surface water temperatures	33.0	33.6	33.0	33.4	33.8	33.7

such action permits the surface waters to heat rapidly. Air temperatures stood well above freezing; the average minimum air temperature was 36.9°F., average maximum 47.0°F., and daily average 41.3°F. Temperatures recorded at the end of August were higher than those recorded on the inbound voyage. The air temperatures for the period August 10 to 26 may be considered similar to the above. Of some 66 recordings taken during the 11-day period at 4-hour intervals only two recorded freezing temperatures. Thawing temperatures were thus prevalent.

Surface and sub-surface water temperatures followed a similar pattern to air temperatures (Table 3a). The daily average for surface water was 35.3°F., and sub-surface water 33.5°F., the surface water being 6°F., and sub-surface water 7.8°F. lower than the daily average for air. As the daily minimum temperatures for surface water stood well above 29°F., thawing processes were not interrupted by freezing periods. It should be observed, however, that in the interval of August 12 to 17, minimum surface water temperatures approached the freezing point, and therefore, prior to mid-August the thawing process was frequently interrupted by freezing periods.

Table 3b indicates temperature effectiveness for air, for surface, and sub-surface waters. The daily heat accumulative temperature for air was 19.9°F., for surface water 12.2°F., and for sub-surface water 8.7°F. These values were substantially lower than those recorded for Baffin Bay. High positive heat level of these values was effective in reducing the ice pack; however, the longer the interval of open water the higher these temperature values are likely to be; this condition provides an explanation for the higher figures recorded for the period August 27 to 31. The main effect was rapid reduction of the icefields entering Lancaster Sound from adjoining channels.

Table 3c shows that highest air temperatures occurred from 1200 to 2000 hours with maximum occurring in the early afternoon and minimum during the early morning hours. The full daily range was marked by effective thawing temperatures; the range between 0400 minimum and 1200 maximum was 6.7°F. Surface and sub-surface water, temperatures were remarkably uniform; the range between minimum and maximum values was .9°F., and for sub-surface water .8°F.

Physical conditions were less favorable than in the 1958 season for the reduction of the icefields in Parry Channel. Favorable conditions consist of above normal regional air temperatures and high water temperatures; strong winds, resulting in surface water turbulence, add to the rapid reduction of icefields.

ICE CONDITIONS: JONES SOUND - EUREKA SOUND
(Figure 3: July 25-27)
(Figure 4: Aug. 12)
(Figure 2A: Aug. 20)
(Figures 9, 10, 11: Aug. 21-25)

Ice Distribution

Ice conditions in the Jones Sound-Norwegian Bay-Eureka Sound area of the Eastern Arctic on July 13, consisted of fields of heavy ice, with landfast ice (10/0010) occupying Norwegian Bay and the southern part of Eureka Sound. The ice cover that existed in this area on July 25 and 27 is shown on Figure 3, that of August 12 on Figure 4, and that of August 20 on Figure 2A. The ship's course to and from Eureka on Slidre Fiord, and the ice conditions encountered, are shown on Figures 9 and 10.

The ice cover for August 20 indicated that the eastern part of Norwegian Bay was occupied by a relatively light ice cover, and presented no serious problem to the progress of the ship to Slidre Fiord. The journey northward on August 21 indicated lighter ice conditions than on August 20; a marked reduction in ice concentration was observed on the return journey of August 25. Perhaps more striking was the almost complete absence of sea ice in Eureka Sound on the northbound journey and the large mass released from Nansen Sound that was encountered on the southbound journey. Except for the ice that poured through Hell Gate Passage and Cardigan Strait into Jones Sound, and that sweeping into the eastern entrance of the sound from northern Baffin Bay, Jones Sound was open water. Ice cover in Slidre Fiord was light (Figure 11).

Ice concentrations in Norwegian Bay on August 21 consisted mainly of <1/100 to 3/300, with individual fields of polar and winter ice. The winter ice, grey-white in color, varied from 6/10 to 9/10 puddled, and its thickness was remarkably uniform (about 1 foot). The polar ice generally averaged 8/10 hummocked and about 2/10 level; its thickness varied from 2 to 5 feet, and its surface was from 2/10 to 6/10 puddled. Polar ice is green-blue and remains so throughout its period of decay.

Factors Affecting Ice Distribution

Climatic conditions varied widely in this area of the ship's route. In Jones Sound and the adjacent northwest corner of Baffin Bay, foggy weather prevailed 44 per cent of the period; cloudy, overcast weather 40 per cent, and sunny skies 16 per cent; however, in the Norwegian Bay-Eureka Sound area from August 21 to 25, cloudy, overcast skies prevailed 28 per cent of the period, and foggy weather 8 per cent; the amount of insolation rose to 65 per cent. On the voyage through Jones Sound easterly quadrant winds (NE-E-SE)

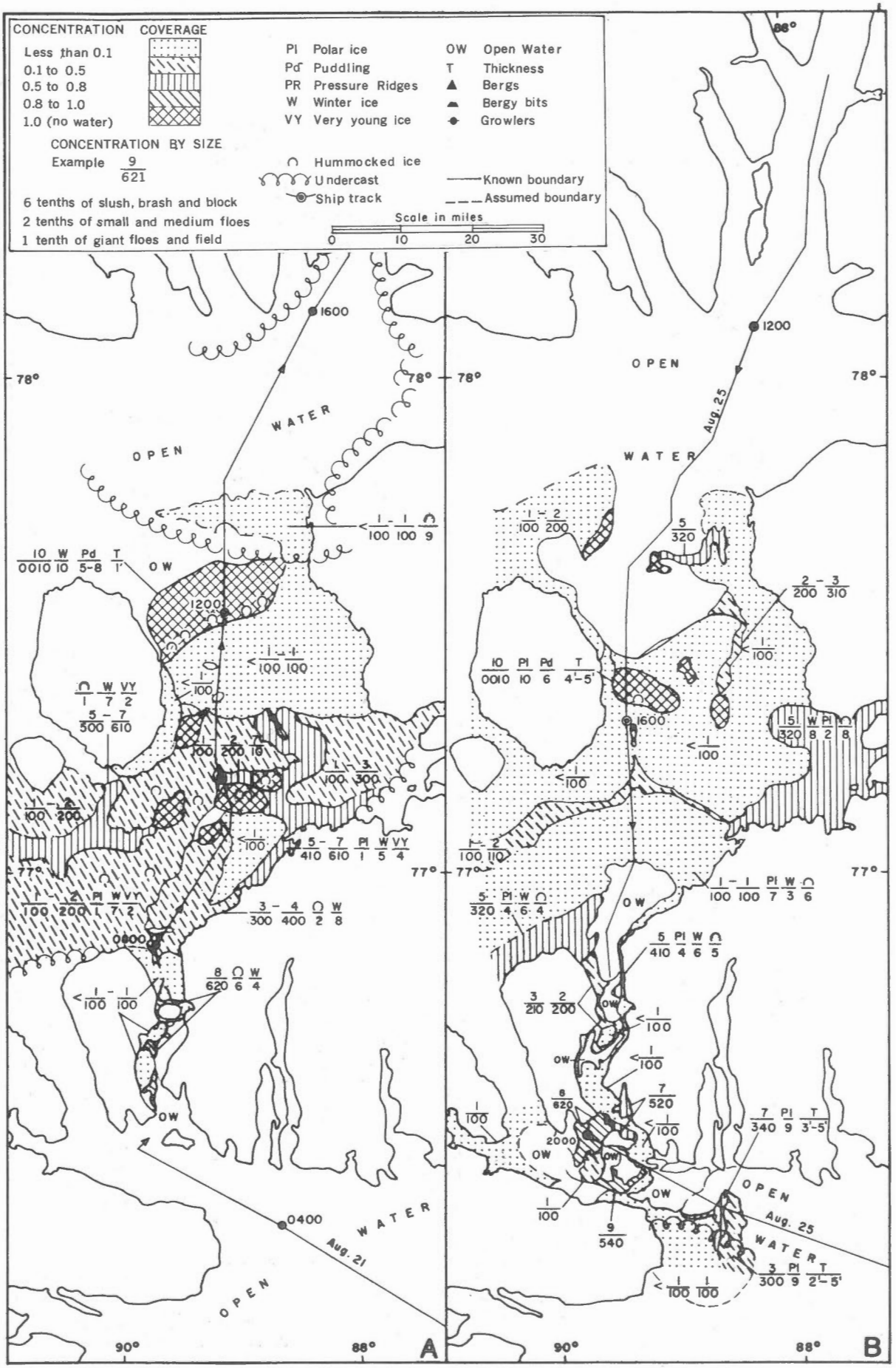

Figure 9 A. Ice distribution, Jones Sound, Hell Gate and Norwegian Bay, August 21.
B. Ice distribution, Jones Sound, Hell Gate and Norwegian Bay, August 25.

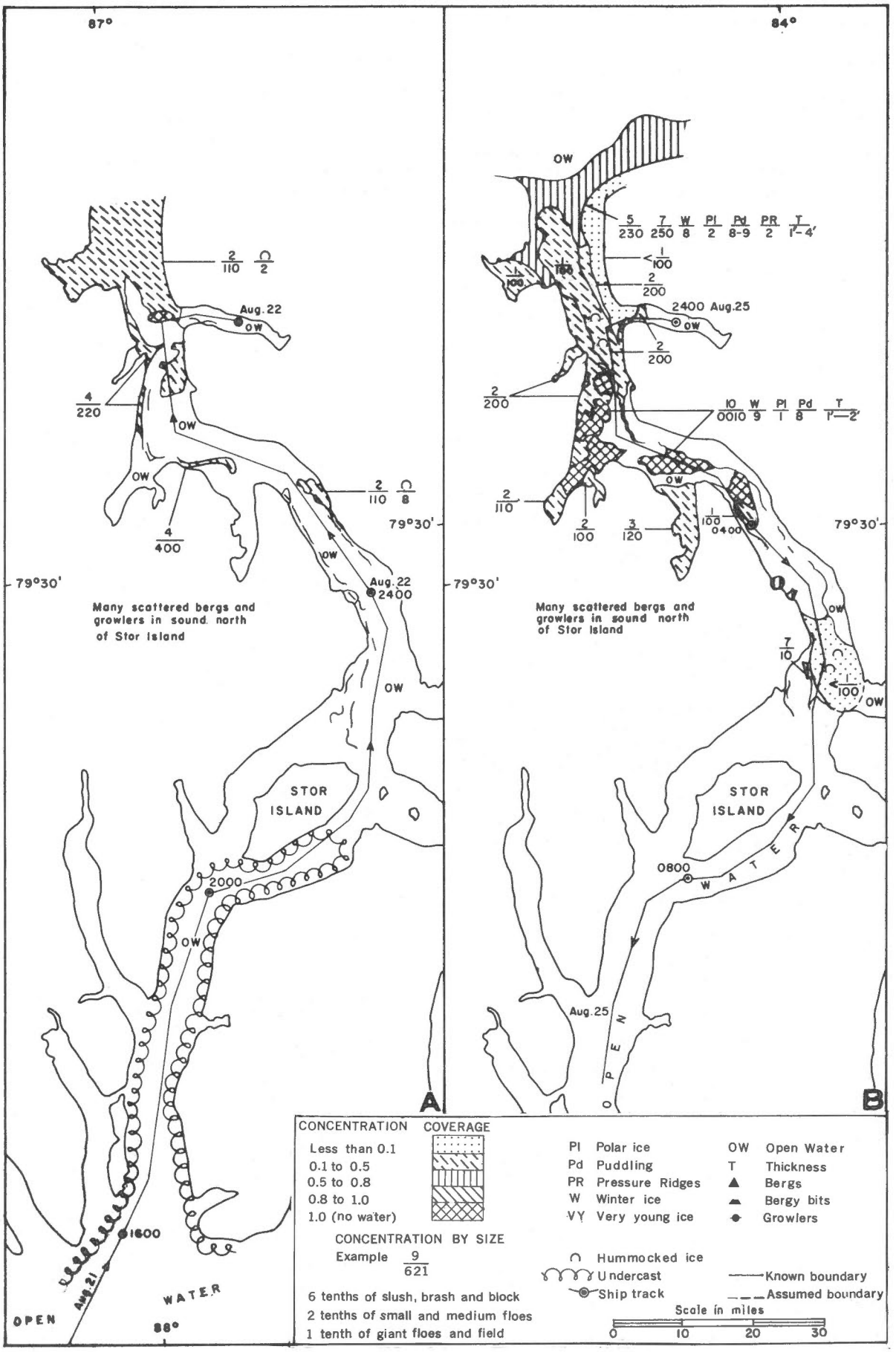

Figure 10 A. **Ice distribution, Eureka Sound, August 21 – 22.**
B. **Ice distribution, Eureka Sound, August 25.**

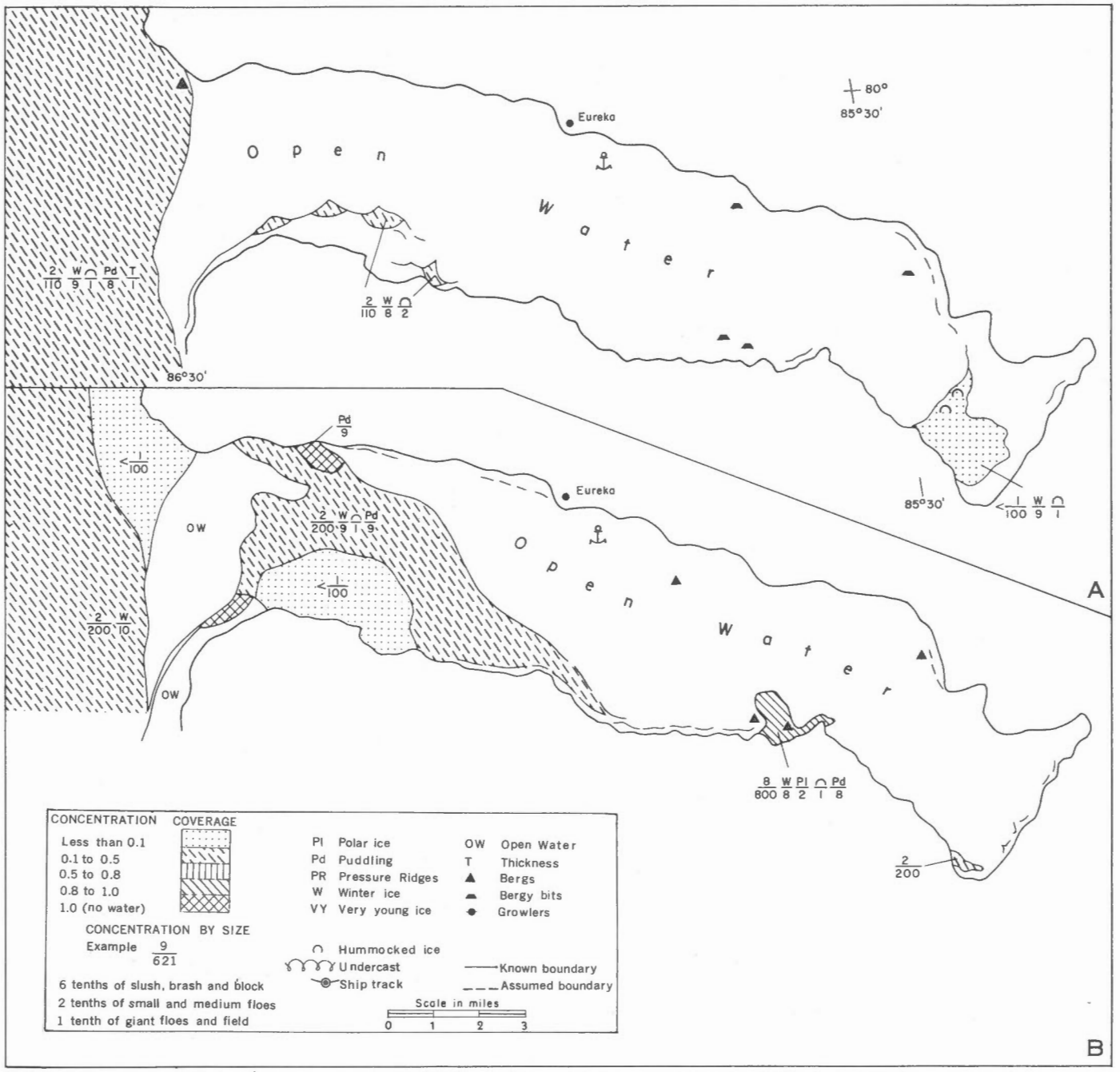

Figure 11 Ice distribution in Slidre Fiord, (A) August 22, 0415 hours; (B) August 24, 1830 hours.

accounted for 74 per cent of wind frequencies and 95 per cent of wind mileage; calms accounted for 13 per cent of the period. Average wind speed was 27 mph, but the average easterly wind speed was 31 mph. On August 18, maximum wind speeds reached 50 mph, and on the 19th reached 45 mph, with gusts up to 65 mph. In the Norwegian Bay area, westerly quadrant winds (NW-W-SW) prevailed, accounting for 55 per cent of wind frequencies. Calms accounted for 13 per cent of the period. Wind speeds averaged 12 mph, with a maximum speed of 20 mph.

The general effect of high winds in Jones Sound produced turbulent seas that resulted in the rapid erosion of sea ice; 67 per cent of the period recorded swells with surface condition varying from wavelets to very rough. In Norwegian Bay and Eureka Sound 48 per cent of the period was calm with glassy seas, and 52 per cent varied from rippled to slightly rough. The apparent effect of light winds combined with a calm sea resulted in an open ice distribution and reduced the effectiveness of factors that normally contribute to deterioration of the icefields.

Air temperatures generally stood well above freezing (Table 4a). The average minimum air temperature was 34.9°F., average maximum 46.0°F., and daily average 39.2°F. The daily average for air was 2.1°F. lower than the Lancaster Sound recordings and 5.2°F. lower than Baffin Bay-Davis Strait temperatures. There was little or no relationship between temperatures taken on the northbound and southbound journeys. Of some 54 recordings taken at 4-hour intervals between August 18 and 26, only two dropped to 32 degrees or lower. There was no apparent difference in the readings taken either in the open water or in the open icefields. Thawing temperatures prevailed.

The range between surface and sub-surface water temperatures was much narrower than that between surface water and air temperatures. The daily average for surface water was 36.5°F., and sub-surface water 32.9°F., the surface water being 2.7°F. and sub-surface 6.3°F. lower than the daily average for air. On the journey north through Norwegian Bay on August 21, and south on August 25, new ice appeared among the floes and half-inch thick glimmer ice on the surface puddles. This formation indicated the existence of local microthermal freezing temperature conditions.

Temperature effectiveness for air, surface water and sub-surface water for this part of the Eastern Arctic is given in Table 4b. Daily heat accumulative temperatures for air, surface water and sub-surface water were 16.9, 14.0 and 6.7°F. respectively, and were marked by high positive heat values. These values were much lower than those encountered in the Baffin Bay area and indicated the shorter open

TABLE 4

Temperature tables, Jones Sound - Slidre Fiord, August 18-26

a. Daily temperatures

	Air (F.°)			Surface Water (F.°)			Sub-surface Water (F.°)		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
Aug. 18	37	43	40.1	34	36	33.2	31	36	34.0
Aug. 19	36	45	39.5	33	35	34.3	31	34	32.7
Aug. 20	34	54	32.0	33	34	33.5	31	32	31.5
Aug. 21	38	44	41.0	32	44	38.5	30	40	34.1
Aug. 22	34	45	39.8	34	49	38.1	32	33	32.1
Aug. 23	32	46	38.3	39	39	39.0	31	33	32.1
Aug. 24	36	45	41.3	39	39	39.0	31	37	33.5
Aug. 25	30	50	41.1	32	42	36.3	30	38	32.8
Aug. 26	37	42	39.5	35	39	37.0	32	38	34.1
Daily Average	34.9	46.0	39.2	34.5	39.1	36.5	31.0	35.7	32.9

b. Daily heat accumulative temperatures

Date	Air (F.°)	Surface Water (F.°)*	Sub-surface Water (F.°)*
Aug. 18	16	10	7
Aug. 19	17	8	5
Aug. 20	24	7	3
Aug. 21	18	14	10
Aug. 22	15	23	5
Aug. 23	14	18	4
Aug. 24	17	18	8
Aug. 25	16	14	8
Aug. 26	15	14	10
Daily Average	16.9	14.0	6.7

* 30°F. is used for the calculation of the freezing point of sea water because of reduced salinity in this area.

c. Cumulative mean temperatures (F.°) at 4-hourly intervals

	0400	0800	1200	1600	2000	2400
Air temperatures	36.5	41.2	45.0	41.9	41.1	36.5
Surface water temperatures	35.5	36.8	37.1	36.9	37.1	37.3
Sub-surface water temperatures	32.9	33.2	32.0	33.9	33.5	32.5

water period, when the water accumulated heat, following the reduction of close pack ice. One of the major effects of the rapid warming of the eastern part of Norwegian Bay was the rapid deterioration of the icefields that entered the area from the northwest. A similar condition existed in Eureka Sound.

Table 4c, indicates that the highest air temperatures occurred from 0800 to 2000 hours with the maximum occurring at 1200 hours. The full daily range stressed effective thawing conditions. The range between the midnight minimum and the noon maximum was 8.5°F. Water temperatures were remarkably uniform, with the range between minimum and maximum temperatures being 1.8 and 1.9 degrees F. for surface and sub-surface water respectively. Undoubtedly the relatively high minimum temperatures resulted from the additional insolation afforded by the sunny weather during the 24-hour long day.

In order to reduce the 10/0010 ice surface that existed in this area on July 13 to the open ice cover that was encountered on August 21, high temperatures must have existed during much of August; likewise, the ice cover must have been composed mainly of relatively thin winter ice. Polar ice, whenever it was observed along the ship's course, was consistently thicker and denser, and more resistant to erosional forces. In addition to climatic factors, tidal currents were particularly strong in Hell Gate Passage and also in Eureka Sound, and were effective in reducing the size of the floes. Ice wreckage, either piled up on the rims of floes, or as brash and small floes, is a feature of 'working' ice, and is characteristic of these areas.

PART III

DISTRIBUTION OF ICEBERGS
(Figure 5: August 7-21)
(Figure 7: August 26-Sept. 5)

Icebergs were encountered in varying concentrations throughout the entire northward route from the Strait of Belle Isle, and averaged 1 to 5 per hour off the Labrador coast. Occasional bergs were sighted in Davis Strait. In Baffin Bay on August 9, the first icebergs in considerable quantity were sighted. Generally, belts of many icebergs were followed by belts of scattered bergs. The heaviest concentration of bergs lay off the coast of Bylot Island and off the east coast of Devon Island. In the latter area a count of 110 bergs was made at the southeast entrance to Jones Sound, 160 to the northeast of Philpots Island, and 90 southeast of the island. This area contained numerous growlers and bergy bits. Many of the growlers observed appeared to be remnants of hummocked polar ice. A concentration of icebergs was observed in the localized icefield that lay near Clyde Inlet. Small scattered icebergs were observed in Norwegian Bay

and Eureka Sound. Some 60 small bergs were counted in Eureka Sound north of Stor Island.

The icebergs encountered in Baffin Bay and Davis Strait were considered to have originated from the two glaciers of Disko Bay, and were particularly numerous in this area. The icebergs of northwestern Baffin Bay originated from glaciers on Bylot, Devon and Ellesmere islands, set adrift with the disappearnce of landfast ice in spring. The small bergs encountered in Eureka Sound originated from local glaciers entering Nansen Sound.

SUMMARY

Above normal weather conditions existed in the Eastern Arctic in the 1960 summer season. In contrast with the 1958 season, air and water temperatures stood substantially higher, and the ice cover in Baffin Bay was considerably less. Ice distribution in Norwegian Bay was similar to that in 1958. A progressive northward reduction in accumulative heat temperatures is evident from the following table:

Daily heat accumulative temperatures by regions, 1960

Region	Air ($F.^{O}$)	Surface Water ($F.^{O}$)	Sub-surface Water ($F.^{O}$)
Baffin Bay-Davis Strait	26.5	23.5	20.2
Lancaster Sd.-Barrow St.	19.9	12.2	8.7
Jones Sound-Slidre Fiord	16.9	14.0	6.7

These temperatures are related mainly to the length of period that the sea water is freed from close ice pack. The mean reduction in temperatures between the northern and southern regions for air is $9.6^{O}F.$, for surface water $9.5^{O}F.$, and for sub-surface water $13.5^{O}F.$

Aerial ice distribution maps issued mainly by the Meteorological Branch were available during the re-supply mission and provided a regional picture of ice conditions that existed in various parts of the Arctic at a given date. With the advance of the season the later maps indicated new patterns of ice distribution, and therefore the amount and nature of the change that had taken place from the previous aerial survey. The ice conditions observed during helicopter flights provided a picture of the immediate local area. Both types of ice charts resulting from the aerial survey and from the shipboard reconnaissance are included in this report. To show the changing patterns of ice coverage; forecast ice conditions for Baffin Bay and Lancaster Sound are also included. The radar screen on shipboard provided the local picture of ice conditions of immediate concern to the ship's officers.

SELECTED ICE TERMINOLOGY

Block: A fragment of sea ice from 6 to 30 feet across.

Brash: Fragments of floating ice, less than 6 feet across, resulting from the wreckage of other forms of ice.

Concentration by size: The first digit indicates tenths of brash and block, the second digit, tenths of small to medium floes and the third digit, tenths of giant floes and field. Example: 621 concentration indicates 6/10 brash and block, 2/10 small to medium floes and 1/10 giant floes and field. Total ice coverage 9/10.

Floe: A piece of sea ice. In terms of size a small floe is from 30 to 600 feet across; a medium floe is 600 to 3,000 feet; a large, or giant floe or pan is 3,000 feet to 5 miles, and an icefield an area of sea ice greater than 5 miles across.

Glimmer ice: Newly-formed ice within a crack or hole of older ice, or in the puddles upon older ice.

Polar ice: Usually ice of more than one winter's growth; surface forms vary from level to hummocked, and the ice is usually over 2 feet thick; it is blue-green throughout its course in melting.

Puddles: Depressions in floe ice filled with water melted from the surface of the ice. In this study puddling is expressed in 10ths coverage.

Ram: An underwater projection of ice.

Rotten ice: Ice that has become honeycombed in the course of melting.

Winter ice: Usually more or less unbroken, level, sea ice of the current winter's growth; it is grey-white in the course of melting.

Young or very young ice: Newly formed level ice, usually transparent, but may be opaque.

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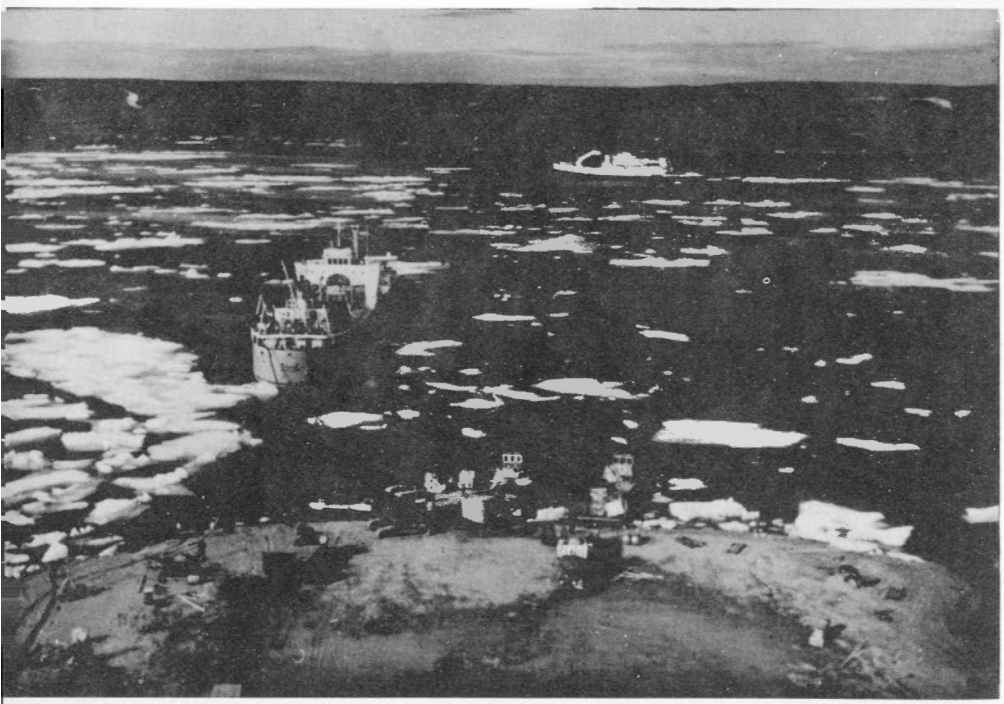
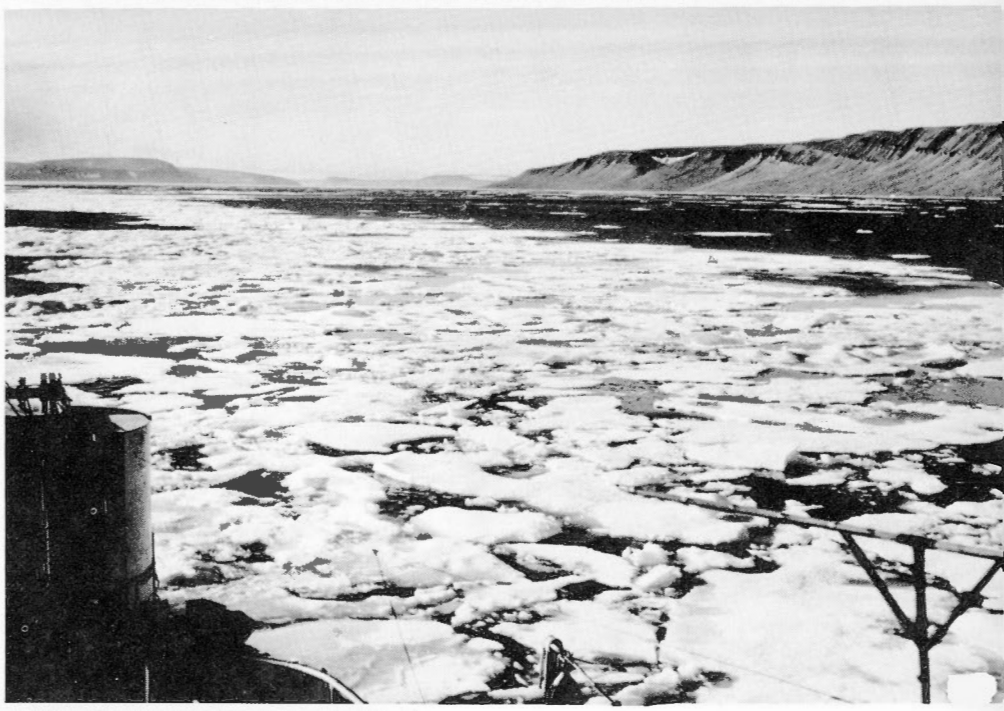
The tanker *Irvinlake* is pushing through an ice-field in low overcast off the entrance to Resolute Bay. (August 12).



Scattered ice in the vicinity of the landing beach at Resolute frequently hampered unloading operations. The tanker is in the foreground, with the *C.M.S. C.D. Howe* anchored in the bay at the edge of the ice. (August 16).

Open ice cover lay close to the landing-beach area at Resolute on August 16. Later, strong winds jammed the ice against the landing beach and hindered unloading operations.

Massive floes drifting against the side of the *C.M.S. d'Iberville* interfered with unloading operations. (August 13).



Norwegian Bay ice usually passes through Hell Gate Passage to Jones Sound in streams of ice wreckage and small floes. (August 21).

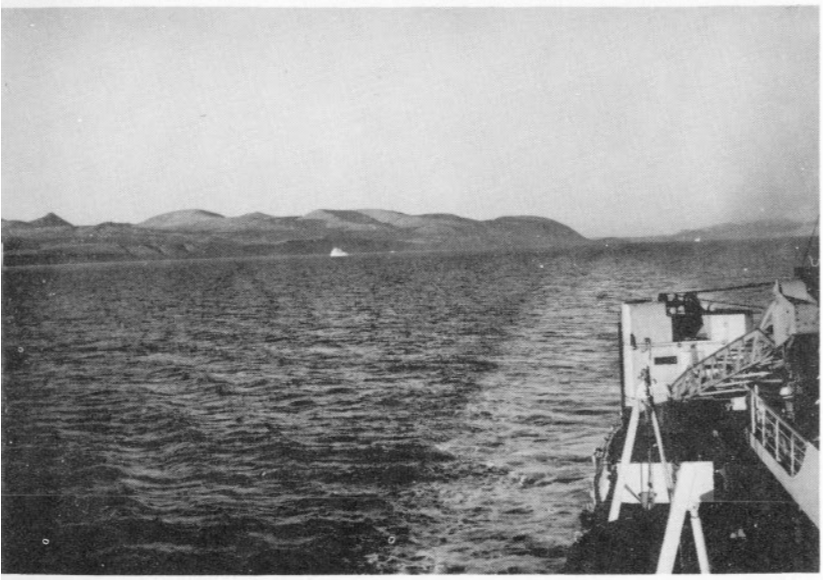
The *C.M.S. d'Iberville* is pushing into a mass of polar ice in Norwegian Bay. (August 21).

Polar ice is more resistant than winter ice to the forces that shatter the large floes which enter Hell Gate Passage. (August 25).

As Slidre Fiord was remarkably free of ice supplies were quickly unloaded at Eureka (August 24).

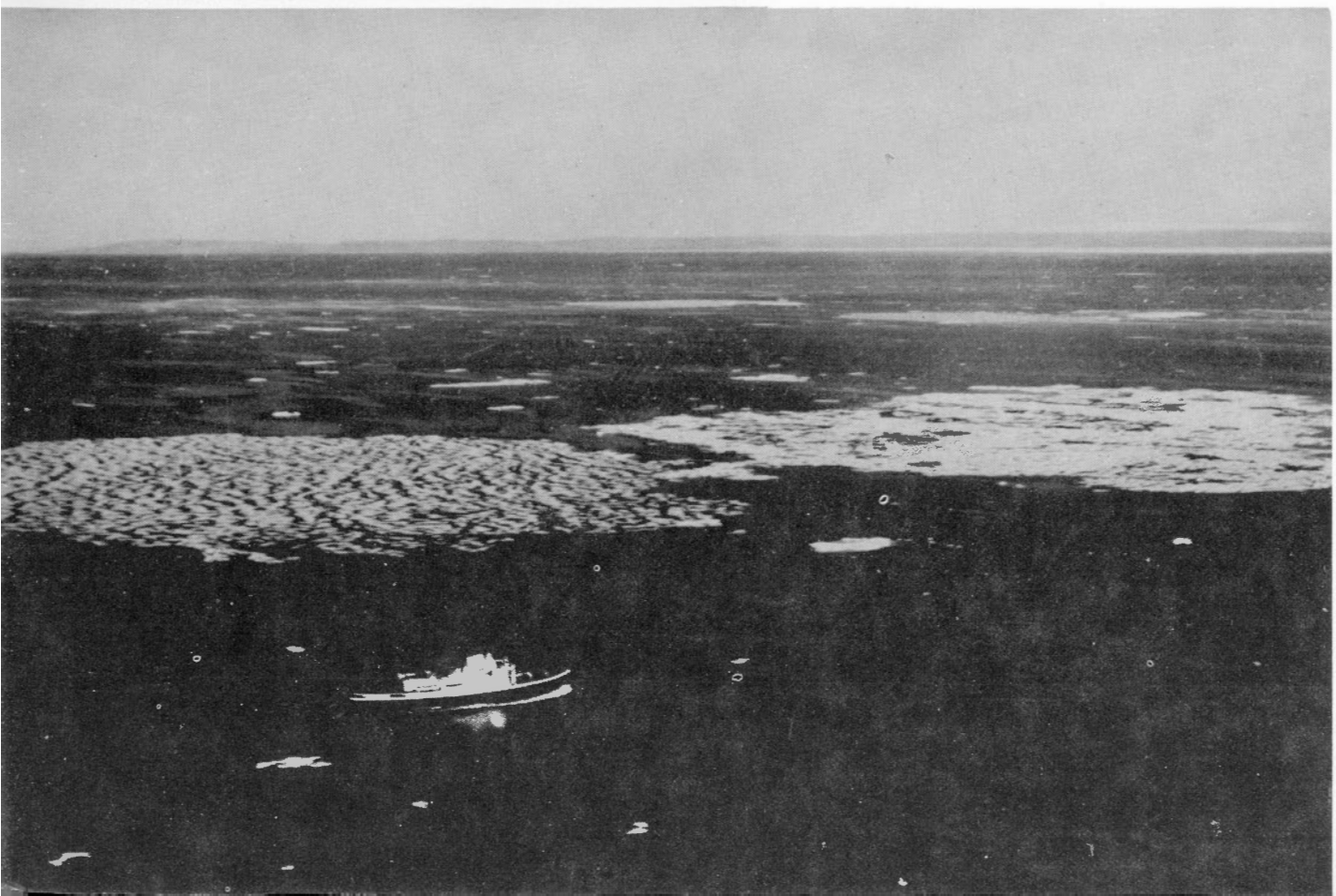
The *C.M.S. d'Iberville* is passing through winter ice in Eureka Sound. Surface puddling amounts to 8/10 of the ice surface; glimmer ice has formed over the puddles. (August 25).

Polar ice encountered in Eureka Sound shows characteristic hummocks. About 2/10 of the surface is puddled, and the puddles are covered with glimmer ice. (August 25).

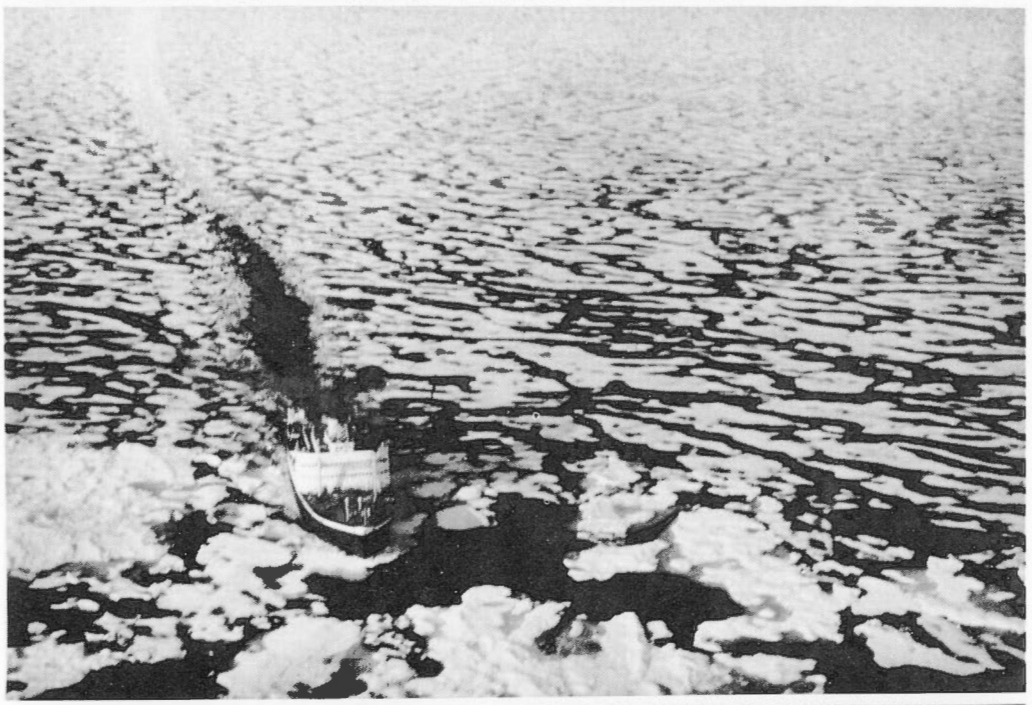


Except for scattered small bergs the southern part of Eureka Sound was ice free. (August 25).

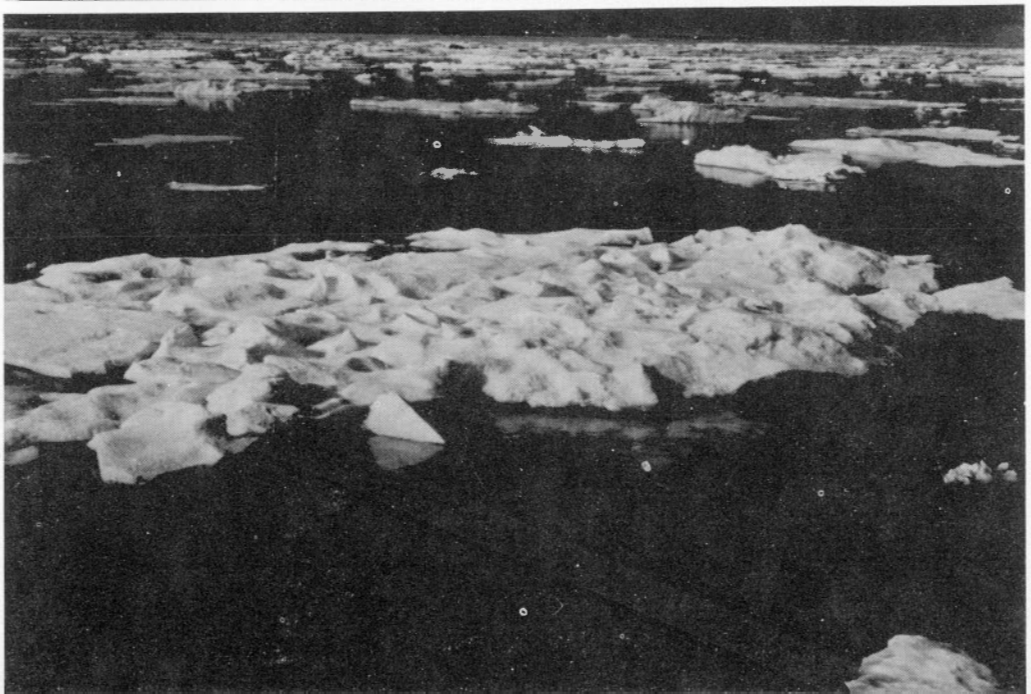
The southern part of Norwegian Bay contained an ice distribution that was less than one-tenth. Two large floes, one of winter ice and one of polar ice, lie beyond the ship. (August 25).



The field of polar ice lying across the bow of the *C.M.S. d'Iberville* is gradually drifting south towards Hell Gate Passage. (August 21).



The *C.M.S. d'Iberville* in Norwegian Bay has just passed through a field of winter ice; a belt of polar ice lies across the ship's bow. (August 25).



On September 2 near Clyde Inlet the *C.M.S. d'Iberville* passed through an open icefield mainly of polar ice.

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No. 9. A Report on Sea Ice Conditions in the Eastern Arctic, Summer 1956. By W.A. Black Ottawa, 1956. 32 p., maps, illus., offset *Price 50 cents.*

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