CANADA

GEOGRAPHICAL PAPER No. 39

Sea-Ice Survey, Queen Elizabeth Islands Region, Summer 1962

W. A. Black

GEOGRAPHICAL BRANCH
Department of Mines and
Technical Surveys, Ottawa

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At the entrance to Wellington Channel, on August 22, 1963, during a resupply mission, the C.C.G.S. *N.B. McLean* clears ice from around the C.C.G.S. *Nanook.* The heavy polar-basin ice visible beyond the *N.B. McLean* passed southward through Wellington Channel in mid-October 1962 after northwesterly gales shattered the consolidated polar-basin icefields in Penny Strait and Queens Channel—Courtesy Department of Transport.

PREFACE

The ice survey of the Queen Elizabeth Islands region made in the summer of 1962 was the second aerial survey conducted over this part of the high Arctic.

It is hoped that this report will bring about a clearer understanding of the extent, distribution, types, topographical forms and circulation of the ice cover as these changing features are observed in the course of the short Arctic summer.

J. D. Ives
Director
Geographical Branch

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SEA-ICE SURVEY, QUEEN ELIZABETH ISLANDS REGION, SUMMER 1962

INTRODUCTION AND ACKNOWLEDGMENTS

The aerial survey of arctic sea ice in the Queen Elizabeth Islands region from June to September 1962 is a continuation of the ice-distribution survey begun in the summer of 1961. The immediate purpose was to observe and map the coverage and distribution of the ice and to relate ice conditions to climatic factors. The long-term objective was to build an annual record showing ice and climatic relations, the variability of the ice cover and the nature of the regional ice circulation.

The survey was conducted by the Geographical Branch and co-ordinated as part of the Polar Continental Shelf Project. A Beachcraft Expediter (D18S) twin-engined aircraft provided by McMurray Air Services Ltd. was used for the aerial reconnaissance. The writer specifically acknowledges the assistance given by Dr. E. F. Roots, co-ordinator of the Polar Continental Shelf Project, and H.B. Burry, of McMurray Air Services Ltd., as well as the fine co-operation received in the field from officers of the Polar Continental Shelf Project and of the Meteorological Branch, Department of Transport.

The operation was planned to begin in mid-June and to continue until the end of September. Isachsen was the base of operations; Eureka, Mould Bay and Resolute were alternates. Originally eight flights were planned, but inclement weather and the austerity program resulted in reorganization of the schedule after mid-August. The various parts of six major flying operations were successfully completed on the following dates: June 21 and 23; July 5 and 6; July 17, 18, 20 and 21; August 4 and 5; August 28 and September 2, 3 and 5; September 24, 25, 26 and 29. The average duration of a flight was three days, and the average flying time was about 27 hours. The aircraft was flown at altitudes varying, according to local visibility, from 100 to 11,000 feet. The flight patterns were arranged so that the physical condition of the ice in the channels among the islands might be compared with that existing in Parry Channel, on the Arctic Front and in Eureka and Jones sounds. As the aerial program covered the period from break-up to freeze-up, it provided a yardstick for the measurement of the progress of sea-ice deterioration and consolidation on a regional basis.

The procedures used in observing and classifying ice were similar to those developed in the Gulf of St. Lawrence ice surveys (Black, W.A., Geographical Papers 23, 25, 32 and 36). It was found necessary to distinguish between ice of polar-basin origin and that of local origin. The graphic and quantitative

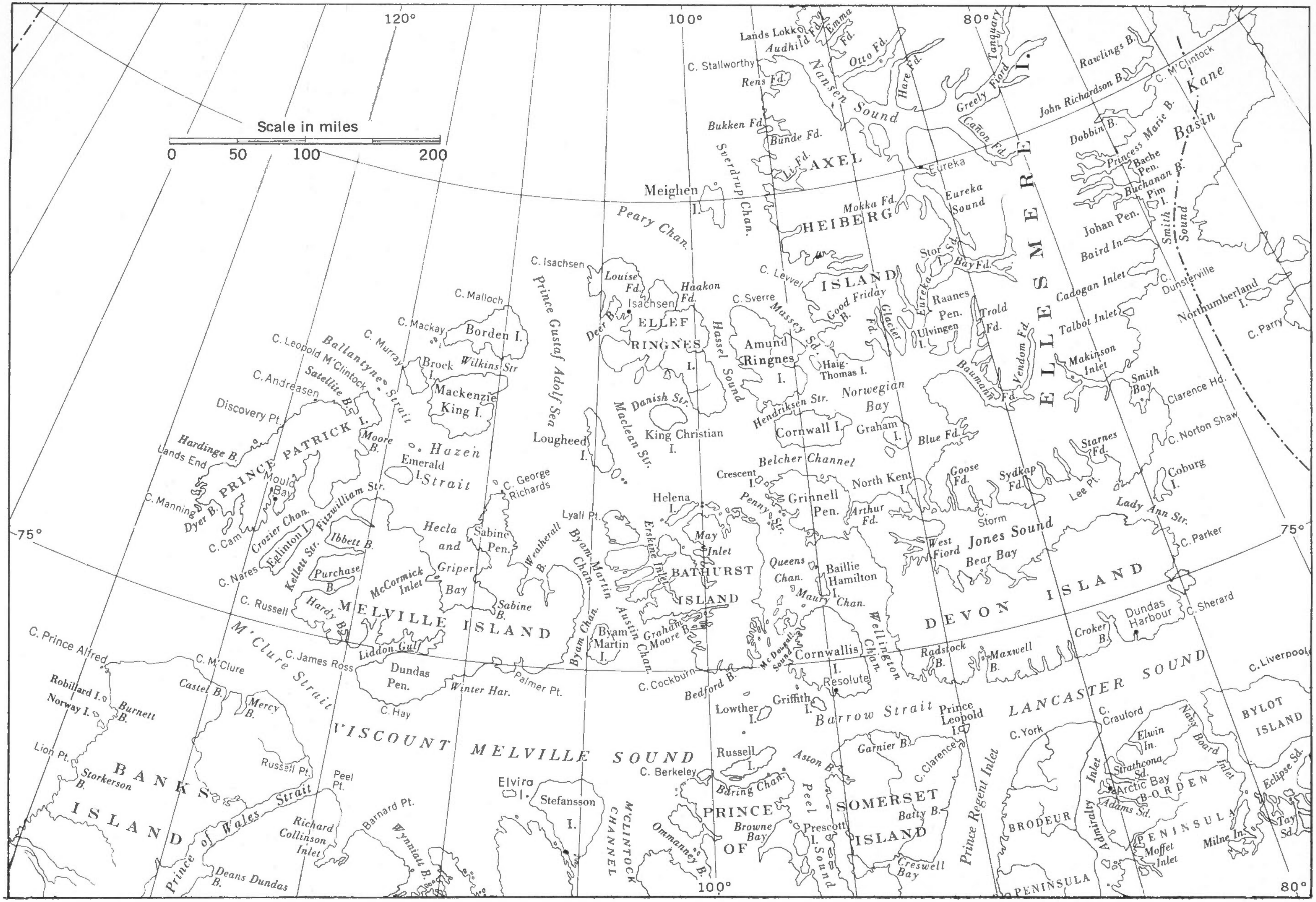

FIGURE 1. Location map, Queen Elizabeth Islands region.

classification methods indicate the main types: ice of polar-basin origin, which may be many years old; winter ice, formed locally and in a single season or similar ice known to have existed in a specific area for two or more seasons; and new and young ice formed during the season of observation. The last-mentioned are included as a unit because in the Arctic the transition from new ice to young ice is of relatively short duration. In graphic presentation the quantity of 3/10 or more of any given ice type is considered the critical value for deciding the type of pattern. Wherever polar-basin ice occurred in the proportion of 3/10 or more in association with winter ice or young and new ice, a close graphic pattern is used. An open pattern represents winter ice, and a wide pattern new and young ice. The quantities of each of the various types are expressed in tenths of the total ice cover. Boundary lines are used to separate the various categories of ice according to type and porportion of concentration.

The sea-ice formations of the Queen Elizabeth Islands region are grouped under four main aspects, namely, ice type, concentration, relief and decay, in that order. In this and previous reports, however, ice-concentration data have preceded those concerning ice types. Each aspect is further divided. The primary ice types are polar, winter, young and new. Concentration is based on the amount of sea surface covered by ice, the latter being indicated according to floe size, as follows: first digit, floes (slush, brash and block) up to 30 feet across; second digit, small to medium-sized floes 30 to 3,000 feet across; third digit, floes exceeding 3,000 feet across. The main relief features of the ice surface are hummocks (⌒), pressure ridges (∧) and shelving (~). The principal indicators of decay are surface puddling (∪) colour (C) and meltwater holes (O). The parts of the descriptive fraction are arranged and applied as follows:

Type	Concentration	Relief	Decay
P W Y N	9	⌒ ∧ ~	∪ C O
4 6 0 0	261	3 4 0	3 3 0

Not all the information is necessarily available. From break-up to the beginning of freeze-up, for instance, only polar and winter ice need be considered. Young and new ice, the main components of the latter being slush, slob and very young ice, occur at freeze-up time. Shelving occurs only in young and very young ice. The symbol R (C,O) is used to show the state of decay. Thus $\frac{R}{6-1}$ indicates that 6/10 of the ice surface is grey (C) and that 1/10 of the puddled ice surface is penetrated by meltwater holes (O).

Removal of the descriptive headings of the numerator gives a numerical code describing the four aspects of an ice formation in their order of sequence - thus, 4,600 261 340 330. This arrangement on maps is awkward and cumbersome, but the data may be grouped for greater clarity and compactness as follows:

$$\frac{\text{Type}}{\text{Concentration}} \quad \frac{\text{Relief}}{\text{Decay}} \quad = \quad \frac{46}{261} \quad \frac{340}{330}$$

Other features of the ice surface, such as the consolidation of a shattered ice surface under low temperatures, the formation of glimmer ice at freeze-up, ice fractures and the amount of snow cover, may be easily shown. Temperatures, wind direction and velocity, the state of the sea and any other pertinent data may likewise be added. The code has proved effective in the field and is easy to apply.

The descriptive headings of the numerator (concentration, type, relief and decay) are used here as in previous reports. As in the gulf reports, they are intended mainly to provide concise, readily understood information on ice distribution.

PART I

REGIONAL TEMPERATURE CONDITIONS

REGIONAL TEMPERATURES

The summer of 1962 was one of the mildest on record. Mean air temperatures for the region were well above normal during June and July (Table I).* Thawing conditions, therefore, well-advanced in June and maintained throughout July and August, resulted in widespread deterioration of the icefields in the Queen Elizabeth Islands region.

TABLE I

Mean monthly temperatures (F°)

Place	May M : N	June M : N	July M : N	August M : N	September M : N
Mould Bay	8 : 12	37 : 31	41 : 38	35 : 34	20 : 20
Isachsen	8 : 11	34 : 31	44 : 38	33 : 34	14 : 16
Meighen Island	- : -	34 : -	39 : -	32 : -	- : -
Alert	11 : 11	34 : 32	42 : 39	35 : 34	14 : 15
Resolute	11 : 14	35 : 33	46 : 40	38 : 37	25 : 23
Jones Sound	13 : -	37 : -	44 : -	38 : -	- : -
Eureka	15 : 14	38 : 37	46 : 42	39 : 38	17 : 19
Monthly average	11 : 12	36 : 33	43 : 39	36 : 35	18 : 19

Note: M - 1962 mean; N - normal mean. Temperatures given to nearest whole number.

Mean monthly temperatures for May varied from 1 degree above to 4 degrees below normal. June temperatures, 1 to 6 degrees above normal, heralded a milder-than-usual season, and July, with temperatures 3 to 6 degrees above normal, was a month of rapid deterioration of landfast ice-cover. The established regional pattern of prevailing high temperatures was halted in mid-August. August temperatures, although above freezing and ranging from 1 degree below to 1 degree above normal, slowed the deterioration process. September temperatures, from 2 degrees above to 2 degrees below normal for the region, were marked by a rapid fall that was 7°F above the mean regional temperature for May, when subarctic winter temperatures prevailed.

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*Information on temperatures and winds used in the tables in this paper have been provided by the Meteorological Branch, Department of Transport; that for Meighen Island by Keith Arnold of the Geographical Branch.

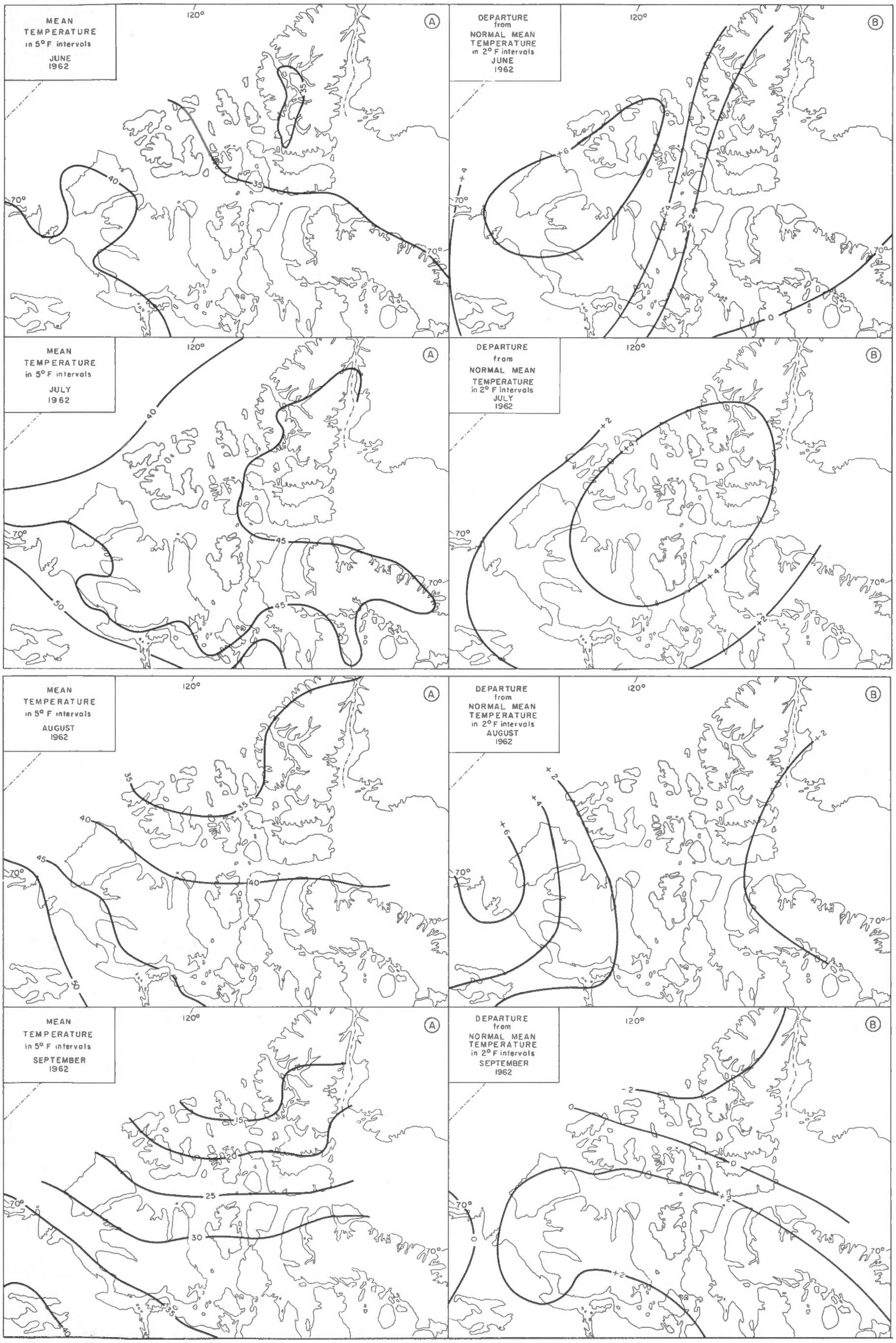

FIGURE 2

(A) Mean temperatures, June to September, 1962. (B) Departure from normal mean temperatures, June to September, 1962.

Temperatures varied within the region (Table I). They were highest in the eastern part, where deterioration of the icefields was most advanced. Lowest summer temperatures were experienced in the Meighen Island area; in the autumn, freezing was first evident in this part of the Arctic. The more northerly area, that about Meighen Island may be said to be the region's "cold" zone. The markedly higher September temperatures representative of Parry Channel, the most southerly part of the region, illustrate the marine influence of open water and the consequent delay in the formation of an extensive ice cover. After mi-September, when daily temperatures were falling sharply, consolidation of the existing icefields and the renewal of the ice cover advanced rapidly under the approaching zero-to-subzero temperatures.

The isotherms representing mean temperatures and departures from normal temperatures for the Arctic region from June to September inclusive are shown in Figure 2 (A and B). The NE-SW trend of the June isotherms shows that, as is indicated by the strong positive anomaly, the temperatures were higher in the western part of the region than in the eastern (Figure 2, A). It could thus be expected that the deterioration of ice conditions would advance more rapidly in the west and that McClure Strait would therefore open before Lancaster Sound. In July, although the temperatures were uniformly high throughout the region, those in the eastern parts had risen more rapidly and were more conducive to ice break-up and the development of open-water areas than those in the west. As these more easterly temperatures were well above normal, the decay of the icefields advanced more rapidly than usual. August isotherms showed a decline in temperatures. The 40-degree isotherm shifted from the Arctic Front to Parry Channel and was followed by the southward-bulging 35-degree isotherm. These changes in position indicated that thawing conditions were tapering off. Above-seasonal temperatures prevailing in the eastern and western areas were caused mainly by ice-free waters. The east-west trend of the 40-degree isotherm parallel to Parry Channel denotes the moderating influence of open water. As August temperatures over most of the region were about normal, ice-decaying processes may also be considered to have been about normal. In September, marked by east-west-trending, low-temperature isotherms indicated the approach of early winter. The freezing of land and water surfaces, and the consolidation of icefields resulted from uniformity of low temperatures characteristic of winter. Temperatures conducive to consolidation of the Arctic icefields were more pronounced in the area centred on Meighen Island and much less so in Parry Channel.

THAWING AND MELTING CONDITIONS

Table II gives the dates on which the region's summer thawing temperatures began, but higher temperatures occurred earlier and lower temperatures later. The significance of the dates is that they mark a clean break between freezing and thawing.

TABLE II

Dates of spring thawing temperatures, 1962

	Mould Bay	Isachsen	Meighen Island	Alert	Resolute	Jones Sound	Eureka	Average date
Maximum temperature over 32°F	June 3	June 4	June 4	June 3	June 4	June 3	June 3	June 3
Minimum temperature over 32°F	" 11	" 15	July 3	July 5	" 20	" 12	" 7	" 20
Daily mean over 32°F	" 4	" 5	June 4	June 6	" 6	" 4	" 5	" 5

Daily maximum temperatures passed above the freezing point on June 3 and 4; daily minimum temperatures, which show greater regional variation in relation to thawing, occurred on June 7, July 5 and intermediate dates. The average duration between the dates when daily maximum and daily minimum temperatures reached 32°F was 18 days.

The melting period is measured from the date on which the daily minimum temperature rises above 32°F in the spring to the date on which it falls below 32°F in the autumn. While it lasts, therefore, temperatures are above freezing for the full day and are thus most effective in the reduction of the icefields. In spring and autumn a period of partial freezing exists between the occurrences at 32°F of the mean daily and the daily minimum temperatures. Although marked by alternate thawing and freezing, it is a time of above-freezing temperatures. The sum of the periods of melting and partial freezing is the duration of the melting or ablation season shown in Table III. It should be noted, however, that the diurnal range of temperature during the melting season is very small.

The melting period was longest in the eastern part of the region, where it reached 92 days. The closeness of the duration totals for Resolute, Jones Sound and Eureka indicates that the melting period for eastern Lancaster Sound may have been about 110 days. The deterioration of the icefields was therefore most advanced in this area (Figure 8). As the length of the optimum-melting period declines, the length of the partial-melting period increases. The shortest melting period and the longest partial-melting period existed in the Alert-Meighen Island area. Hence, the last remaining area of sea-ice to break up was centred on Meighen Island (Figure 11).

TABLE III

Duration of melting period in days, 1962

	Mould Bay	Isachsen	Meighen Island	Alert	Resolute	Jones Sound	Eureka	Average duration
Optimum-melting period	63	53	36	38	58	72	70	55
Partial-melting period	23	18	35	35	34	20	19	26
Total length of period	86	71	71	73	92	92	89	81

The first recognizable stage of the melting process is the formation of surface water pools, which is followed by greying of the ice surface and later by the occurrence of meltwater holes in the deeper parts of the surface pools. The progression in colour from shades of light grey to dark grey is characteristic of the decaying of winter-type sea ice. The decay is aided, particularly near islands, by large quantities of dust blown over the ice surface. This sediment, swept by the meltwater into the deeper parts of the pools, causes meltwater holes to form in the icefields, first near the coasts and then farther out. On winter ice the meltwater constitutes an interlocking mosaic of long narrow pools and so results in the formation of the first floes, narrow and splinter-like, dark-coloured and about 10 to 20 feet long. The final decay of polar-basin ice in situ produces an irregular network of meltwater pools, few of which penetrate the ice. The resulting floes are angular and irregular in shape and pale green-blue.

As local open-water areas (polynyas) are centres where solar radiation may be absorbed by sea-water rather than reflected into the atmosphere, they contribute to the deterioration of the surrounding ice-fields and thus become increasingly important as the season advances. A comparison of figures 8, 9 and 10 (June 21 and July 5 and 21) shows the growth of polynyas and the close relation between break-up and these early-formed water areas. Another factor is the development of coast-bordering water strips. Because of these, the ice is able to shift and thus become subject to particularly strong stresses where it impinges on headlands, capes and small islands. At such points of impingement, which become the foci of networks of cracks radiating for many miles, the first shattering of the icefields takes place. These cracks, associated with imminent ice break-up, should be distinguished from incipient cracks, which occur earlier in the season. The latter, caused by atmospheric and other pressures, freeze over again and the refrozen scar often remains until the ice disintegrates.

Most of the polynyas are narrow and are formed where higher temperatures over islands make it possible for higher temperatures to prevail over adjacent icefields. Such was the origin of the island-bordering water strips that came into being in the first half of July. The water strips varied considerably throughout the region, affected by the higher temperature of surface runoff water, which began to flow in early June. On June 21, the runoff stages were similar at Isachsen and Resolute but were considerably more advanced in the extreme southwestern and eastern parts of the region.

The melting of the ice in situ over the extensive shoals bordering the western coasts of Prince Patrick, Brock, Borden and Ellef Ringnes islands, is aided by surface runoff and the shallowness of the ice cover. In these areas, higher temperatures over land melted the snow cover, whereas over polar-basin ice lower temperatures prevailed. That a small amount of the Arctic Front ice continued during the summer to be new in type indicated the prevalence of low temperatures at the ice surface.

Because of wide temperature variations and the great extent of the region, the number of melting degree-days would be expected to vary greatly, as shown in Table IV. The monthly mean of melting degree-days was 131 for June and 143 for August. At its best, in July, it was one and a quarter times the combined means for June and August. Mould Bay, with 599 melting degree-days, was closest to the regional average which was 623. The Isachsen-Meighen Island-Alert area was below average and the eastern and south-eastern areas above average. The melting of the icefields throughout the region, therefore, progressed at an uneven rate, as is shown by the scattered distribution of local open-water areas (Figures 8, 9 and 10).

TABLE IV

Melting degree-days, Queen Elizabeth Islands, 1962

Month	Mould Bay	Isachsen	Meighen Island	Alert	Resolute	Jones Sound	Eureka	Average
June	176	93	49	96	115	177	210	131
July	297	360	231	328	429	367	423	348
Aug.	126	73	42	156	178	190	235	143
Sept.	-	-	-	-	7	2	0	1
Total	599	526	322	580	729	736	868	623

Observations taken on June 21 and 23 (Figure 8) indicated that puddles in the channels adjoining Parry Channel and the eastern parts of the region occupied from 6/10 to 9/10 of the ice cover. In these areas, where puddles were most highly concentrated, the number of melting degree-days was also highest. On June 22, the accumulated melting degree-days numbered 124 for Mould Bay, 145 Jones Sound and 146 for Eureka. The higher concentrations of surface puddling developed on the flat-surface winter ice and showed a clearer relation to the melting process than those that developed on the hummocked polar-basin ice.

On these dates, in the central, western and northeastern parts of the region, puddling covered from 3/10 to 5/10 of the icefields. Over the Arctic Front and the Meighen Island area glimmer ice covered the pools or coexisted with surface puddles. These areas, having the lowest concentration of puddles, also had the lowest number of melting degree-days as represented by Isachsen (68), Meighen Island (46) and Alert (81). In Parry and Queens channels, McDougall Sound, Penny Strait and the Edinburgh Sea,* when puddling on winter ice was about 5/10, Isachsen had 68 melting degree-days and Resolute had 71.

A comparison of Figure 8 (June 21 and 23) with Figure 9 (July 5 and 6) showed a significant expansion in open-water areas and an increase in the concentration of surface puddling on winter ice in the eastern half of the region. Decaying ice appeared for the first time in Eureka Sound, Belcher Channel and Hendriksen Strait. In fact the high puddle concentration together with ice decay seemed to indicate that the number of melting degree-days was similar to that for Eureka (July 5 - 266). The amount of surface puddling as recorded on July 5 and 6 indicated the importance of the melting factor in the deterioration of the consolidated icefields in these areas. Everywhere except Lancaster Sound and Barrow Strait, the first open-water or ice-free areas occurred almost entirely through the melting of ice in situ.

A comparison of ice-surface topography observed from July 17 to 21 (Figure 10), with that observed on July 5 and 6 (Figure 8) indicated important surface changes. The concentration of decaying ice, almost nonexistent on July 5 and 6, was widespread from July 17 to 21. The only exceptions were the icefields of polar-basin origin of the west-central part of the region and the polar-basin icefields of the Arctic Front.

These changes resulted from a period of high temperatures that occurred in July and varied from one to three weeks. The duration of effective melting is shown in Table V. It is the summer period, when the melting degree-days exceeded 10 or more a day and therefore indicates that melting in the region

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*In this report, the name Edinburgh Sea is applied to the body of water bounded by Ellef Ringnes Island on the north, Bathurst Island on the south, Lougheed Island on the west and Cornwall Island on the east. Up to the present, this water area has received no official name from the Canadian Permanent Committee on Geographical Names.

was at its maximum. With the exception of those for Alert, about one third to one half of the melting degree-days for the summer season were accumulated at this time. In the Meighen Island area the period was of eight days' duration and resulted in the lowest number (110) of accumulated melting degree-days. The melting period was longest in the Resolute area, being 22 days; there, accumulated melting degree-days totalled 368 and averaged 17 a day. The Eureka area was second, having only 337 accumulated melting degree-days. The duration of effective maximum melting at Mould Bay, Isachsen and Jones Sound was from 15 to 18 days, but melting effectiveness was reduced by the considerably lower number of accumulated melting degree-days. An additional important effect of such climatic conditions as were observed on the icefields from July 17 to 21 was the concentration of decaying ice (R-rotten), which indicated a reduction of ice thickness by surface weathering. The decay index ranged from 0 to 5; that is, from 0/10 to 5/10 of the ice surface was covered with meltwater holes.

TABLE V

Period of effective maximum melting, 1962

Place	Duration	Days	Cumulative total, melting degree-days	Percentage of total of melting degree-days	Average of melting degree-days
Mould Bay	July 5-22	18	237	39.5	13
Isachsen	" 9-23	15	253	48.0	17
Meighen Island	" 9-16	8	110	34.1	14
Alert	" 10-17	8	122	21.0	15
Resolute	" 8-29	22	368	50.4	17
Jones Sound	" 9-24	16	250	34.0	16
Eureka	" 2-23	22	337	38.8	15

The relation among melting degree-days, puddling, colour and meltwater holes of the winter icefields is given in Table VI. This criterion is applicable as it represents mainly the absorption of solar energy, and is therefore less affected by wind or oceanographic factors. The deterioration of winter icefields as indicated by puddling, colour and meltwater holes may be observed whether the ice remains in situ as part of an unbroken ice cover or continued to drift in packs.

TABLE VI

Relation of melting degree-days to deterioration of winter icefields

Cumulative melting degree-days	Puddling	Greying (tenths)	Meltwater holes	State of deterioration
50 - 125	4 - 5	white	0	beginning
125 - 200	6 - 8	off-white	0	progressing
200 - 275	6 - 8	1 - 4	0 - 1	advancing
275 - 350	6 - 8	4 - 8	1 - 2	advanced
350 - 425	6 - 8	8 - 10	2 - 3	well-advanced
425 - 500	6 - 8	10	3+	final

The table shows that a direct relationship exists: wherever the accumulated melting degree-days exceeded 425, the winter icefields were in the final stage of deterioration and the ice surface was a dark shade of grey; wherever they ranged from 275 to 425, ice deterioration was advancing rapidly and the ice colour was mottled grey. Below 200, the accumulated melting degree-days represent the energy stored and expended in the melting of snow and exposed ice and in the formation of surface pools. The early development of open water at bayheads and along the shores is related to local microthermal environments where melting degree-days, accumulating quickly, result in early deterioration of the ice surface. The concentration of puddling in local areas varied considerably from time to time. It was not unusual to find areas having 8/10 puddling reduced to 6/10 a week or so later, or areas where the puddles had coalesced to form ice-surface lakes. The largest of these, observed on July 18 off South Fiord, had an estimated area of 75 square miles. Such reductions in surface-water area usually occur in the early stages of melting, before the ice surface becomes incised by the meltwater pools. The withdrawal of such water leaves the ice surface coarse-grained and off-white in colour.

The close relation between the accumulated melting degree-days and the stage of deterioration of the winter icefields seemed to indicate that the mean thickness of winter ice must be almost uniform throughout the region. This view is supported by the fact that the winter ice has a prevailing flat surface and very little pressure ridging. The latter, varying from 0/10 to 1/10 in concentration, was general throughout the region (Figures 8 and 9). Also observed were local areas of more rapid ice deterioration, which consisted mainly of bays and narrow channels. These areas may have a higher-than-average aggregate of melting degree-days. The reduction of the consolidated ice sheet to floes from icefields deteriorating in situ is also closely related to the concentration of meltwater holes reached a concentration of 2/10 or more, any additional stress, such as that caused by changes in wind velocity or direction, shattered the icefields.

The concentration of puddling on polar ice varied considerably from that developed on winter ice. On the icefields of the Arctic Front puddling remained about 3/10 to 4/10 throughout the season. As the icefields beyond the Front are part of the Arctic gyral, which revolves clockwise off the islands, and are drifting from higher latitudes of low temperatures to lower latitudes, active melting is of much shorter duration so that puddling seldom covers 4/10 of the ice surface.

Surface puddling on the unbroken icefields of polar-basin origin lodged in the channels among the islands presented a different picture. On June 21 and 23 (Figure 8) the concentration of surface puddling was from 3/10 to 4/10; six and a half weeks later, on August 4 and 5 (Figure 10) the amount of puddling varied from 5/10 to 7/10 and ice decay from 0/10 to 1/10. These icefields were now shattered and the polar-basin ice was beginning to crowd into the channels along the Arctic Front. The relation between the number of melting degree-days, surface puddling and ice decay is given in Table VII.

TABLE VII
Relation of melting degree-days* to deterioration of polar-basin ice

	June 21	July 5	July 20	August 4
Surface puddling (tenths)	3 - 4	4 - 5	5 - 6	5 - 7
Cumulative degree-days	70	160	380	480
Rate of increase, cumulative degree-days	1.0	2.3	5.4	6.8

*Melting degree-days based on Isachsen statistics

Because of the variation of ice decay from 0/10 to 1/10 noted on August 4, when the number of melting degree-days was 480 and surface puddling varied from 5/10 to 7/10, it seems that the occurrence of meltwater holes in polar-basin ice formed in situ begins when melting degree-days total 450, or about 6.4 times those of June 21. A comparison between the number of melting degree-days required for the progressive deterioration of winter ice (Table VI) and the number required for the deterioration of polar-basin ice shows that substantially more heat is needed to cause the decay of the latter. A specific comparison may be made: in winter ice the meltwater-hole concentration of 0/10 to 1/10 occurs between 200 and

275 melting degree-days, but in polar ice it occurs after the 450 mark. The primary factors that make a larger number of melting degree-days necessary to bring the decay of polar ice to the same stage as that of winter ice seem to be the greater thickness of polar-basin ice (less dust on its surface and less consistent open-water shore lanes), rime deposition, and frequent periods of surface freezing during the polar summer.

A second but small maximum of melting degree-days occurred. It lasted longest in the eastern Arctic, but was also of notable duration in the western and southern parts of the region (Table VIII).

TABLE VIII

Second period of effective maximum melting, 1962

Place	Duration	Days	Cumulative total, melting degree-days	Percentage of total of melting degree-days	Average of melting degree-days
Mould Bay	Aug. 3-7	5	65	10.8	13
Isachsen	" 3-7	5	51	9.7	10
Meighen Island	" 6	1	11	3.4	11
Alert	July 29 - Aug. 10	13	197	33.9	15
Resolute	Aug. 2-3	8	111	15.2	14
Jones Sound	July 30 - Aug. 8	10	116	15.8	12
Eureka	" 30 - " 13	15	215	24.8	14

The initial shattering of the icefields, advancing quickly in the first period of effective maximum melting, was completed before the second period had begun (Figure 11). After the second period, effective melting fell rapidly, particularly in the western Arctic. In Viscount Melville Sound, the melting of winter ice slowed down, and in September, when freeze-up began, fragments remained in the sound. Winter ice-lying near the south coast of Mackenzie King Island also remained throughout the season. The rapid decline in melting seemed to be one of the important reasons for the continued congestion in Hazen Strait and to obstruct the flow of ice from the strait. In the eastern part of the Arctic, high temperatures contributed to the rapid deterioration of the icefields and, aided by oceanographic factors, facilitated the rapid clearing of the local icefields by the wind. The withdrawal of the local icefields into the interior channels left the way open for a fresh invasion of the region by polar-basin ice.

FREEZING CONDITIONS

The dates of the beginning of freeze-up of the Arctic ice pack are given in Table IX. They mark a clean break between thawing and freezing conditions, and are followed by a prevalence of freezing temperatures.

The daily minimum temperatures for the region dropped below the freezing point on August 14, and the daily maximum dropped below 32°F on August 31. Daily minimum temperatures fell below the freezing point first in the Isachsen-Meighen Island area, on August 8, and last in the Jones Sound area, on August 23. The two-week interval between the two extremes is reflected in the corresponding daily mean temperatures. Daily mean temperatures dropped below freezing in the Meighen Island area on August 14, in Jones Sound on September 4, and in Barrow Strait on September 6. The maximum range for the region was therefore about three weeks.

TABLE IX

Dates of autumn freeze-up, 1962

	Mould Bay	Isachsen	Meighen Island	Alert	Resolute	Jones Sound	Eureka	Average date
Maximum temperature under 32°F	Aug. 31	Aug. 30	Aug. 16	Aug. 20	Sept. 8	Sept. 9	Sept. 10	Aug. 31
Minimum temperature under 32°F	" 13	" 8	" 8	" 12	Aug. 17	Aug. 23	Aug. 16	" 14
Daily mean under 32°F	" 29	" 16	" 14	" 18	Sept. 6	Sept. 4	Sept. 2	" 26

The approach of freezing temperatures caused the formation of glimmer ice on fresh-water pools, thus providing the first evidence that consolidation of the icefields was imminent. Although no observations were made over the icefields in mid-August to obtain data on the regional distribution of this phenomenon, observations made on August 4 and 5 (Figure 11) showed that young and glimmer ice existed in the icefields beyond the Arctic Front. Observed ice conditions (Figure 12, September 2 to 5) showed the puddles to be entirely ice-covered everywhere but in the southern and southeastern parts of the region. Wherever they existed, puddles were associated with icefields lying adjacent to extensive areas of open water. This pattern of the regional distribution of glimmer ice and surface pools coincided with freezing conditions that prevailed throughout the region at the end of August (Table X).

TABLE X

Freezing degree-days, Queen Elizabeth Islands, 1962

Month	Mould Bay	Isachsen	Meighen Island	Alert	Resolute	Jones Sound	Eureka
Aug.	13	40	119	69	0	0	0
Sept.	365	542	-	548	210	-	434
Total	378	582	-	617	210	-	434

There is a direct relation between the number of freezing degree-days and the formation of glimmer ice. On September 3, when the surface pools in the Isachsen-Meighen Island area were completely ice-covered, the accumulated freezing degree-days ranged from 73 at Isachsen to 150 (estimated) at Meighen Island. At Mould Bay - in the McClure Strait area, where the surface pools were only partly ice-covered - freezing degree-days numbered 27. It seems that complete freezing of the pools is attained with the accumulation of 50 freezing degree-days. The concentration of surface pools in Viscount Melville Sound was much greater than the amount of glimmer ice. The number of accumulated freezing degree-days was between 10 and 15 - that is, midway between those of Resolute and those of Mould Bay. The entire southeastern part of the region from Eureka Sound to Austin Channel, where temperatures were above freezing, was free of glimmer ice.

By the end of September, the advance of freezing was greatest in the north. Next came the western parts and then the southeastern, where the advance was smallest (Figure 13). By September 24, when the accumulated freezing degree-days for Mould Bay totalled 264, the areas of previously open water had become ice-covered with an 8/10 to 9/10 concentration of new and young ice. The young ice was the more prevalent and was usually associated with, or adjacent to, fields of polar-basin ice. On September 28, when accumulated freezing degree-days in the Isachsen-Meighen Island area numbered 533, the bays were covered with winter ice, which at Isachsen, was 10 to 12 inches thick. Eureka, with 434 freezing degree-days on this date, was reported covered with young ice at an advanced stage. On September 14, when new ice was gradually extending over Parry Channel between Cornwallis and Byam Martin islands and when Wellington and Queens channels, McDougall Sound and Penny Strait had become ice-covered, freezing degree-days at Resolute numbered 167. After the violent storm of September 27 and 28, the fields of ice recently formed in Queens and Wellington channels, Penny Strait and McDougall Sound disappeared and the eastward advance of the ice cover to Lancaster Sound, in Parry Channel, was temporarily arrested. Lancaster Sound, the first important area to become ice-free and the last in the region to become ice-covered, was the region's "warm" zone.

PART II

WINDS AND ICE CIRCULATION

GENERAL WIND CONDITIONS

The polar summer is a time of maximum cyclonic activity. This activity is associated with the period of continuous daylight and with the periods of heaviest snowfall, which occur in April and May and in the months from September to November. It is also associated with the break-up of the icefields, ice circulation and the expansion of open-water areas and finally, in September, with the consolidation of the icefields and freeze-up.

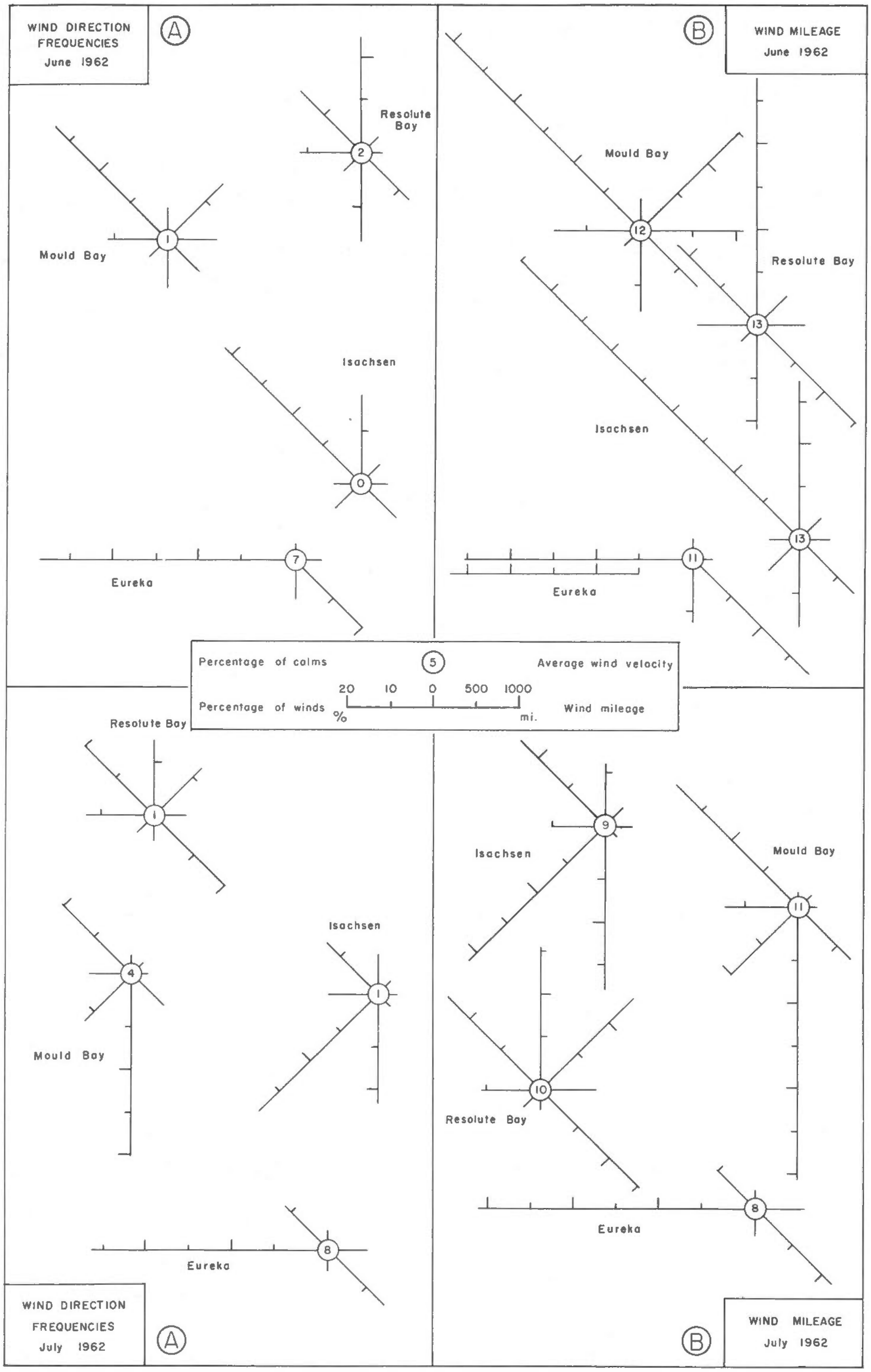
Surface-wind mileage and velocity for the Queen Elizabeth Islands region are shown in Table XI. Both varied greatly within each month and from month to month. The winds were weakest in July. Subsequently increasing in strength, they reached their maximum in September, at the time of greatest cyclonic activity. The winds weakest in both mileage and velocity from June to September occurred in the north-eastern parts of the region as represented by Eureka and Alert. During June and August, the strongest winds occurred in the area of the Arctic Front; in July and September, they occurred around Parry Channel. The areas of greatest ice movement was associated with those of the strongest prevailing winds, which occurred in the western and central parts of the region.

The main characteristics of the winds in terms of hourly and mileage frequencies and ice drift are given in detail for the Queen Elizabeth Islands region from June to September in tables XII to XV.

TABLE XI

Surface-wind mileage and velocity (m.p.h.), Queen Elizabeth Islands, June to September, 1962

Winds	June	July	Aug.	Sept.
Mean mileage	7,805	6,541	7,545	8,727
Mileage range	5,214 - 9,125	5,169 - 7,858	5,194 - 9,027	4,619 - 11,770
Mean velocity	11.0	8.7	10.3	12.2
Velocity range	7.2 - 12.6	6.9 - 10.5	7.0 - 12.2	6.4 - 16.3
Per cent of July winds	119.3	100	115.3	133.4



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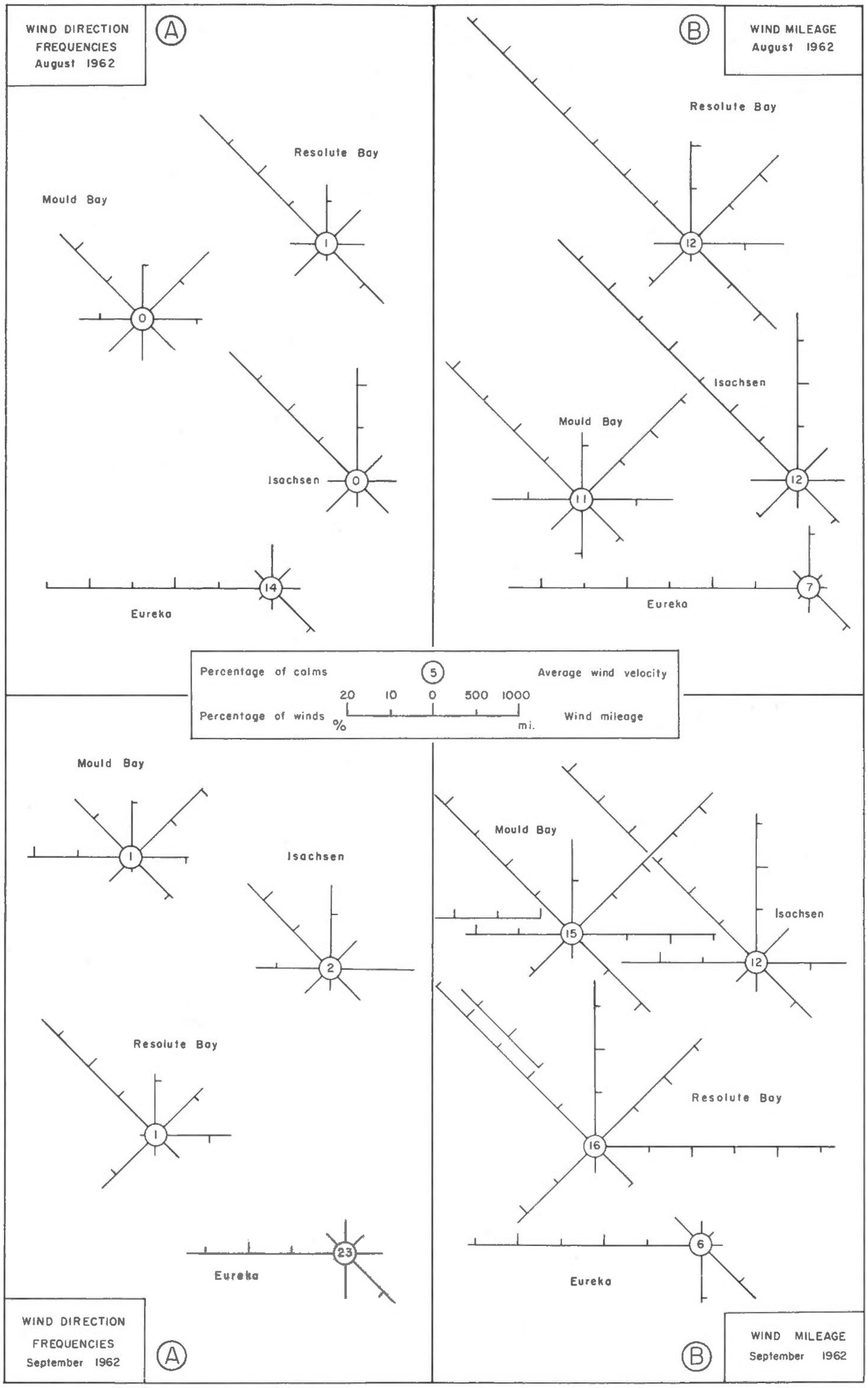
(A) Wind-direction freque

(B) Wind mileage, June t



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Shuleykin's ratio of ice drift to wind speed (1:25)* provides a practical estimate of the rate at which ice drifts with the wind.

The June winds were highly variable (Table XII), but because of the prevalence of consolidated ice over much of the region, they had little effect on the shifting of the icefields. In the Resolute area, the NW and N components were dominant, accounting for 48 per cent of mileage frequencies and providing an ice-drift rate of 10 to 16 miles a day. Icefields in Barrow Strait and Lancaster Sound were in motion during June, the generally eastward drift being opposed only by weak NE, E and SE winds that accounted for 29 per cent of the mileage frequencies. In June, a consolidated ice cover extended over much of McClure Strait. With the exception of a strong NW component (36 per cent), the winds tended to offset one another and, although effective for shattering the icefields, were not conducive to the establishment of a strong surface drift. In the northern part of the region the N and NW components, accounting for 68 per cent of the mileage frequencies and causing an ice drift with a potential of 13 to 14 miles a day, were particularly strong. The southerly components were much weaker than those of the southern parts of the Queen Elizabeth Islands region.

TABLE XII

Wind frequencies and ice drift, June 1962

	N	NE	E	SE	S	SW	W	NW
Resolute								
Hours frequency	26	3	3	14	19	4	12	18
Mileage frequency	33	5	5	19	14	2	7	15
Ice drift	16	18	23	16	9	7	7	10
Mould Bay								
Hours frequency	4	16	10	9	9	4	11	36
Mileage frequency	4	17	12	9	10	2	10	36
Ice drift	9	13	15	12	12	7	10	12
Isachsen								
Hours frequency	18	3	4	9	13	8	4	42
Mileage frequency	19	3	3	9	10	5	2	49
Ice drift	13	10	9	12	8	8	8	14

Note: In Tables XII to XV, hours frequency (per cent) and mileage frequency (per cent) are given to the nearest whole number. Ice drift, expressed in miles per day, is based on the mileage and duration of each wind component and is also given to the nearest whole number.

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*Armstrong, Terence. Soviet work in ice forecasting. The Polar Record, v. 7, no. 49 (1955), 302-311.

During July melting spread rapidly, as indicated by the lanes of open water bordering the islands and the state of ice decay. The winds were variable throughout the region (Table XIII). In the southeastern part NW, N and NE winds accounted for 60 per cent of the mileage frequencies, while the NE, E and SE winds accounted for 48 per cent. The effect of such winds was a substantial reduction in the amount of ice passing eastward into Barrow Strait and Lancaster Sound. In the rest of the region, the S, SW, W and NW winds accounted for 87 per cent of the mileage frequencies in the western and for 85 per cent in the northern parts of the region. The daily rate of the ice drift varied from 10 to 12 miles in the Mould Bay area to 7 to 11 miles in the Isachsen area. Such winds tended to delay the evacuation of the icefields from the western part of Parry Channel.

TABLE XIII*

Wind frequencies and ice drift, July 1962

	N	NE	E	SE	S	SW	W	NW
Resolute								
Hours frequency	15	13	5	20	4	3	14	25
Mileage frequency	21	20	7	21	2	2	8	19
Ice drift	14	14	15	10	5	6	5	7
Mould Bay								
Hours frequency	2	1	1	9	41	13	8	21
Mileage frequency	1	1	1	10	39	13	10	25
Ice drift	6	12	11	11	10	10	12	12
Isachsen								
Hours frequency	8	2	2	2	24	38	10	14
Mileage frequency	9	2	3	1	27	32	7	19
Ice drift	10	10	11	5	10	7	7	11

*See note appended to Table XII.

August was noted for the southward advance of the polar-basin ice through the channels. In the northern sections, this southward drift coincided with powerful NW and N prevailing winds that accounted for 70 per cent of the mileage frequencies (Table XIV). The potential rate of the daily ice drift caused by these winds was 10 to 13 miles a day. In the western part of the region the W and NW components, constituting 40 per cent of the mileage frequencies, tended to balance the N and NE winds which accounted for 29 per cent of the frequencies. Such winds resulted in an erratic discharge of ice through the western channels and an erratic movement of the icefields along the western entrance of McClure Strait. In the southeastern, the NW, N and NE component winds accounted for 65 per cent of the mileage frequencies and the NE, E and SE winds for 37 per cent. For the most part this area continued to be marked by a diminution in the quantity of ice.

The inflow of polar-basin ice along the Arctic Front into the northern channels and the sustained drift of ice from Byam Martin Channel into Viscount Melville Sound continued during September. In the Isachsen area W, NW and N component winds accounted for 69 per cent of the mileage frequencies (Table XV). The NW component constituted 35 per cent of the frequencies and caused a drift with a potential of 16 miles a day. In the western part of the region the balance between the competing wind quadrants tended to hold the polar-basin icefields along the western entrance of McClure Strait. In the southeastern area the NW, N, NE and E component winds amounted to 84 per cent of the total mileage, and the easterly-quadrant winds (NE, E and SE) to 41 per cent. The strength of the easterly-quadrant winds, which caused drift that varied from 13 to 23 miles a day, undoubtedly helped to keep the waters of Barrow and Lancaster sounds ice-free during much of September.

TABLE XIV*

Wind frequencies and ice drift, August 1962

	N	NE	E	SE	S	SW	W	NW
Resolute								
Hours frequency	11	10	7	16	1	8	7	39
Mileage frequency	12	13	10	14	1	7	3	40
Ice drift	13	16	18	10	12	10	5	12
Mould Bay								
Hours frequency	10	19	11	8	7	8	12	25
Mileage frequency	9	20	12	7	7	5	12	28
Ice drift	9	11	11	9	10	6	10	11
Isachsen								
Hours frequency	24	6	7	8	4	8	4	39
Mileage frequency	22	5	6	6	2	6	5	48
Ice drift	10	8	9	9	7	9	13	13

*See note appended to Table XII.

The regional wind pattern (Figure 3) showed considerable variation both areally and temporally. Effected by such winds, the shifting and breaking of the icefields would therefore also vary considerably throughout the region. Figure 4 consolidates the ice circulation observed in the course of the survey.

TABLE XV*

Wind frequencies and ice drift, September 1962

	N	NE	E	SE	S	SW	W	NW
Resolute								
Hours frequency	12	13	16	5	3	14	1	34
Mileage frequency	15	14	23	4	2	10	0	32
Ice drift	20	15	23	13	9	11	6	15
Mould Bay								
Hours frequency	10	22	11	12	1	5	21	17
Mileage frequency	8	20	14	11	1	5	21	20
Ice drift	12	13	19	13	11	13	15	18
Isachsen								
Hours frequency	18	6	16	8	3	6	16	25
Mileage frequency	18	5	12	9	2	3	16	35
Ice drift	12	9	8	11	8	5	7	16

*See note appended to Table XII.

ICE DRIFT AND RELATED WINDS FOR JUNE AND JULY

Ice movement during June and July was restricted mainly to various parts of Parry Channel and the channels leading into it. The period, which ended about August 1, was marked by the shattering of the icefields within the interior channels and then by the discharge of ice, largely of polar-basin origin, into Parry Channel.

In June the principal areas of ice movement were in Parry Channel, Penny Strait and Queens Channel, where melting conditions were favourable. By June 23, about 300 nautical miles of ice had shattered in Lancaster Sound and Barrow Strait. The edge of the consolidated ice cover extended southwest in a broad arc from Resolute to Russell Island. Moreover, the area of shattered ice, drifting eastward and melting rapidly, was reduced to about one fifth of the surface-water area (Figure 8). In this area the NW, N and NE winds which prevailed from June 11 to 22 accounted for 68 per cent of the mileage frequencies, the north wind contributing 52 per cent. The corresponding combined daily rate of ice drift was 8.0 miles. The mean daily wind speed averaged 22 miles an hour from June 11 to 14 and 7 miles an hour from June 15 to 22. These winds seemed to account for a number of important features observed on June 23 (Figure 8). The ice was first dislodged from the southern part of Barrow Strait and then removed from the north side. It therefore became detached from the consolidated ice cover with the result that extensive icefields alternated with open water areas in Lancaster Sound and Barrow Strait. The ice that broke off before June 23 was in the initial stage of decay.

By July 6 (Figure 9) the retreat of the consolidated ice edge had proceeded but a short distance westward in Barrow Strait. The ice dislodged on the north coast off Resolute during the 13 days from June 23 to July 5 covered 4 nautical miles; that dislodged in the southern part of Barrow Strait in the same period covered 25. Although deterioration of the icefields was progressing, the ice surface at this stage was hard and firm. The rapid disappearance of the ice cover from Lancaster Sound before July 4 seems to be related to oceanographic and other physical factors. In the period from June 29 to July 6, the winds from the W and NW accounted for 42 per cent and those from the NE and E for 33 per cent of the wind mileage. In terms of ice drift, the former contributed 3.7 miles a day and the latter 2.8 miles. The NE and E winds blowing from open water to and over the consolidated ice cover seem to have retarded the break-up that normally accompanies the W and NW winds.

In Queens and Wellington channels and Penny Strait open-water areas steadily expanded. The ice dislodged from the northern parts of Penny Strait drifted southward through the open waters of Queens Channel and melted rapidly. The consolidated icefields at the southern exit to Wellington Channel held fast, but a tongue of open water extended southward through the consolidated ice cover of McDougall Sound. By July 6, the consolidated icefields in Jones Sound had shattered and were rapidly disappearing. The pattern of ice break-up and dispersal as observed on July 5 and 6 (Figure 9) was similar to that observed from June 21 and 23.

Melting conditions over the western part of Parry Channel were not so favourable as those existing over the southeastern part of the region. In June, a consolidated ice cover blocked McClure Strait; whereas along the Arctic Front polar-basin icefields were in motion. On June 21 (Figure 8) the first extensive area of shifting ice was observed on the north side of McClure Strait - that is, on the downwind side of the prevailing winds, which came from the NE-N-NW quadrant. These winds, with an average speed of 11 miles an hour and a combined daily ice drift rate of 8.1 miles, provided 77 per cent of the mileage frequencies from June 11 to 21. South of the area of shifting ice, however, the winds had but little effect: pressure ridging, a diagnostic characteristic of ice pressure and movement, had a concentration of only 0/10 to 1/10 of the extensive, consolidated ice cover.

By July 5, about 90 nautical miles of ice had shattered in the western two thirds of McClure Strait (Figure 9) and a large wedge of polar-basin ice had entered and occupied the westernmost third. These changes were closely related to the prevalence of NW-N-NE quadrant winds, which from June 22 to 30

FIGURE 4. Ice circulation, Queen Elizabeth Islands, June to September, 1962.

accounted for 88 per cent of the mileage frequencies. The flow of polar-basin ice into the strait closely paralleled the NW wind, which alone accounted for 51 per cent of the winds of the quadrant. From July 1 to 5, winds from the SE, S and SW accounted for 71 per cent of the mileage frequencies and caused a combined daily ice drift rate of 7.2 miles. By July 5, the invading polar ice had been turned back and was moving out of McClure Strait under the influence of prevailing winds from the SE and E. In the three days from July 3 to 5, these winds had a mean daily speed of 13 miles an hour and contributed 59 per cent of the wind mileage. A consolidated ice cover still dominated Fitzwilliam Strait and Crozier Channel.

The shattering of the icefields progressed westward from July 5 to 20 into Viscount Melville Sound and reached 108° W longitude; the consolidated ice cover that remained occupied the western two thirds of the sound. In 15 days, 120 nautical miles of ice were shattered off the south shore and 205 off the north, the daily shattering averages being 8 and 14 miles respectively. The break-up pattern at first progressed more rapidly on the south side of Parry Channel but between July 5 and 20 gradually switched to the north side. The consolidated ice cover of the western entrance of Viscount Melville Sound held against the pressure of variable winds when the concentration of meltwater holes was only 1/10 to 2/10. It shattered, however, when deterioration had become widespread, as indicated by a meltwater-hole concentration of 2/10 or more. The importance of ice decay in situ as a factor in ice break-up is thus indicated.

The barrier of consolidated ice that extended across the southern entrance of Wellington Channel seemed to be maintained in position by the E, SE and S winds. From July 9 to 17, these winds accounted for 67 per cent of the mileage frequencies. The combined rate of ice drift was 6.0 miles a day. Daily wind speeds ranged from 3 to 20 miles an hour, daily average being 9 miles an hour. The eastward drift in Barrow Strait noted on July 17 and 18 appeared very small, but rapid decay of the icefields was much in evidence. The dominant SE wind was a major factor in clearing the icefields off the south coast of Cornwallis Island. On the north side of Barrow Strait, open water gave way almost abruptly to heavy ice concentrations; on the south side about 40 nautical miles of open icefields with a concentration of 1/10 to 5/10 intervened between the open sea and closely concentrated sea ice.

In the rest of Wellington and Queens channels and Penny Strait, the shattered icefields, driven back and forth by the prevailing winds, continued to shrink in area. On July 17 and 18, the most extensive area of shattered ice within the interior channels occupied the Edinburgh Sea, Belcher Channel and Eureka Sound; but the Norwegian Bay icefields held fast.

The 60-nautical-mile eastward extension of shifting ice that occurred mainly in the southern two thirds of McClure Strait from July 6 to 21 (Figure 10) coincided closely with the prevailing winds, particularly the S wind. The latter, accounting for 67 per cent of the wind mileage, had a daily ice drift rate of 5.4 miles. The SE, S and SW component winds combined, making up 84 per cent of the mileage frequencies, tended to concentrate the icefields mainly along the north side of the strait and gradually enlarged the open-water area that first appeared off Banks Island on July 5. A marked inflow of polar ice entered on the north side of McClure Strait, and a compensating outgoing drift on the south side. The ice discharge from McClure Strait, being greater, made possible the shattering of the consolidated ice cover as far east as 116°W. East of this meridian the consolidated ice cover, not having deteriorated sufficiently to shatter, acted as a barrier to block any eastward drift of the ice into Viscount Melville Sound.

The progress of ice-shatter from McClure Strait into Crozier Channel and Kellett Strait was slow. On June 23, shifting icefields lay off these channels. By July 20, the shattering of the consolidated ice cover had advanced only into the southern half of Crozier Channel and the southern three quarters of Kellett Strait. Ice decay had not advanced sufficiently for the prevailing NW and N winds that dominated the area from June 11 to July 1 to clear the ice from these channels. From July 6 to 21, when decay of the icefields in situ was advancing rapidly, the dominance of the SE, S and SW winds, contributing 84 per cent of the mileage frequency, virtually blocked the evacuation of the icefields from the straits.

The 16-day interval from July 20 to August 4 was a period of widespread change in the Parry Channel region. The consolidated ice cover that extended over the eastern half of Viscount Melville Sound on July 20 was greatly altered by August 4 (Figure 11). On this date the southeastern and eastern parts of the region were remarkably ice-free, and an extensive area of open water bordered the north side of McClure Strait and occupied about two thirds of Viscount Melville Sound. A marked southward drift of ice into M'Clintock Channel was backed by a southward-expanding area of open water in the northern half of Viscount Melville Sound.

In the period from July 27 to August 4, the NW, N and NE winds, constituting 78 per cent of the mileage frequencies, resulted in a general SE-S-SW drift of the icefields. Their combined daily rate of drift was 9.4 miles. In addition to driving the icefields from the north to the south side of Parry Channel, these winds forced ice into M'Clintock Channel and, to a lesser extent, into Peel Sound. The icefields that entered Viscount Melville Sound after passing through McDougall Sound drifted toward the southwest, but on the south side of Viscount Melville the drift was decidedly eastward.

In McClure Strait on August 4 and 5 polar-basin icefields (Figure 11) lay off the south coast of Prince Patrick Island. In Fitzwilliam Strait the winter icefields had shattered but the amount of ice issuing from Crozier Channel and Kellett Strait was remarkably light. The reason was that from July 22 to August 1 these channels lay in the wind-shadow of Prince Patrick Island. In this period the prevailing winds, which came from the SW-W-NW quadrant, constituted 78 per cent of the mileage frequencies. The NW component alone amounted to 42 per cent and contributed substantially to the expansion of open water areas that now existed off the southeast coasts of Melville, Prince Patrick and Eglinton islands.

Wind direction again changed. From August 2 to 4, the NE-E-SE winds comprised 88 per cent of the mileage frequencies and, combined, produced a daily ice-drift rate of 10.8 miles. They shifted the icefields toward the western entrance of McClure Strait and expanded the open-water areas bordering the northern shores of the strait.

The shattering of the consolidated ice cover and the withdrawal of the icefields from the northern shores of Parry Channel brought about a relaxation of the pressure that supported the ice barriers occupying Fitzwilliam Strait, McDougall Sound, and Byam Martin and Wellington channels. The immediate result was the breaching of the consolidated ice barriers at the exits of these bodies of water and the drift of icefields, largely of polar-basin origin, into Parry Channel. This invasion of Parry Channel began about August 1.

ICE DRIFT AND RELATED WINDS FOR AUGUST AND SEPTEMBER

In this period, which began about August 1, the circulation of the icefields increased throughout the region. The increase started with the shattering of the consolidated ice cover of the interior channels and continued until the consolidation of the icefields, which occurred in early October.

A consolidated ice cover prevailed over the interior seas and channels throughout June and until mid-July (Figures 8, 9 and 10). On July 17 (Figure 10) the consolidated ice cover, stretching across the northern entrance of Penny Strait, extended unbroken into and beyond Desbarats Strait. North of this barrier shattered and shifting ice extended in a broad convex arc from Belcher Channel to Lougheed Island. Much of this area was covered with winter ice and, as deterioration of the ice cover was in an advanced state, it readily shattered under the stress of the prevailing winds. Shifting winter ice in a similar state of deterioration occupied the south end of Norwegian Bay and Eureka Sound. The break-up pattern of the consolidated ice cover could be expected to progress in an upwind direction beginning with the open-water areas in Belcher Channel and Hendriksen Strait.

From July 6 to 17, the shattering process pushed 120 nautical miles to the west. The S and SW components of the prevailing winds were dominant during this period. They accounted respectively for 41 and 36 per cent of the mileage frequencies and ice-drift rates of 3.1 and 2.9 miles a day. Daily mean wind speeds averaged 9 miles an hour. Pressure ridging, of concentration ranging from 0/10 and 1/10 throughout the area, indicated that the icefields had not been subjected to strong pressure or, alternatively, that widespread shattering was of recent occurrence. The local thinning of the icefields observed off the south coast of Ellef Ringnes Island marked the beginning of the expansion of the open-water area that followed the shattering of the consolidated ice cover in the Edinburgh Sea.

From July 18 to 30, the winds of the S-SW-W quadrant accounted for 81 per cent of the mileage frequencies. These prevailing winds delayed the main push of polar-basin ice into Penny Strait and Byam Martin Channel. Much of the winter icefield area, in the Edinburgh Sea melted away, and only a small quantity of ice appeared to pass through Penny Strait. Thus on August 4 (Figure 11) open water extended over the northern half of the Edinburgh Sea. Ice was moving out of Hassel Sound, and in Peary Channel shattering of the icefields was in progress. A broad barrier of polar-basin ice extended southeast from Prince Gustaf Adolf Sea to the entrance of Penny Strait.

The most striking feature of the polar-basin drift was the breaching of the channel entrances by the polar-basin ice along the Arctic Front in late July and early August. There was a general northeast progression in that the breaching of the channels was further advanced in Ballantyne Strait and least in Peary and Sverdrup channels and Nansen Sound. Associated with the severe pressure exerted by this invasion at the northern entrances was the breaching of the ice barriers in the entrances opening into Parry Channel, both events occurring almost simultaneously.

Up to July 22 in the northwestern area, the NW and W winds of that month contributed only 16 per cent of the wind mileage and so were of minor significance. It seems, however, that in the period from July 22 to 27, when the NW winds accounted for 67 per cent of the wind mileage, the consolidated ice cover in Ballantyne Strait broke up and the polar-basin ice began to push into the strait. By August 4 and 5 (Figure 11) this ice extended in a broad tongue to the north entrance of Fitzwilliam Strait. As the southwestward continuation of the ice movement through Crozier Channel and Kellett Strait was negligible, the flow of polar-basin ice into Fitzwilliam Strait after the break-up of the Arctic Front must have depended largely on the strength of the N and NE wind components, which through July and up to August 4 were of no consequence.

On July 31 a major shift in wind direction occurred in the area around Prince Gustaf Adolf Sea. From that date until August 4, the NW and N components accounted for 98 per cent of the wind mileage frequencies. For the first two days of the period, daily mean wind speeds were 24 and 20 miles an hour; from August 2 to 4, they averaged 8 to 13 miles an hour. During the five day period, polar-basin ice advanced from the Arctic Front into this sea, thus beginning a full-scale invasion that was to extend into Parry Channel and continue until halted by consolidation of the icefields under the zero and subzero temperatures of October. The icefields in Prince Gustaf Adolf Sea began to move about August 1. By August 4 and 5, the northern entrance had been forced and the discharge of local polar-basin ice through Byam Martin Channel and Penny Strait had simultaneously began. By mid-August, the consolidated icefields that had so recently occupied the Prince Gustaf Adolf Sea and Byam Martin Channel discharge routes were replaced by the intruding polar-basin ice. Because of this movement, the ice island T_1 and a number of smaller ice-island fragments from Prince Gustaf Adolf Sea showed a marked southward drift.

Two major ice-drift flows occurred in this area (Figure 4) and were directed largely by the position and trend of Lougheed Island. The first followed the direct south route west of the island into Byam Martin Channel; the second moved southeastward through Maclean Strait into the Edinburgh Sea. With the opening of the Desbarats route, however, the largest part of the Maclean Strait discharge swung through Desbarats Strait and then turned south into Byam Martin Channel. This drift also limited the westward expansion of open water into the western part of the Edinburgh Sea.

The westward drift of ice through Desbarats Strait indicated that the main surface flow from the polar-basin to Viscount Melville Sound was through Prince Gustaf Adolf Sea and Byam Martin Channel. From Byam Martin Channel the largest part of the icefields passed through Byam Channel. They then entered Viscount Melville Sound and drifted westward toward McClure Strait. A smaller segment drifted across Viscount Melville Sound into M'Clintock Channel. As the set of the drift in Viscount Melville Sound was westward, the ice discharged through Byam Channel on the west side of Byam Martin Island. This directional pattern seems to have continued until mid-September, after which, under dominant W and NW winds, the polar-basin icefields drifted south and southeast into M'Clintock Channel. The drift therefore circulated counterclockwise in the western part of Viscount Melville Sound and even extended into Peel Sound (Figure 4). A change in the direction of the wind increased the flow through Austin Channel, thus reducing the previously heavy flow through Byam Channel.

The discharge through Prince Gustaf Adolf Sea continued heavy and congested until August 27, and for a short time on August 24 the icefields moved out of Isachsen "bay". The freeing of the west coast of Ellef Ringnes Island, however, was associated with NE, E and SE winds that from August 27 to 30 contributed 60 per cent of the mileage frequencies. N and NW winds again prevailed from August 31 to September 3, accounting for 98 per cent of the wind mileage and causing a daily ice-drift rate of 10.6 miles. The result was a strong southeastward drift of the polar-basin icefields through Maclean Strait into the Edinburgh Sea. When the wind shifted to the E and SE, much of this ice was discharged through Desbarats Strait.

In the period from September 6 to 15, the E and SE winds made up 60 per cent of the wind mileage and their combined ice-drift rate was 6.5 miles a day. This period, in which only scattered strings of ice occurred, coincides closely with the maximum extent of open water in the Edinburgh Sea. On September 14 (Figure 12) a narrow belt of open icefields paralleled the east coast of Lougheed Island, while Desbarats Strait was mainly open water that extended along the west side of Lougheed Island, and strings of ice bordered the coast or occupied the bays on the north side of Bathurst Island and Grinnell Peninsula.

After September 16, the drift of polar-basin ice through Maclean Strait extended the ice area in the western part of the Edinburgh Sea, and the discharge route through Desbarats Strait became congested. The volume of polar-basin ice entering Penny Strait also increased. The W, NW and N winds that prevailed from September 16 to 29 coincided with this generally southward drift of the icefields. They accounted for 91 per cent of the wind mileage and provided a combined daily ice-drift rate of 13.4 miles.

Because of the rapid reduction that occurred in the ice of Barrow Strait during August, the icefields entering this part of Parry Channel from McDougall Sound drifted erratically with the prevailing wind. While ice from the western part of the Edinburgh Sea was drifting through Desbarats Strait, the discharge from Penny Strait into McDougall Sound was relatively small and continued so throughout August and until mid-September. This scarcity of ice available for passage through the strait arose from the westward extension of open water in the Edinburgh Sea. A result of this virtual freedom of Penny Strait and its northern entrance from polar-basin ice (Figure 12) was that icefields passing into Viscount Melville Sound from McDougall Sound amounted to no more than trailing strings and patches. These drifted west and southwest toward M'Clintock Channel. Some of them entered Peel Sound; others extended northeastward, simulating a counterclockwise rotation. This orientation of drift continued after the shattering of the consolidated ice cover. After mid-September, a prevailing NW wind contributing 79 per cent of the mileage and giving rise to an average daily ice-drift rate of 9.6 miles brought an influx of polar-basin ice into Penny Strait and

Queens Channel. Low temperatures, however, caused these icefields to congest in the two narrow channels formed by Little Cornwallis Island, which lies on the north side of McDougall Sound, and only a small amount of ice passed through Crozier Strait into the sound.

Although Wellington Channel at the end of July was relatively free of ice and continued so until freeze-up, intermittent strings of polar ice from Queens Channel moved southeast into it and drifted south along the east coast of Cornwallis Island. On entering Barrow Strait they bent westward, only to swing southward and eastward, as it were, a counterclockwise rotation in the eastern part of the strait similar to those observed in the western part and in Viscount Melville Sound (Figure 4). In addition, there were local on- and offshore movements.

The open-water areas observed on August 4 and 5 (Figure 11) off the southeast coasts of Prince Patrick and Eglinton islands and the south coast of Melville Island had, by September 5 (Figure 12), expanded to include all of McClure Strait. In this region the August winds were variable. The SW, W and NW components, associated with the advance of icefields into the strait, accounted for 45 per cent of the mileage frequencies; the NE, E and SE winds for 39 per cent; the NW, N and NE winds, associated with a drift of ice to the south side of the strait, for 57 per cent; those from the SE, S and SW for 19 per cent. The winds therefore contributed to the erratic movement of icefields at the entrance to McClure Strait.

In the period from September 1 to 5, when the E, SE and S wind component were causing 54 per cent of the mileage frequencies and the mean daily wind speed was 11 miles an hour and the daily rate of ice drift 7.8 miles, the icefields were moving out of McClure Strait. The icefields in Fitzwilliam Strait lay adjacent to the Prince Patrick coast. Open icefields occupied Ballantyne Strait, and heavy polar-basin ice lay off its northwestern entrance.

Variable winds again prevailed during September. Those from the NE, E and SE, which accounted for 45 per cent of the mileage, and those from the W, NW and N, which accounted for 48 per cent, resulted in a constant in-and-out flow of ice at the entrance to McClure Strait. In the period from September 17 to 24, the W and NW winds were the basis of 87 per cent of the mileage frequencies, their mean speed being 15 miles an hour and their combined ice-drift rate 12.5 miles a day. Thus on September 24 (Figure 13) a wedge of polar-basin ice extended into McClure Strait. Coinciding with the direction of such inshore winds was the heavy concentration of polar-basin ice extending through Ballantyne Strait and new icefields bordering the eastern, or lee side of Prince Patrick Island. In these previously open-water areas there was a pronounced offshore drift of heavy ice. As the flow of ice through Fitzwilliam Strait was relatively weak, what now filled the areas adjacent to Prince Patrick Island was ice that had resulted from recent freezing temperatures.

The heavy ice concentration that existed in Hazen Strait showed that there was very little westward drift toward Fitzwilliam Strait a powerful E wind was required, followed by a strong NE wind to cause movement through the strait. In the last week of September, however, strong prevailing N and NE winds caused an invasion of polar ice from Hazen Strait. This ice extended through Fitzwilliam Strait into Kellett Strait and consolidated under low freezing temperatures.

Discharge of the Hazen Strait icefields toward the southeast was also quite small. On September 24, an examination of the shear zone between the icefields in Hazen Strait and those of Prince Gustaf Adolf Sea showed a marked southeast movement from the southeastern area of Hazen Strait. This drift undoubtedly began about mid-September, when the prevailing winds changed to W and NW. As the consolidation of the icefields in Hazen Strait toward the end of September was well advanced and as the winds shifted to the N and NE, the drift in this direction could only be of short duration. The movement of the icefields trapped in the deep pocket of Hecla and Griper Bay was marked by intensive pressure ridging. These icefields were the first to consolidate so that a sharp shear zone separated these from the moving icefields of Hazen Strait.

The rupturing of the ice barriers in Peary and Sverdrup channels and Nansen Sound resulted in an influx of polar-basin ice into these passages that forced local icefields south through Hassel Sound into the Edinburgh Sea and southeast through Massey Sound into Norwegian Bay. The shattering began in the Meighen Island area during the period from July 31 to August 4, when NW, N and NE quadrant winds were accounting for 86 per cent of the hourly frequencies. Maximum velocities, ranging from 11 to 17 miles an hour, occurred on July 31 and on August 3 and 4. By August 5 the shattering of the consolidated ice cover, although in progress, was not yet completed. The southward drift of polar-basin ice through Massey Sound into Norwegian Bay coincided closely with the prevailing NW, N and NE winds. They accounted for 70 per cent of the mileage. The polar-basin ice, entering the relatively warm waters of the Edinburgh Sea and Norwegian Bay, thinned out and melted rapidly.

Amund Ringnes Island divided the ice discharge through Peary Channel in much the same way as Lougheed Island divided the Prince Gustaf Adolf Sea discharge. The icefields from Hassel Sound, depending on the prevailing wind, drifted to the southwest, the south or even the southeast. In the period from September 6 to 15, when the prevailing winds were E and SE, the discharge of ice through Hassel Sound was relatively light, but strings of ice drifted west and southwest toward Desbarats Strait. From September 16 to 29, when W, NW and N component winds were strong, a heavy discharge of ice occurred, the icefields heading southward toward Penny Strait. A large part of the ice, drifting well to the east of Penny Strait, moved into Belcher Channel. On the whole, because of the lateness of the season and the subzero temperatures that prevailed at the end of September, the icefields consolidated rapidly, and the drift ceased in early October.

Hendriksen Strait was remarkably free of ice once initial shattering had occurred. Usually, a small stream of ice enters this strait from the northeast, but any substantial discharge through it depends largely on the prevalence of N, NE and E winds.

The drift of polar-basin ice through Massey Sound was equally marked. Although the drifting icefields tended to thin out on entering the warmer waters of Norwegian Bay, there was a strong southeast drift toward Cardigan Strait. At times ice swung east from Massey Sound and after bending south around Graham Island, entered Hell Gate Passage or Cardigan Strait. The volume of ice passing through Massey Sound was considerably greater than that passing through Hassel Sound, which lay in the wind shadow of Ellef Ringnes Island. The direction of the ice drift in Massey Sound resulted from the NW-SE orientation of the sound and the prevalence of W, NW and N winds.

The striking difference in Eureka Sound icefield distribution as it was on July 18 and August 5 is shown in Figures 10 and 11. On July 18 (Figure 10) the edge of the consolidated ice cover extended across Nansen Sound from Schei Point and across Greely Fiord from Canyon Fiord; thereby forming an extensive rectangular area of working and shrinking icefields at the north entrance to Eureka Sound. On August 5 (Figure 11) Eureka Sound was virtually icefree, the consolidated ice cover east of Canyon Fiord has disappeared and in the western reaches of Nansen Sound some 70 nautical miles of ice had shattered. The breaching of the remaining 15-mile-wide barrier at the entrance to the sound occurred shortly after August 5 and permitted an inflow of polar-basin ice, which, drifting south through the relatively warm waters of Eureka Sound, melted rapidly. On August 28 (Figure 12) the remnants of the invasion were observed as far south as May Point.

The August inflow of ice occurred in relatively small concentrations; any significant invasion of ice tending to coincide closely with the prevailing W and NW winds. September, marked by freezing temperatures and a growing prevalence of W, NW and N wind components, brought a flow of polar-basin ice into Nansen Sound. The occurrence of extensive areas of this kind of ice in both Nansen and Eureka sounds at the time of freeze-up and their alternation with areas of locally formed ice indicated that the prevailing winds varied in direction between those that supported the drift of polar-basin ice into Nansen Sound and those that held the ice away from the sound.

At the end of September, temperatures in the northern parts of the region were reaching zero and subzero levels. Floe size had increased to dimensions that indicated consolidation of the icefields and greatly reduced movement. Icefields formed by new and young ice occupied what had recently been the open-water areas of the western, northern and central parts. Thus the interior channels, including the discharge routes into Parry Channel, could be expected to stabilize and develop a consolidated ice cover early in October. The icefields in Parry Channel, however, could continue active a week or two longer.

With prevailing northerly winds, polar-basin ice drifted to the south side of Parry Channel, and a cover of new ice formed behind it. From Viscount Melville Sound a strong drift of Polar ice passed into M'Clintock Channel and continued to do so until the ice cover in the sound stabilized. The consolidation and stabilization of the ice cover was completed in early October.

DRIFTING ICE ISLANDS

Scattered ice islands in the consolidated ice cover of Prince Gustaf Adolf Sea and Peary Channel, provided information, when the ice cover disintegrated, on the general nature of the circulation of the ice.

On August 2 a small ice island was found southeast of Borden Island. On September 5 it lay to the west of Winter Harbour, having travelled an average of 11 miles a day. It drifted southward through Byam Martin Channel, entered Viscount Melville Sound and turned westward. It came to rest at 113°00' W, 73°30' N, after drifting some 430 statute miles.

Ice island T_1, located off the east coast of Lougheed Island, began to move about July 20 and by August 4 it stood off Edmund Walker Island, having drifted 1.3 miles a day. On September 24 (Figure 13), now in Viscount Melville Sound, it lay off the entrance to Byam Channel. From Edmund Walker Island to the position on which it was last observed on that date, T_1 had drifted 4.5 miles a day. The ice island had cart-wheeled around Patterson Island into Desbarats Strait, passed through Byam Martin Channel into Austin Channel and, after cart-wheeling again around the southeast corner of Byam Martin Island, had entered Viscount Melville Sound. It finally came to rest at 108°30' W, 74°35' N, having drifted 325 statue miles. T_1, which was roughly triangular in shape, measured 18 miles in length and 12 miles across its base and had its surface corrugations parallel to its long axis, lost about 8 per cent of its area on the journey. The fragments, forced off one side when it grounded on the coast of Patterson Island and on the shoal ledge off the southeast corner of Byam Martin Island, indicated that there was little rotation in its drift. The difference in the drift rate of 4.5 miles a day shown by T_1 and that of 11 miles a day observed for the smaller island drifting with the polar ice pack indicated that polar icefields of much shallower draft move considerably faster than deep-drafted, extensive masses of ice such as T_1.

The final resting place of T_1, about 70 statute miles southwest of the position observed on September 24, showed that the polar ice associated with it was drifting southwest under the influence of N, NE and E winds, which dominated the region during the last week of the month. Then, in early October, when W, NW and N winds prevailed, later fragments drifted into M'Clintock Channel; a large fragment also entered Peel Sound. Shortly after, with temperatures approaching zero, T_1 and the polar-basin icefields formed a consolidated cover.

Before the rupturing of the barriers, some two dozen ice-island fragments, the largest measuring 4.2 by 4.3 miles, were clustered along the Arctic Front near the entrance to Peary Channel. From June 21 to August 4, they lay in the same area, drifting only a small distance to the southwest. This area, which lies to the northeast and southwest of Meighen Island and extends from Ellef Ringnes to Axel Heiberg Island, showed limited ice movement. The ice discharging southward after the breaching of the Peary Channel ice barrier was substantially less than the polar-basin ice passing through Prince Gustaf Adolf Sea. However, the largest ice-island fragment that entered Peary Channel came to rest in Hassel Sound at 98°13' W, 78°15' N, having drifted 130 statute miles. A number of other fragments passed southward into Penny Strait and Queens Channel. A smaller fragment, passing through Peary Channel and Massey Sound came to rest in Norwegian Bay at 90°45' W, 78°00' N, having drifted some 240 statute miles. A number of small fragments were caught up in the clockwise rotation of the Arctic gyral, drifted southwestward. One of these grounded and broke up on shoals a few miles northeast of Brock Island.

PART III

ICE CONDITIONS AND NAVIGATION

In July the icefields in Baffin Bay and Davis Strait dissipated rapidly. By mid-month (Figure 5, A) the ice was restricted to the east coast of Baffin Island, and in August and September (Figures 5, B; and 6, B) its area continued to shrink. Toward the end of October (Figure 6, B) new ice began to extend outward from the coast, and by mid-November it stretched well across Baffin Bay and Davis Strait. Thus the weather station at Resolute was accessible by ship as early as June 21 and continued so for three full months (from July to September inclusive) and until October 7. This unusually long navigation season was matched on the Hudson Bay route. In the eastern Arctic, in fact, good navigation conditions were widespread.

Navigation conditions were much less favourable at the west end of Parry Channel, and in early July the route into Amundsen Gulf and McClure Strait (Figure 7, A) was blocked by heavy concentrations of ice. Although the Amundsen Gulf icefields continued to dissipate, thus leaving good prospects for navigation, the polar-basin icefields lay in close to the McClure Strait entrance (Figure 7, B). The best period for approaching McClure Strait from the southwest extended from the last week of July almost to the second week of September; that is, for about seven weeks. It should be noted, however, that at an earlier date it was possible to enter McClure Strait by passing around Cape Prince Alfred, at the northwest corner of Banks Island. During most of the time from July 15 to October 1 at the earliest, water or open icefields generally extended from 5 to 15 or more miles out from the cape.

East-west navigation in Parry Channel was practicable after August 1 and continued so until September 24. During these two months, however, polar-basin ice flowed into Viscount Melville Sound and constituted a hazard. For a successful east-west passage, it became necessary to know the disposition of these icefields. During this season, the course along the south side of the sound was easily the best, but the barrier of polar-basin ice that extended from Byam Martin Island southward across the sound on September 24 would have prevented any further east-west movement by ship. At most, the period for the east-west navigation of Parry Channel lasted about eight weeks.

Successful navigation of Arctic channels depends on a number of factors, the most important of which are the concentration and type of sea ice and a ship's power and hull strength. In the period from August 24 to September 7, the Canadian Coast Guard Ship John A. Macdonald, sailing from Eureka Sound to Resolute, passed through the waters of Norwegian Bay, Belcher Channel, Penny Strait, and Queens, Maury

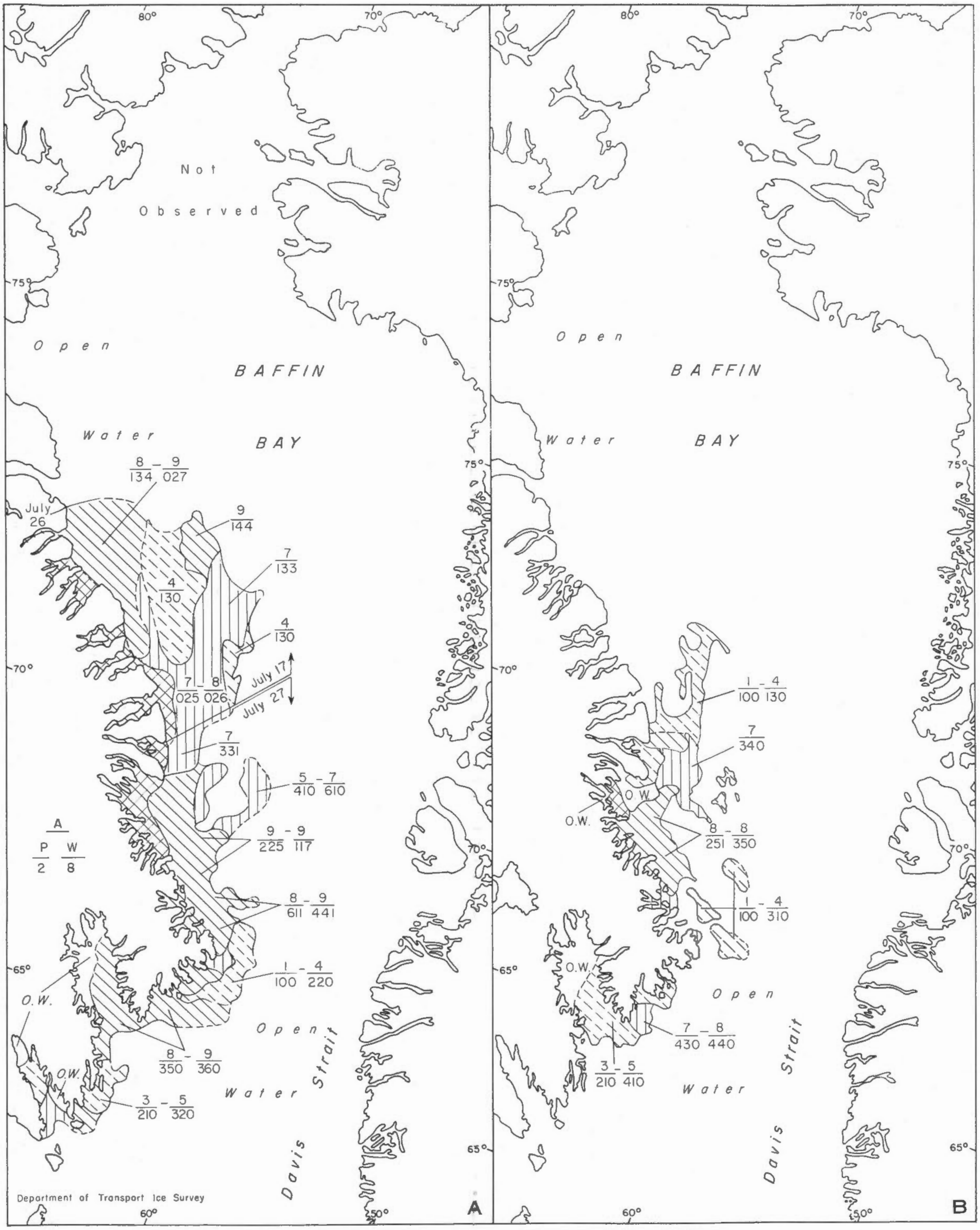


FIGURE 5

(A) Ice distribution, Davis Strait–Baffin Bay, June 17 and 27, 1962.

(B) Ice distribution, Davis Strait–Baffin Bay, August 13, 1962.

ERRATUM
Page 39 (Figure 5, A) for June read July.

FIGURE 6

(A) Ice distribution, Davis Strait–Baffin Bay, August 27, 1962.

(B) Ice distribution, Davis Strait–Baffin Bay, October 27, 1962.

FIGURE 7

(A) Ice distribution, Beaufort Sea, July 4 and 7, 1962.

(B) Ice distribution, Beaufort Sea, August 24, 1962.

and Wellington channels. Sailing westward from Resolute in Viscount Melville Sound the ship entered Austin Channel and passed westward into McClure Strait. The icebreaker then sailed northward from Cape McClure, on Banks Island. At the southwest entrance to Crozier Channel the ship turned eastward, then entered Kellett Strait but continued southeast to the north entrance of Prince of Wales Strait. From this point it continued to Resolute and, on the way, entered Byam Channel. Its attempted entrance into M'Clintock Channel was barred by heavy polar-basin icefields. Sailing east, the ship entered Peel Sound and circumnavigated Prince of Wales Island before returning to Resolute.

Another important factor is the use of tactical air support to obtain information on the distribution of the icefields. At the height of the melting season, winter ice is generally little more than a nuisance to an icebreaker, but close concentrations of polar-basin ice are at all times hazardous, even for icebreakers. Massive icefields of the polar-basin type that existed when the John A. Macdonald was returning to Resolute from McLure Strait extended deep into Viscount Melville Sound. The distribution of ice in Parry Channel on September 5 (Figure 12) shows that the ship could have pushed south on M'Clintock Channel with ease and that the heavy concentrations of polar-basin ice in Byam Channel and off the south coast of Melville Island would have blocked an icebreaker. Thus, tactical air support is undoubtedly the most important requisite for successful navigation of the Arctic channels.

When the ice conditions experienced by the crews of Department of Transport ships are compared with those encountered by the Royal Navy ships of the 1850's, it may seem that the latter were more severe. This, however, is not necessarily so. The British ship Resolute, after being abandoned about 30 miles southwest of Cape Cockburn (Bathurst Island) in May 1854, drifted into Davis Strait and was picked up off Cape Mercy, at the entrance to Cumberland Sound in September 1855. This passage suggests that the ship drifted into Barrow Strait as the icefields shattered and had drifted eastward before the consolidated ice cover in Viscount Melville Sound broke up. The counterclockwise circulation observed in Viscount Melville Sound begins with the shattering of the consolidated ice cover. Had the Resolute been caught up in this circulation, it would have been sucked into M'Clintock Channel. With air support both the Resolute and the Intrepid, which was lost, could have been directed safely from the area. The severity of ice conditions is partly related to the availability of technological means to overcome the physical hazards that ice imposes on navigation.

SUMMARY OF ICE CONDITIONS

As the summer of 1962 was unusual in its mildness, the season's ice deterioration was unusual in its pattern. July temperatures, being well above normal for the region, caused a rapid decay of the icefields. This decay and the accompanying break-up progressed unevenly, being more advanced in the eastern than in the western Arctic and most retarded in the Meighen Island area. It should be noted, however, that the Arctic-basin icefields, beyond the Arctic Front were shattered and in motion before mid-June. The break-up of the consolidated ice cover began with the melting of the icefields in situ. Local open-water areas developed and expanded in size with the advance of the season. Open-water stretches bordering the island coasts allowed the icefields to shift, thus producing undue stress that initiated the shattering of the cover.

Because the ice cover, consisting mainly of the ice types known as winter and polar, was not uniform, the characteristics of melting and decaying varied considerably. To reach the same stage of deterioration as winter ice, polar-basin ice required about twice as many melting degree-days. When, however, the concentration of meltwater holes in winter sea ice had reached 2/10 or more of the total cover, any additional stress such as that caused by changes in wind velocity or direction resulted in widespread shattering.

This stage in ice decay, although reached at different times throughout the Queen Elizabeth Islands region, was most widespread in July. From July 5 to 20, the shattering of the icefields extended some 120 to 205 miles westward into Viscount Melville Sound, but the 16-day interval from July 20 to August 4 was the period of greatest change in the ice cover. In early August the consolidated cover of the region was almost entirely shattered; polar-basin icefields crowded into the channels rupturing the Arctic Front and simultaneously forced south into Parry Channel the icefields existing in the interior channels. In the eastern half of the region the shifting resulted in the expansion of open-water seas. As the discharge of ice via the Peary and Sverdrup routes was limited, the icefields that drifted into the open-water seas melted away. In the western part of the region, however, the full-scale invasion of polar-basin ice extended into Parry Channel and continued until halted by consolidation under the zero temperatures of October. The maximum extent of open-water was reached between September 10 and 16. In the latter half of September, with falling freezing temperatures, a new cover expanded rapidly over the previously open seas.

The most spectacular feature was the drift of the ice island T_1. On July 20 it began to move with the surrounding icefield from its position off the east coast of Lougheed Island. In October it finally came to rest 35 miles south of Bridport Inlet, having drifted 325 statute miles before becoming lodged within the consolidated ice cover of Viscount Melville Sound. The general ice circulation observed during the season is shown in Figure 4.

MAPS OF ARCTIC ICE DISTRIBUTION

The principal features of ice distribution that were observed in the course of the 1962 Arctic ice reconnaissance survey and have been discussed are shown in Figures 7 to 12. These maps cover a period of changing ice conditions that extends from June 21 to September 29.

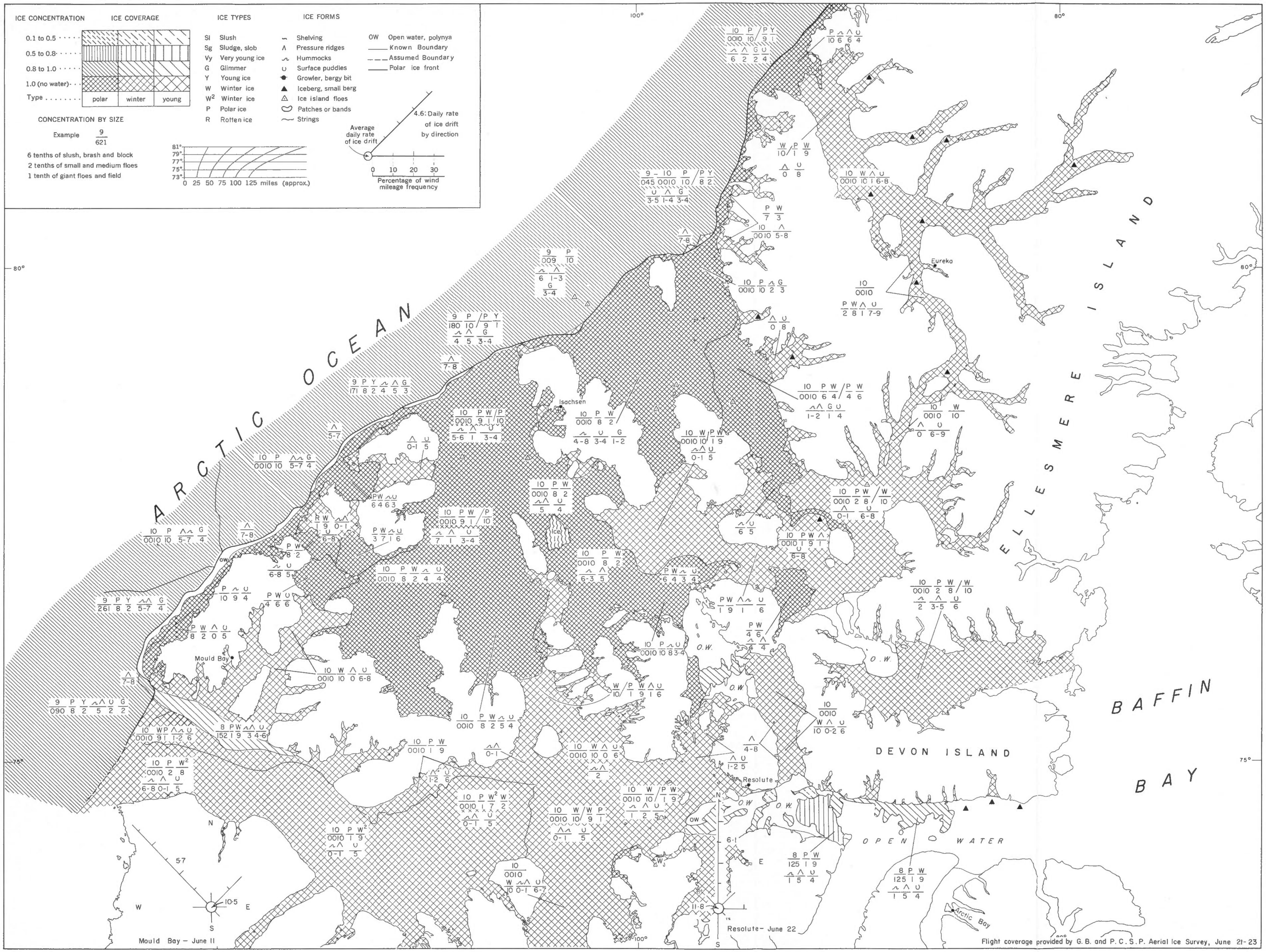


FIGURE 8. Ice distribution, Queen Elizabeth Islands, June 21 and 23, 1962.

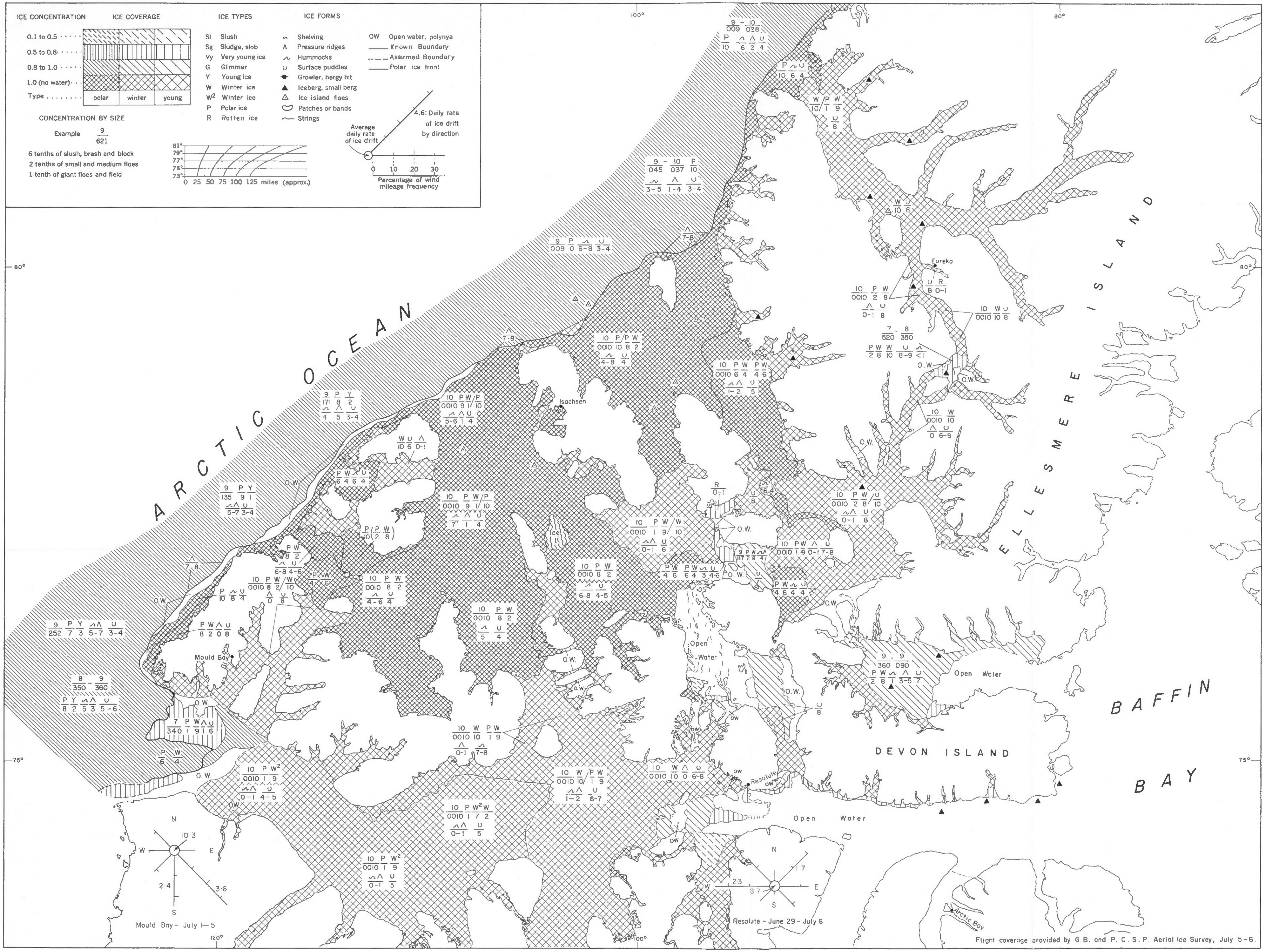


FIGURE 9. Ice distribution, Queen Elizabeth Islands, July 5 and 6, 1962.

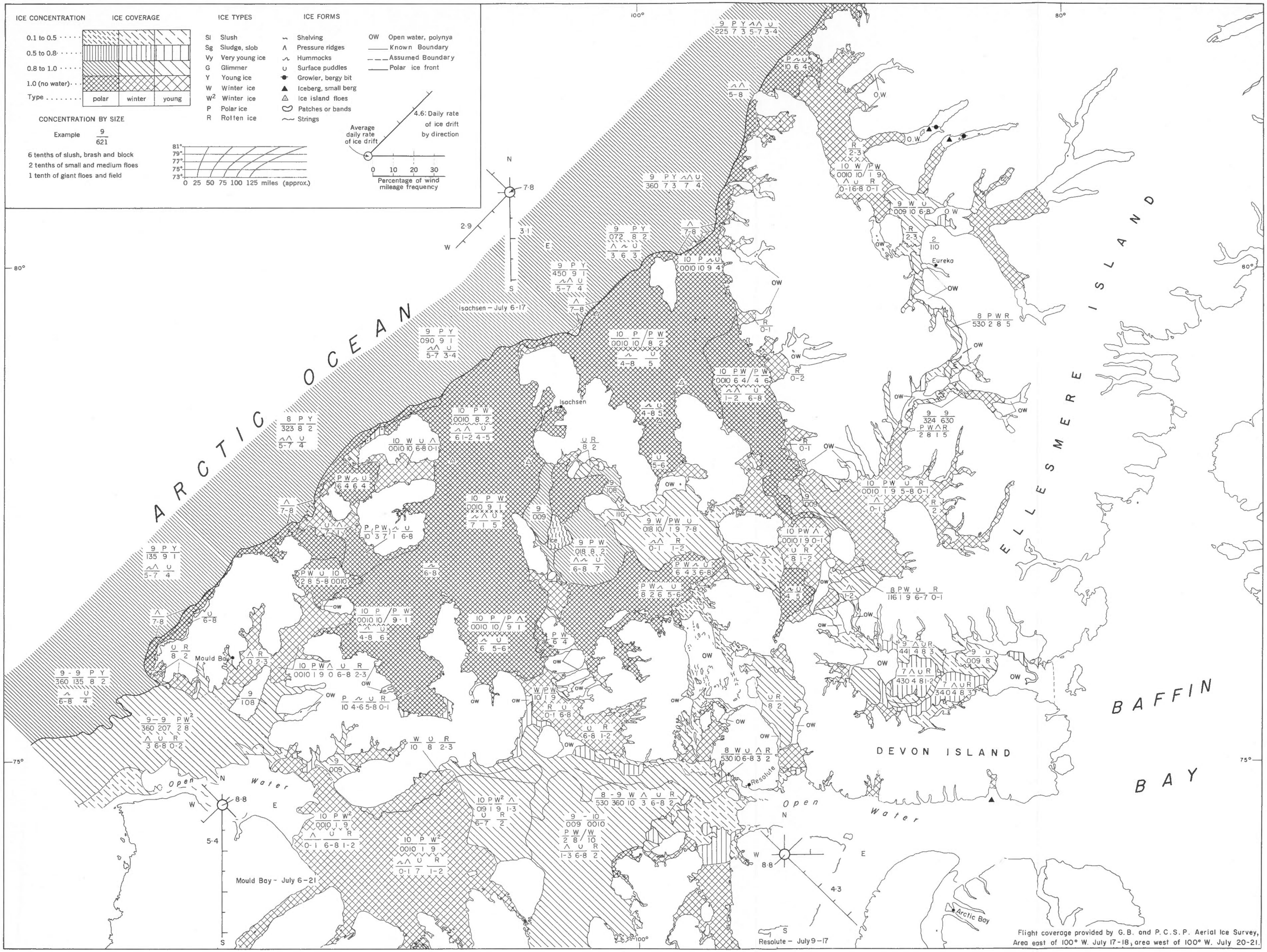


FIGURE 10. Ice distribution, Queen Elizabeth Islands, July 17, 18, 20 and 21, 1962.

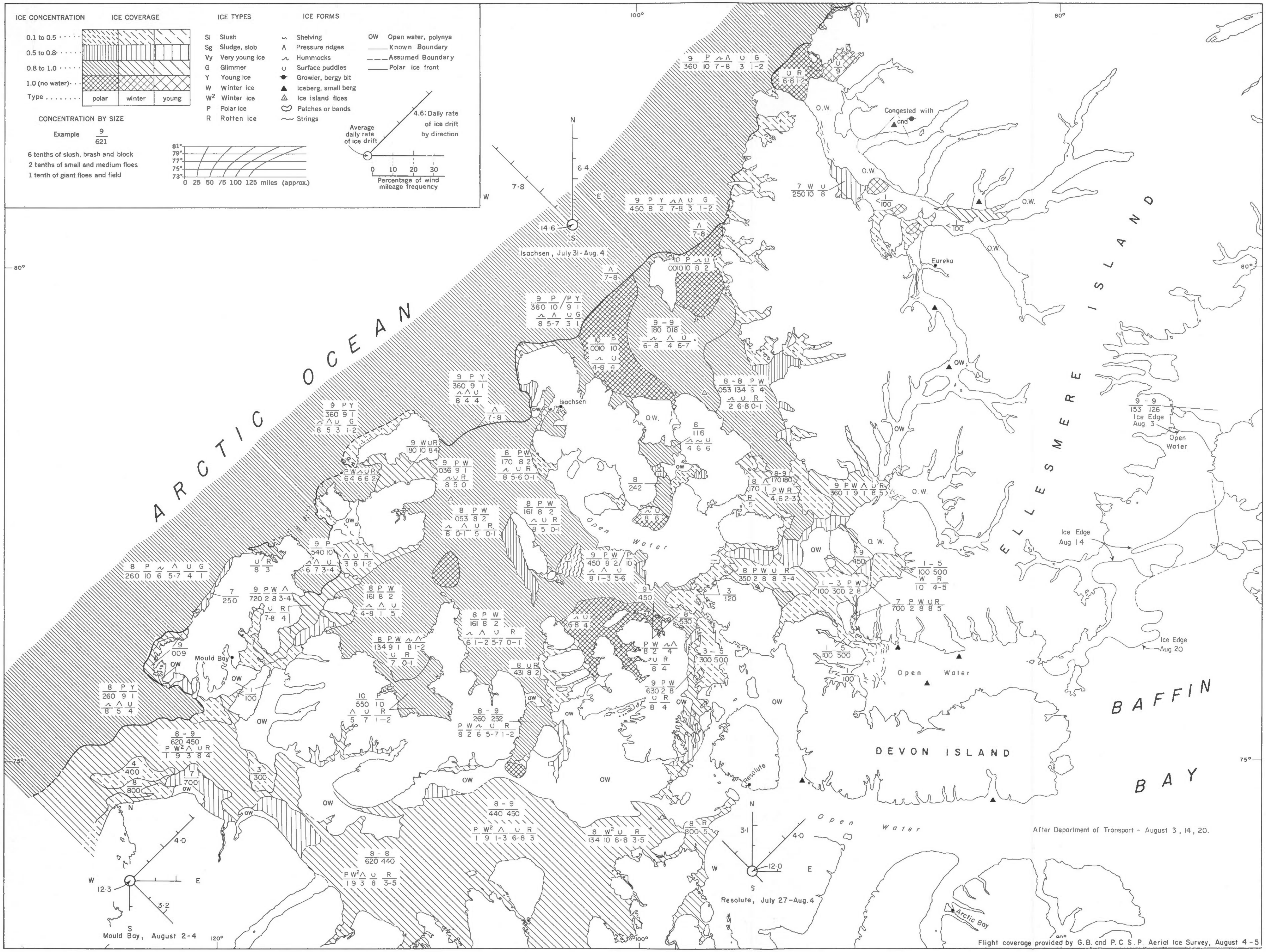
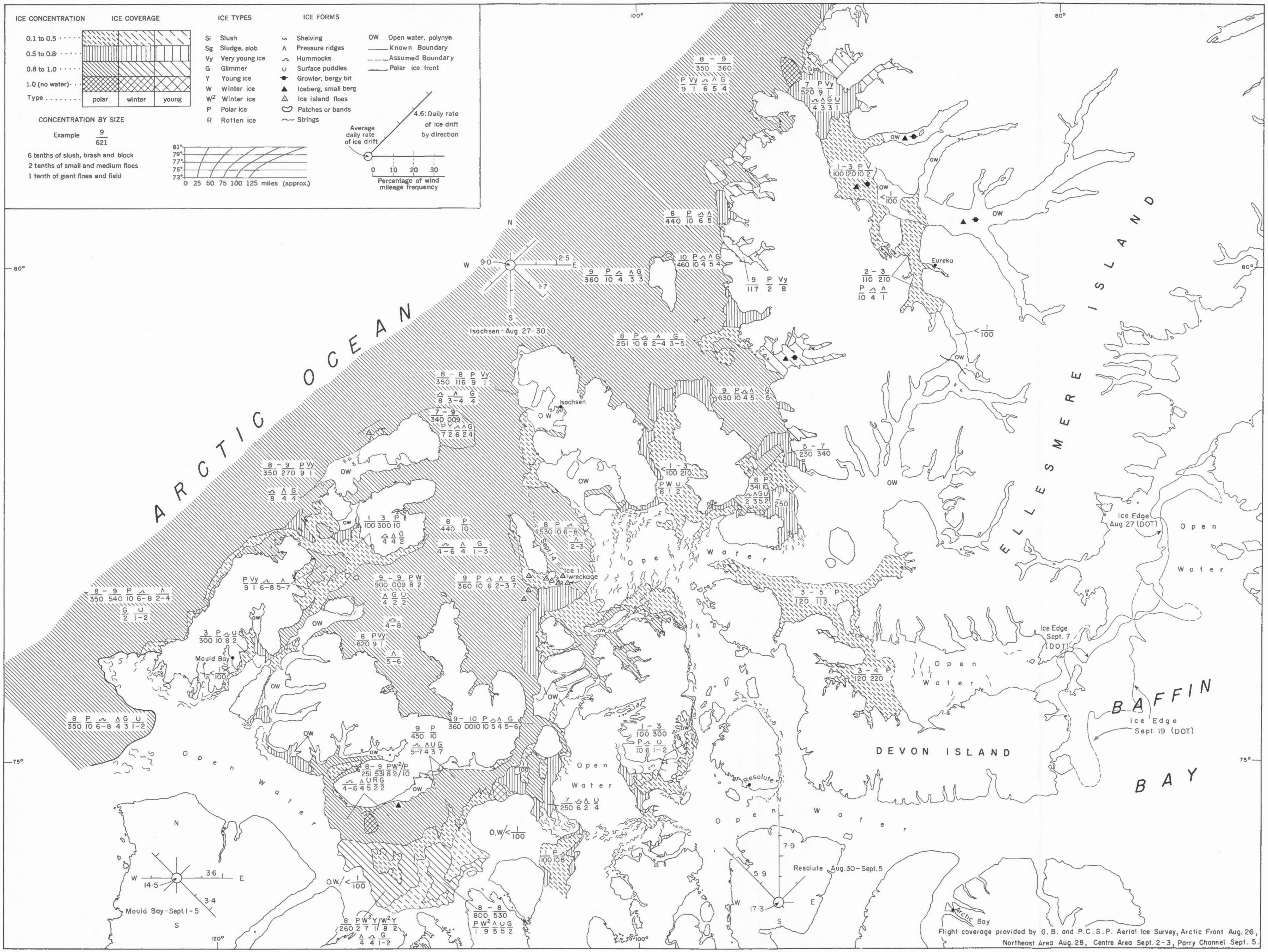


FIGURE 11. Ice distribution, Queen Elizabeth Islands, August 4 and 5, 1962.



Flight coverage provided by G. B. and P. C. S. P. Aerial Ice Survey, Arctic Front Aug. 26, Northeast Area Aug. 28, Centre Area Sept. 2-3, Parry Channel Sept. 5.

FIGURE 12. Ice distribution, Queen Elizabeth Islands, August 26 and 28 and September 2, 3 and 5, 1962.

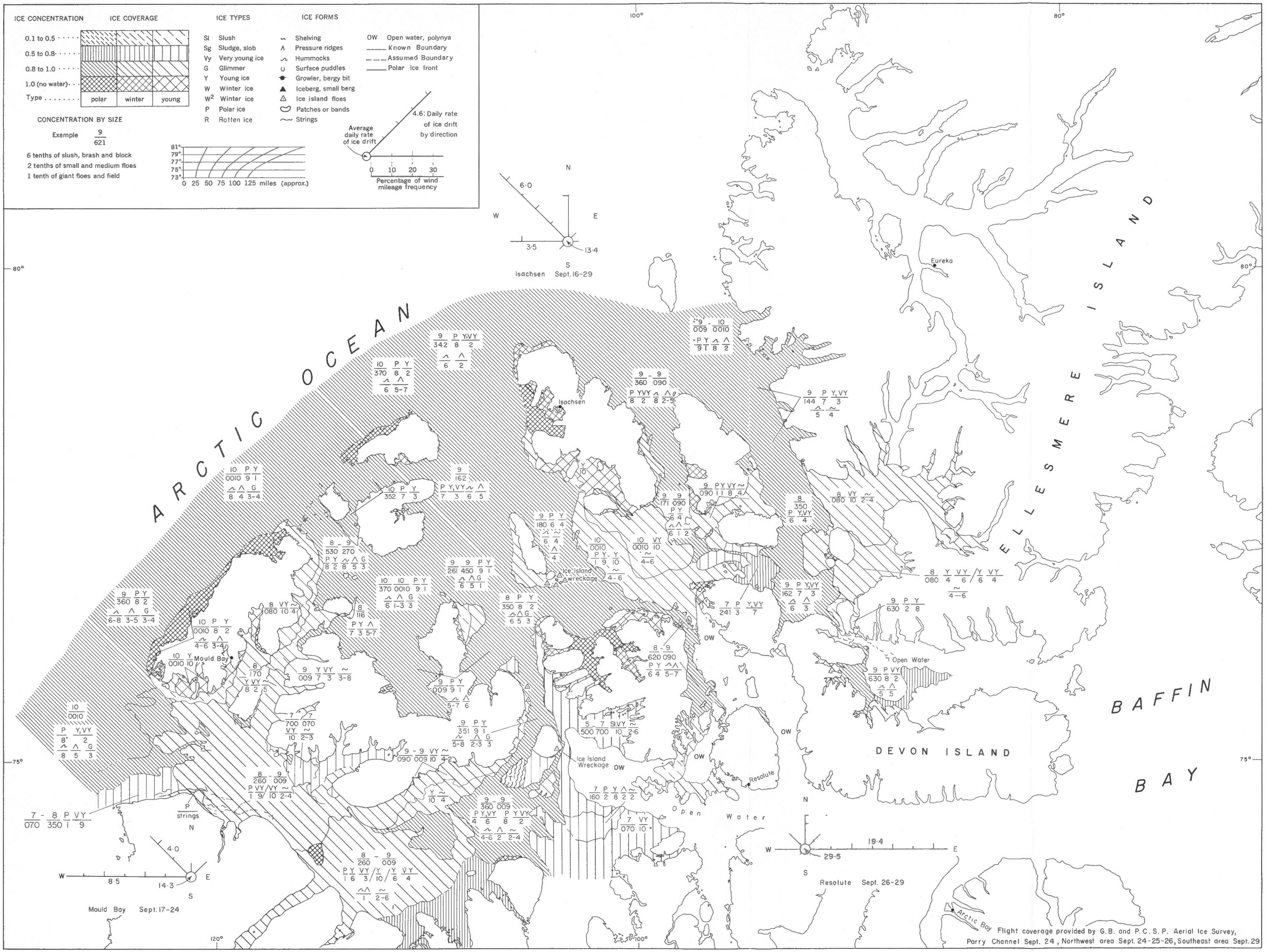


FIGURE 13. Ice distribution, Queen Elizabeth Islands, September 24, 25, 26 and 29, 1962.

GEOGRAPHICAL PAPERS
(Études géographiques)

Papers Nos. 1 to 6 are out of print. Les numéros 1 à 6 de la présente série sont maintenant épuisés.

No. 7.	Extracts relating to the navigability of Canadian inland waterways. W.A. Black, Ottawa, 1956. 55 p.	50 cents.
No. 8.	Notes on potential building sites in the Bathurst Inlet area, N.W.T. J.B. Bird and M.B. Bird, Ottawa, 1956. 15 p., map.	25 cents.
No. 9.	A report on sea ice conditions in the Eastern Arctic, summer 1956. W.A. Black, Ottawa, 1956. 32 p., maps, illus.	50 cents.
No. 10.	A preliminary report on ice conditions at Cacouna Island, Quebec. Rapport préliminaire sur les glaces fluviales à l'île Cacouna, estuaire du Saint-Laurent, province de Québec. B. Robitaille, Ottawa, 1957. 24 p., maps, illus.	Out of Print — Epuisé
No. 11.	An illustrated glossary of ice types in the Gulf of St. Lawrence. W.A. Black. Ottawa, 1957. 50 p., maps, illus.	75 cents.
No. 12.	Gulf of St. Lawrence ice survey, winter 1956. W.A. Black and C.N. Forward, Ottawa, 1957. 23 p., maps.	25 cents.
No. 13.	Notes on small boat harbours, N.W.T. J. Ross MacKay, Ottawa, 1957. 12 p., illus.	25 cents.
No. 14.	Gulf of St. Lawrence ice survey, winter 1957. W.A. Black, Ottawa, 1957. 29 p., maps, illus.	75 cents.
No. 15.	A report on sea ice conditions in the Eastern Arctic, summer 1957. W.A. Black, Ottawa, 1958. 32 p., maps, illus.	50 cents.
No. 16.	Ice conditions in the Gulf of St. Lawrence during the spring seasons 1953-1957. C.N. Forward, Ottawa, 1958. 13 p., maps.	25 cents.
No. 17.	Etude du Port de Québec. P. Camu, Ottawa, 1958. 79 p., cartes, illus.	75 cents.
No. 18.	A subsurface organic layer associated with permafrost in the Western Arctic. J. Ross Mackay, Ottawa, 1958. 22 p., maps, illus.	50 cents.
No. 19.	Gulf of St. Lawrence ice survey, winter 1958. W.A. Black, Ottawa, 1959. 56 p., maps, illus.	75 cents.
No. 20.	A report on sea ice conditions in the Eastern Arctic, summer 1958. W.A. Black, Ottawa, 1959. 36 p., maps, illus.	75 cents.
No. 21.	Sea ice conditions in the Northumberland Strait area. C.N. Forward, Ottawa, 1959. illus.	50 cents.
No. 22.	Notes on the glaciation of King William Island and Adelaide Peninsula, N.W.T. J. Keith Fraser and W.E.S. Henoch, Ottawa, 1959. 39 p., maps, illus.	75 cents.
No. 23.	Gulf of St. Lawrence ice survey, winter 1959. W.A. Black, Ottawa, 1959. 56 p., maps, illus.	75 cents.
No. 24.	Dynamique et caractéristiques des glaces de dérive de l'estuaire et de la partie nord-est du golfe Saint-Laurent, hiver 1957-58. Michel Brochu. Ottawa, 1960. 93 pages, cartes.	$1.00
No. 25.	Gulf of St. Lawrence ice survey, winter 1960. W.A. Black, Ottawa, 1960. 64 p., maps, illus.	$1.50
No. 26.	Shoreline changes in Egmont Bay and Bedeque Bay, Prince Edward Island. Charles N. Forward. Ottawa, 1960. 15 p., maps, illus.	75 cents.
No. 27.	A report on sea ice conditions in the Eastern Arctic, summer 1960. W.A. Black, Ottawa, 1960. 34 p., maps, illus.	75 cents.
No. 28.	A pilot project for permafrost investigations in central Labrador-Ungava. J.D. Ives, Ottawa, 1961. 24 p., maps, illus.	50 cents.
No. 29.	Geomorphological studies in northeastern Labrador-Ungava. J.T. Andrews and E.M. Matthew. Ottawa, 1961. 36 p., maps, illus.	50 cents.
No. 30.	Déplacement de blocs par la glace le long du Saint-Laurent. Movement of boulders by ice along the St. Lawrence River. Michel Brochu. Ottawa, 1961. 27 p., maps, illus.	50 cents.
No. 31.	Canadian land-use mapping. Cartographie de l'utilisation des terres au Canada. N.L. Nicholson, I.H.B. Cornwall and C.W. Raymond. Ottawa, 1961. 40 p., maps, illus.	75 cents.
No. 32.	Gulf of St. Lawrence ice survey, winter 1961. W.A. Black. Ottawa, 1961. 52 p., maps, illus.	$1.50
No. 33.	Glaciers of northern Baffin and Bylot islands, N.W.T. G. Falconer. Ottawa, 1962. 58p., maps, illus.	$2.00
No. 34.	River-ice conditions in the Nelson River drainage system. D.K. MacKay. Ottawa, 1962. 42p., maps, illus.	50 cents.
No. 35.	Trends and factors affecting break-up and freeze-up dates in the Nelson River drainage system. D.K. MacKay. Ottawa, 1962. 37 p., maps, illus.	50 cents.
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