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GEOGRAPHICAL PAPER No. 36

Gulf of St. Lawrence Ice Survey, Winter 1962

W. A. Black

GEOGRAPHICAL BRANCH
Department of Mines and
Technical Surveys, Ottawa

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70121-9—1

The Canadian National Railways ferry *Prince Edward Island* pushing through heavy icefields off Borden, in Northumberland Strait, was pressed into service on March 8 to assist the MV *Abegweit* clear a backlog of freight. (1424–2, 2 (m) OTU, Mar. 9, 1962).

PREFACE

The Gulf of St. Lawrence ice survey, winter 1962, is a study resulting from the seventh winter aerial ice survey conducted over the Gulf of St. Lawrence region. In addition, a survey of the St. Lawrence River below Montreal is included.

It is hoped that this report, together with the previous reports, will add to the understanding of the nature, extent and distribution of the ice, and thus contribute to the solution of problems associated with winter navigation of the St. Lawrence River and the Gulf of St. Lawrence.

N. L. Nicholson
Director
Geographical Branch

70121-9—2

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GULF OF ST. LAWRENCE ICE SURVEY, WINTER 1962

INTRODUCTION AND ACKNOWLEDGMENTS

The aerial survey of sea-ice conditions in the Gulf of St. Lawrence from December 1961 to April 1962 is a continuation of the ice-distribution surveys begun by the Branch in the winter of 1956 and extended in 1959 to include the St. Lawrence River upstream to Montreal. The primary purpose of the survey was to observe and map the coverage and distribution of the various types of ice and to relate ice conditions to climatic factors.

The ice survey was conducted by the Geographical Branch with the cooperation of Air Transport Command, RCAF, and was coordinated by the Geophysical Research Section of the Defence Research Board. Specific acknowledgments are made to W/C S.F. Cowan, CO 408 (R) Squadron, RCAF, T.A. Harwood, Geophysical Research Section, Defence Research Board, and P.D. McTaggart-Cowan, Meteorological Branch, Department of Transport. The writer also wishes to acknowledge the excellent cooperation received from the RCAF officers and crews who participated in the ice-survey program.

The operation in 1962 was planned to begin in December 1961 and to continue until mid-April; the first flight was made on December 28 and the last on April 19. The squadron provided Lancaster aircraft, and RCAF station Rockcliffe was the base of operations; RCAF station Summerside was the forward base. Air Transport Command organized 10 flights for the following dates: December 28; January 9, 17 and 29; February 19 and 27; March 12 and 21; April 3 and 18. The average duration of each operation was about two days, and the average flying time was about 15 hours. Flights were made at heights up to 9,000 feet according to local visibility. Two flights were cancelled: one for December 18 and subsequent days because of continuing unfavorable weather over the gulf, and one for early February because of the program of the weather satellite Tiros IV.

The aerial reconnaissance was conducted so that the St. Lawrence River from Montreal to the Saguenay River was surveyed, whenever possible, during the outward and return flights. The river from Cornwall to Lake St. Louis was surveyed during the freeze-up and break-up period. Cornwall, Ont., formed the western limit of the survey and the Strait of Belle Isle the eastern limit. Flight patterns were arranged to permit the greatest possible observation of ice conditions, to avoid unfavorable local weather and to provide the officers of the Canadian Coast Guard Service with ice information of immediate value.

In April, when the Tiros IV satellite again passed over the gulf region, the two remaining flights of the program were arranged to cover its initial and final passage.

In conjunction with the ice survey, a systematic photographic record of ice conditions was made by RCAF photographers. The photographs reproduced in this report are by courtesy of the RCAF; the Tiros IV photo, Figure 35, is included by courtesy of the Joint Photographic Intelligence Centre (JPIC).

The symbols and main outline of ice classification used in this report are similar in plan to those developed by the writer in Geographical Paper no. 19. The graphic and quantitative classification method that was developed to include new, young and winter ice is also followed. Polar ice, which enters the gulf through the Strait of Belle Isle, is treated quantitatively as a unit; graphically it is represented by the winter-ice pattern. The amount of winter ice in the total distribution is considered the critical element in the ice cover. Whenever winter ice occurs in the proportion of 3/10 or more in association with new or young ice, a close graphic pattern is used. A more open pattern representing young ice is used to show an ice distribution that consists 3/10 or more of young ice in association with new ice. A still more open pattern represents new-ice types and includes grease, frazil, slush, very young ice or ice crust, and the early stages of slob or sludge ice. The quantities of each of the various ice types are expressed in tenths of the total ice cover.

A similar procedure is followed in describing the topographic forms of relief. The quantities of brash and block, small to medium floes, large floes and field ice are given in tenths of the total ice cover. Because shelving and pressure ridging add substantially to the thickness of the ice cover, these forms are shown in tenths of the total ice surface. All parts of the quantitative fraction describing the ice are therefore expressed in tenths. Boundary lines are used to separate the various categories according to the type of ice cover and the amount of ice concentration.

PART I

THE GULF OF ST. LAWRENCE

TEMPERATURE CONDITIONS

The winter of 1961-62 was variable: in November and December mean temperatures were well above average; average conditions prevailed in January; February temperatures for the gulf region were well below average; in March and April mean temperatures were well above. As a result, icefields developed considerably later than usual. Their development, however, was in the latter half of January and continued unabated through February, so that icefields in the gulf became extensive. They deteriorated slowly in March but remained until late spring.

Mean monthly temperatures throughout the gulf region varied from 4 to 6 degrees above normal for November and from 3 to 10 degrees above normal for December, the range in the northern parts of the gulf being from 6 to 10 degrees. In January, mean monthly temperatures ranged from 2 degrees below normal to 1 degree above it, and in February, from normal to 6 degrees lower, the greatest deficiencies occurring in the northern gulf areas. March mean monthly temperatures were substantially above normal, varying from 3 to 12 degrees, and ranges of 7 to 12 degrees above normal occurred in the northern parts of the gulf. April mean temperatures varied from normal to 2 degrees below it. In the gulf regions only the Strait of Belle Isle experienced normal to above-normal mean monthly temperatures throughout the winter. Except those for February, the mean monthly temperatures for the gulf region were above normal.

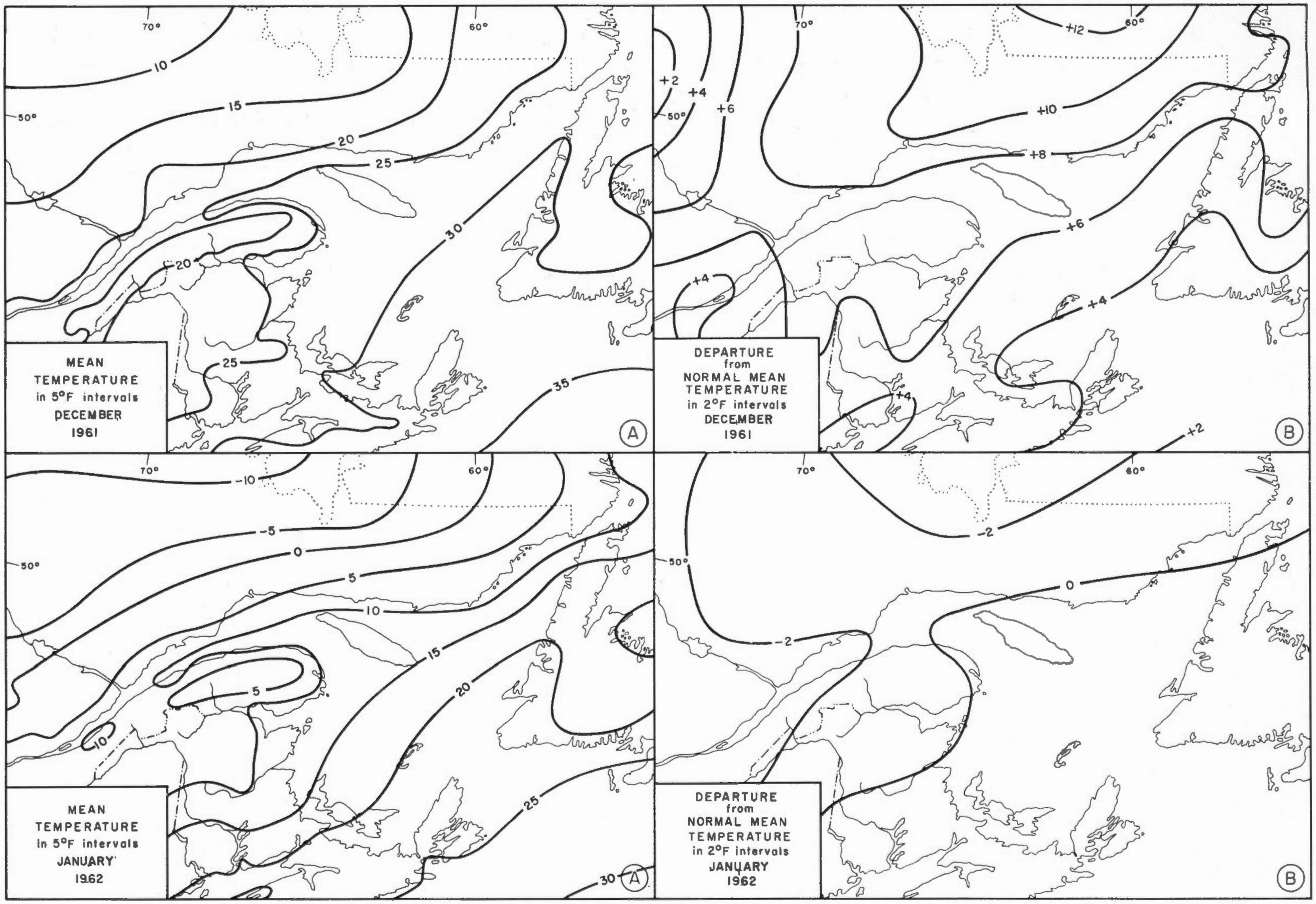
Regional variations in temperature are shown in Table I. The northern and northwestern parts of the gulf experienced the lowest temperatures in November. In December, the St. Lawrence estuary, North Shore and Gaspé-Chaleur areas continued to experience the lowest mean monthly temperatures (23^{o} to 26^{o}). In these areas and the Strait of Belle Isle the January temperatures (7^{o} and 11^{o}) were markedly lower than elsewhere in the gulf. Temperatures throughout the gulf continued to fall in February, the St. Lawrence

TABLE I

Mean and normal* temperatures (F^{o}) for gulf region from November 1961 to April 1962

	Nov.		Dec.		Jan.		Feb.		Mar.		Apr.	
	M.	N.	M.	N.	M.	N.	M.	N.	M.	N.	M.	N.
St. Lawrence estuary	36	30	23	17	8	10	6	12	30	23	36	35
North Shore	34	28	24	14	7	7	4	9	31	19	31	30
Strait of Belle Isle	34	28	28	19	11	11	10	10	29	19	27	27
Gaspé-Chaleur	36	31	26	19	11	12	9	13	31	23	36	34
Eastern gulf	41	36	31	27	21	20	15	18	33	25	34	34
Central gulf	41	36	30	26	20	19	13	16	28	24	34	32
Southern gulf	40	36	30	26	18	17	11	16	29	26	37	37
Cabot Strait	43	38	32	29	23	23	17	20	32	27	36	36
Average gulf temperatures	38	33	28	22	15	15	11	14	30	23	34	33

*M. - mean; N. - normal.


MEAN
TEMPERATURE
in 5°F intervals
DECEMBER
1961
A
DEPARTURE
from
NORMAL MEAN
TEMPERATURE
in 2°F intervals
DECEMBER
1961
B
MEAN
TEMPERATURE
in 5°F intervals
JANUARY
1962
A
DEPARTURE
from
NORMAL MEAN
TEMPERATURE
in 2°F intervals
JANUARY
1962
B
70°
60°
50°

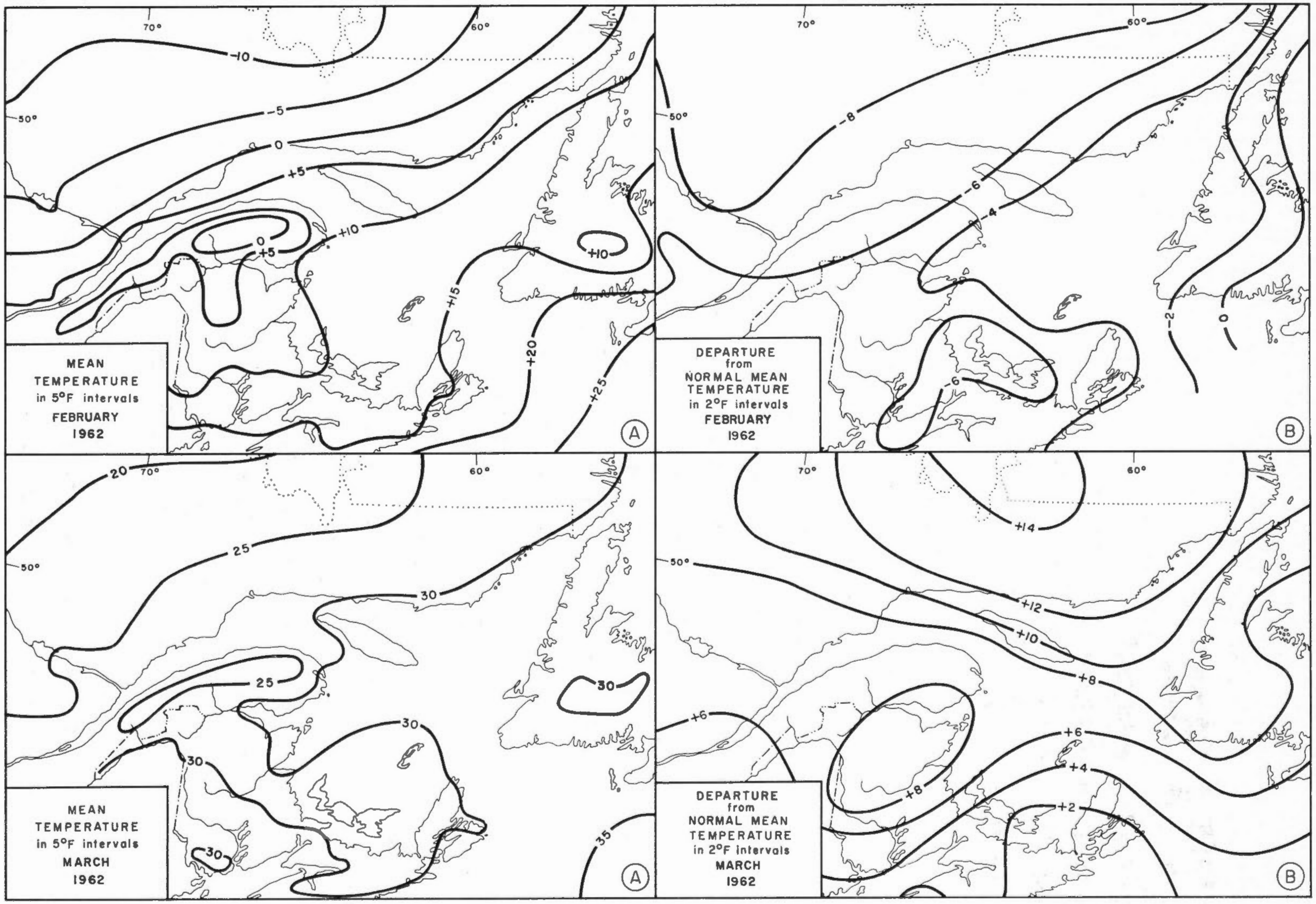


FIGURE 1 (A). Mean temperatures, December 1961 to March 1962.

FIGURE 1 (B). Departure from normal mean temperature, December 1961 to March 1962.

estuary and the North Shore having the lowest (4^o and 6^o) and Cabot Strait the highest (17^o). Such prolonged and sustained low temperatures resulted in the formation and maintenance of an extensive ice cover. In March the temperatures went up rapidly, the most marked rises being those of the St. Lawrence estuary and the North Shore, which reached 30 and 31 degrees respectively, temperatures almost as high as those of Cabot Strait. In most parts of the gulf ice-forming processes were retarded. Temperatures slowly climbed in April and, everywhere but in the Strait of Belle Isle, ceased to be an important factor in ice formation.

The mean isotherms from December to March for the gulf region are shown in Figure 1A. The northeast-southwest trend indicates that air temperatures from December to February were generally uniform from the St. Lawrence River to the Strait of Belle Isle. Over the gulf the trend was more southerly because of the moderating influence of the water, and the temperature trend for March was from north to south, with generally uniform temperatures from the Strait of Belle Isle to the southern gulf region. The isotherms indicate where ice formation first began and where the main ice-forming conditions existed during the winter. They also indicate where temperature, as an ice-forming factor, was not effective. The North Shore, the St. Lawrence estuary and the Strait of Belle Isle were the primary areas of ice formation and were closely followed by Gaspé Passage, Chaleur Bay and the western gulf coast.

Figure 1B shows the departure from the normal isotherms, the extent to which temperatures in various parts of the gulf differed from normal mean winter temperatures. Above-normal temperatures prevailed throughout the gulf regions during December and March; below normal temperatures prevailed during January and February. The general effect was that the tempo of the ice-forming processes was retarded in December, quickened in January and sustained in February. In March,the ice-forming processes were restricted mainly to the northern, western and southern parts of the gulf.

Low freezing temperatures advanced from the northwest to the southeast but did not reach Cabot Strait area until January. They receded from that area in March. Thus the Cabot Strait area had two months of sustained low temperatures that resulted in the development of a long-lasting and extensive ice cover. In the Strait of Belle Isle the temperature was, on the whole, midway between that in the St. Lawrence estuary and that in Cabot Strait. It became suitable for ice growth in December and continued so into February. At the end of the first week in February, icefields covered the gulf and a constant but erratic flow of ice began to drift southward through Cabot Strait. After mid-February, Labrador ice began to enter the gulf through the Strait of Belle Isle.

WINTER WIND CONDITIONS

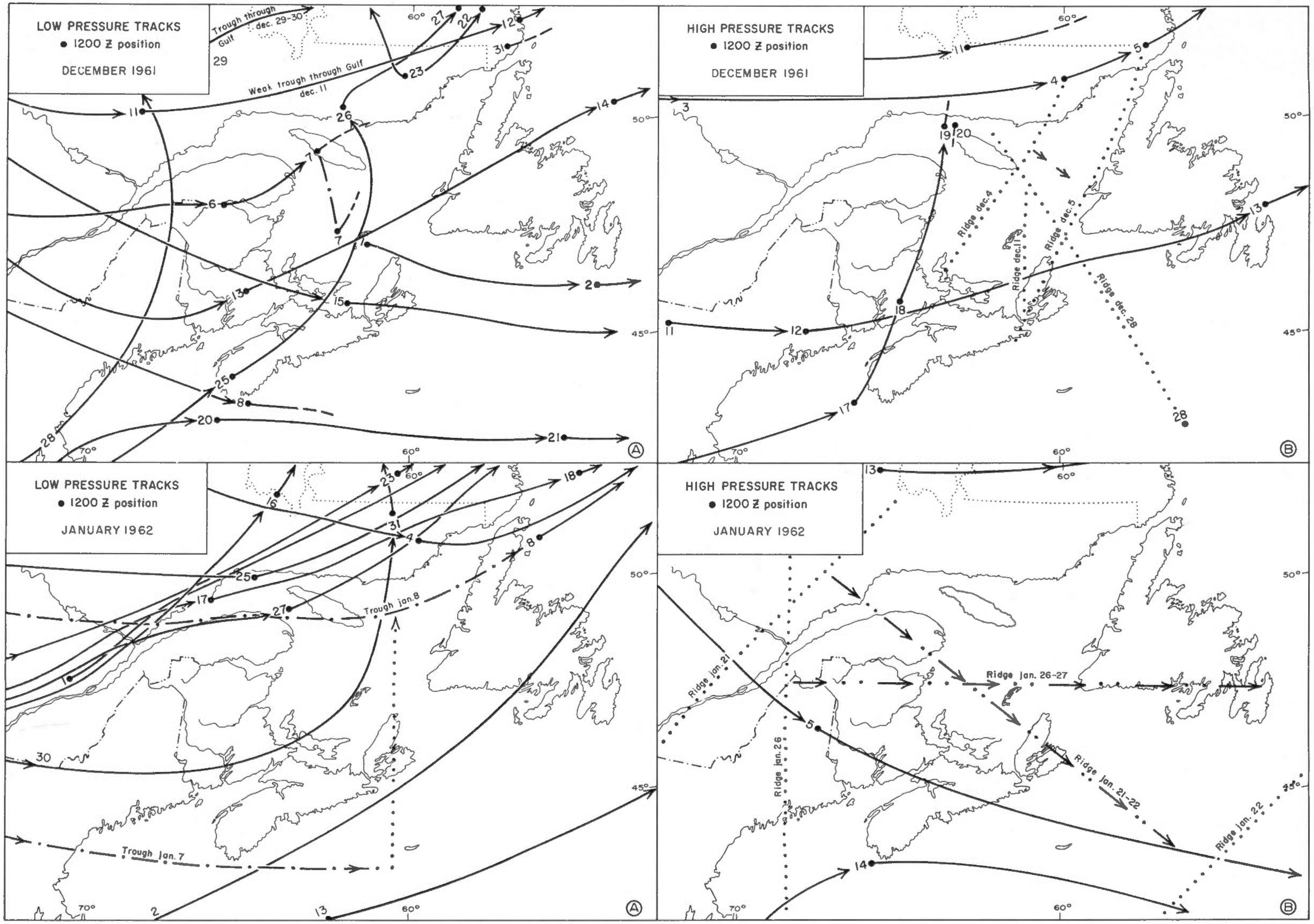
The prevailing winds carried low- and high-pressure air masses across the gulf region, as shown in Figure 2 (A and B). The flow of continental Arctic air gave rise to northerly-sector winds, and of maritime Atlantic air to milder, southerly winds.

In December, the region lay in the path of westerly flows of continental air; in the latter part of the month southwesterly flows of mild Atlantic-air masses pushed in. The storms of December 6, 11, 26 and 29 brought in mild air; those of December 13, 15 and 20 brought in cold air and subsequent low temperatures. In January, most of the storms passed to the north of the gulf region, and mild Atlantic air was thereby drawn into it. Brief outbreaks of cold air occurred, and from January 17 onward the daily mean temperature at Summerside, P.E.I., was below freezing. Sustained winter cold set in on January 26, and minimum air temperatures hovered close to zero.

The storm tracks of February, generally passing to the south of the gulf region, introduced cold continental Arctic-air masses; the only spell of mild weather was the brief one that occurred on February 5 and 6. The near-zero minimum temperatures gave way to higher temperatures on February 28. In March, well-developed storm tracks usually lay to the south of the gulf region, but a series of storms passed up the Atlantic coast to stagnate off the eastern and southeastern parts of the gulf. Fairly strong northeasterly flows of modified Arctic air prevailed in the southern and eastern areas of the gulf from March 1 to 7, 13 to 17, and 23 to 29 and brought higher temperatures. Continental air with northerly prevailing winds dominated the northern and western parts of the gulf. The daily mean temperatures, which at Summerside after January 17 were generally below freezing, rose above the freezing point after March 24. In April, the gulf region was under strong cyclonic influence, and the storms thus caused brought in flows of mild Atlantic air and modified continental air.

Cyclonic storms passing over the gulf ice shattered and opened the icefields to wind and wave action. High-pressure air masses, normally continental Arctic in origin and with attendant low freezing temperatures, resulted in the consolidation and thickening of the icefields. The shattering and compaction produced pressure-ridged ice, the area of which increased with the advance of the winter season and which, partly on account of its greater thickness, made the ice cover slow to melt away.

Because of the variability in the pattern of the storm tracks and the intensity of the cyclonic storms, the prevailing winds vary considerably from month to month throughout the gulf region (Table II).


LOW PRESSURE TRACKS
● 1200 Z position
DECEMBER 1961
Trough through Gulf dec. 29-30
29
Weak trough through Gulf dec. 11
HIGH PRESSURE TRACKS
● 1200 Z position
DECEMBER 1961
Ridge dec. 4
Ridge dec. 5
Ridge dec. 11
Ridge dec. 28
LOW PRESSURE TRACKS
● 1200 Z position
JANUARY 1962
Trough jan. 8
Trough jan. 7
HIGH PRESSURE TRACKS
● 1200 Z position
JANUARY 1962
Ridge jan. 21
Ridge jan. 26
Ridge jan. 26-27
Ridge jan. 21-22
Ridge jan. 22
50°
45°
60°
70°
Ⓐ
Ⓑ

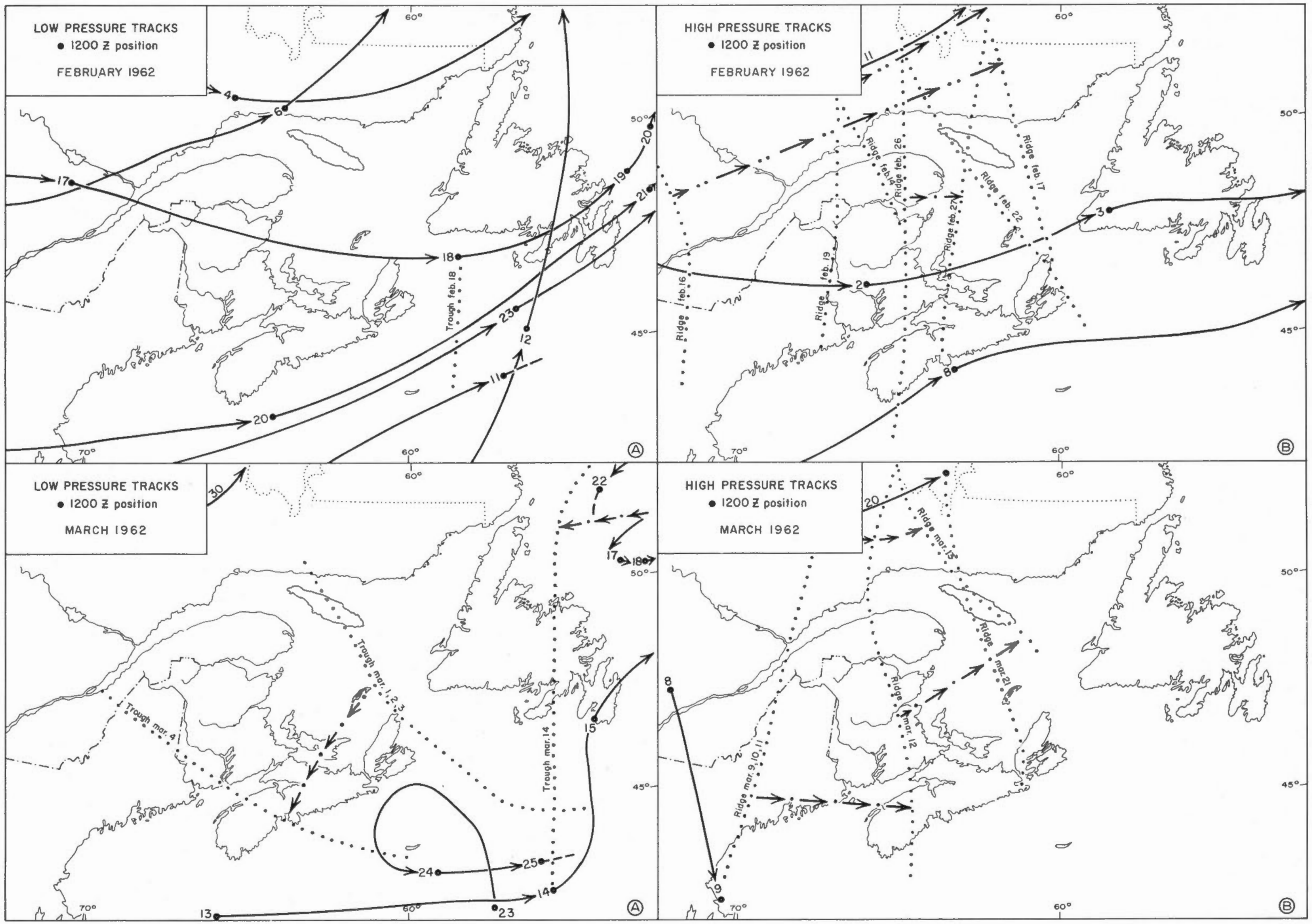


FIGURE 2 (A). Passage of low-pressure air masses, December 1961 to March 1962.

FIGURE 2 (B). Passage of high-pressure air masses, December 1961 to March 1962.

(continued on page 10)

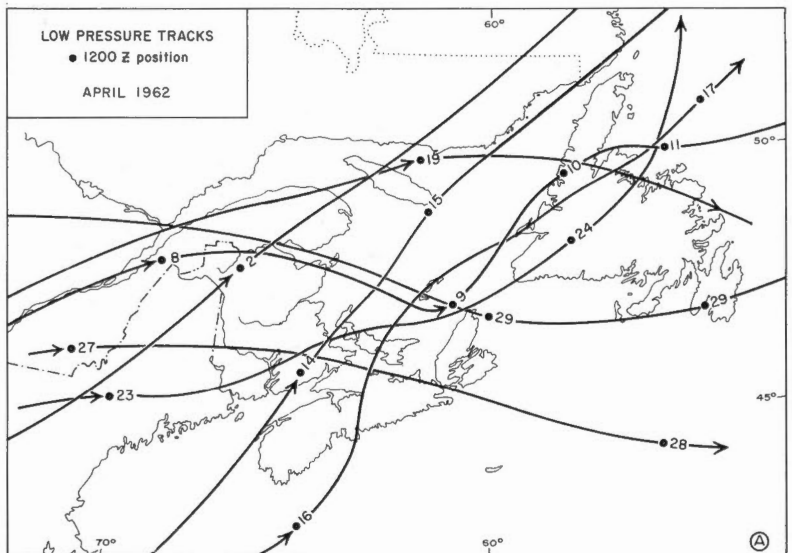


FIGURE 2 (A) (cont'd). Passage of low-pressure air masses, April 1962.

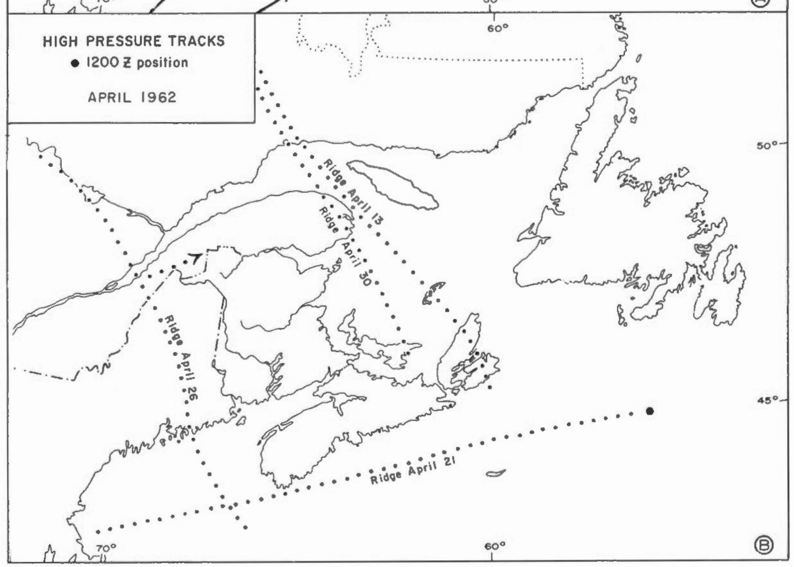


FIGURE 2 (B) (cont'd). Passage of high-pressure air masses, April 1962.

TABLE II

Cumulative wind frequencies,
Gulf of St. Lawrence, December 1961 to April 1962
(per cent)

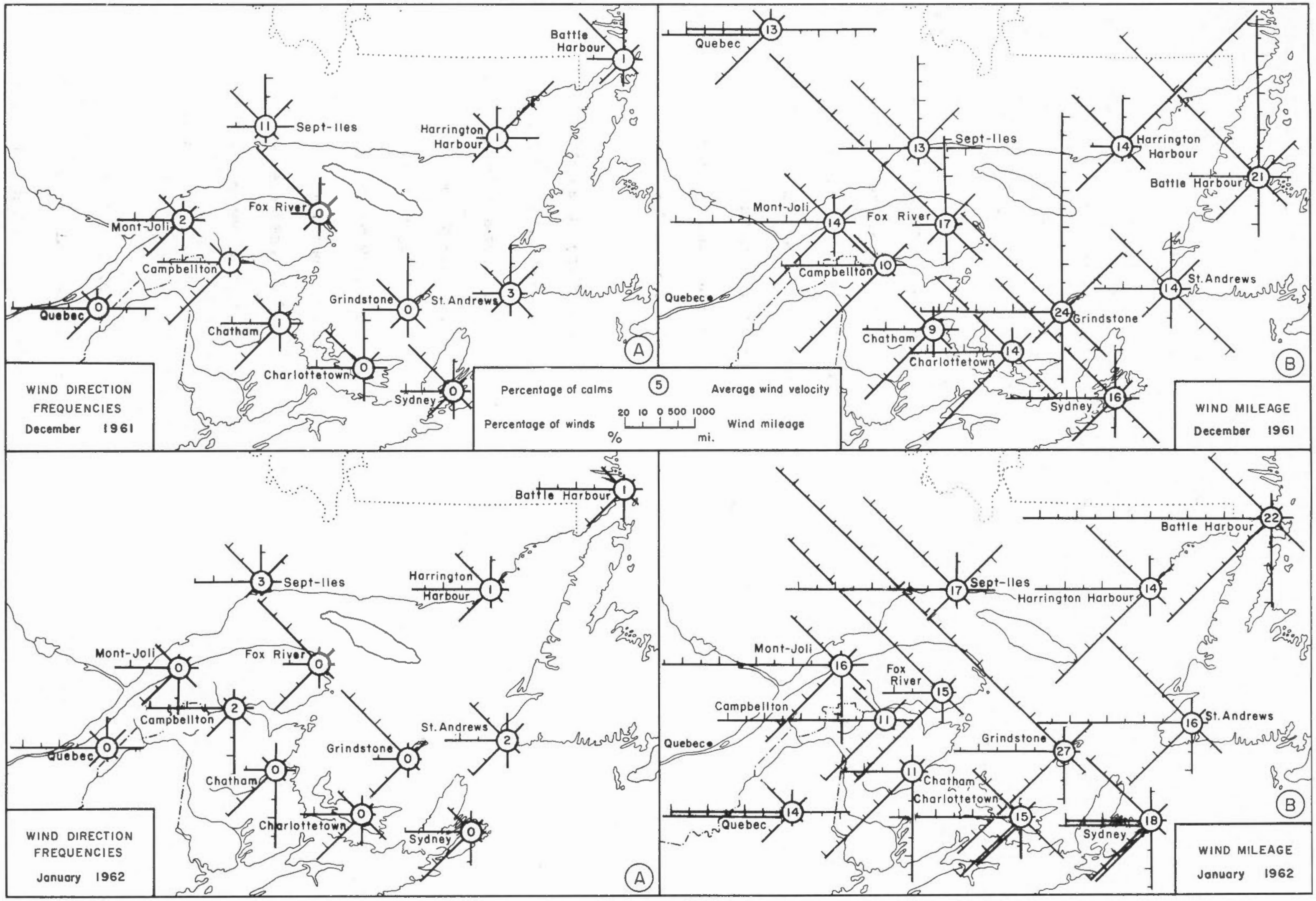
Month	N	NE	E	SE	S	SW	W	NW	Calm	Total
December	11.8	10.2	6.4	6.3	5.3	17.3	21.2	20.1	1.4	100
January	5.3	5.2	3.8	3.8	9.5	22.5	30.6	18.5	0.8	100
February	17.8	13.5	7.2	4.1	5.4	10.7	17.1	21.0	3.2	100
March	25.3	18.3	5.2	1.7	2.8	8.1	12.2	22.2	4.2	100
April	10.2	12.2	7.5	4.8	6.6	23.1	16.9	15.4	3.3	100
Mean frequency	14.1	11.9	6.0	4.1	5.9	16.3	19.6	19.5	2.6	100

During December and January the SW, W and NW winds were consistently strong; the E, SE and S winds were weak. The former winds, associated with inflows of arctic air, contributed to ice-forming processes; the latter winds were usually associated with inflows of mild maritime air. Throughout February and March, however, the N and NE components increased, and only the NW component persisted as a strong wind. April brought a reversal in the trend of wind direction; the SW, W and NW winds were dominant compared with the N, NE and E components. The E, SE and S winds were consistently infrequent from December to April.

The winds varied considerably from place to place, with strongly developed winds from specific sectors (Figure 3A). The ice distribution in a given area depended largely on the shifts in the local prevailing wind. In December, the prevailing winds were W in the St. Lawrence estuary, SW in the southern gulf, and N to NE in the northern and central gulf areas. During January, the prevailing winds in the northern parts of the gulf were W with strong support from the SW or NW sectors; in the southern parts of the gulf the prevailing winds were SW strongly supported by W winds. In February, the prevailing winds in the central and southeastern parts of the gulf were N and NE with strong support from the NW, and in the Strait of Belle Isle area and the western parts of the gulf W and NW winds were prevalent. In March, the N, NE and NW components were dominant over much of the gulf region, but in April SW sector winds prevailed in the southern parts of the gulf while in the northern and central parts N and NW winds were prevalent.

The persistence of a wind as expressed by its mileage and velocity indicates the wind sectors that are most effective in moving drifting ice and producing wind-induced surface currents (Table III).

Wind mileage, expressed in per cent, tends to coincide with wind frequency (Table II), and the


WIND DIRECTION FREQUENCIES December 1961
Battle Harbour
Sept-Iles
Harrington Harbour
Fox River
Mont-Joli
Campbellton
Grindstone
St. Andrews
Quebec
Chatham
Charlottetown
Sydney
A
Percentage of calms
5
Average wind velocity
Percentage of winds
20 10 0 500 1000
%
mi.
Wind mileage
WIND MILEAGE December 1961
B
WIND DIRECTION FREQUENCIES January 1962
WIND MILEAGE January 1962

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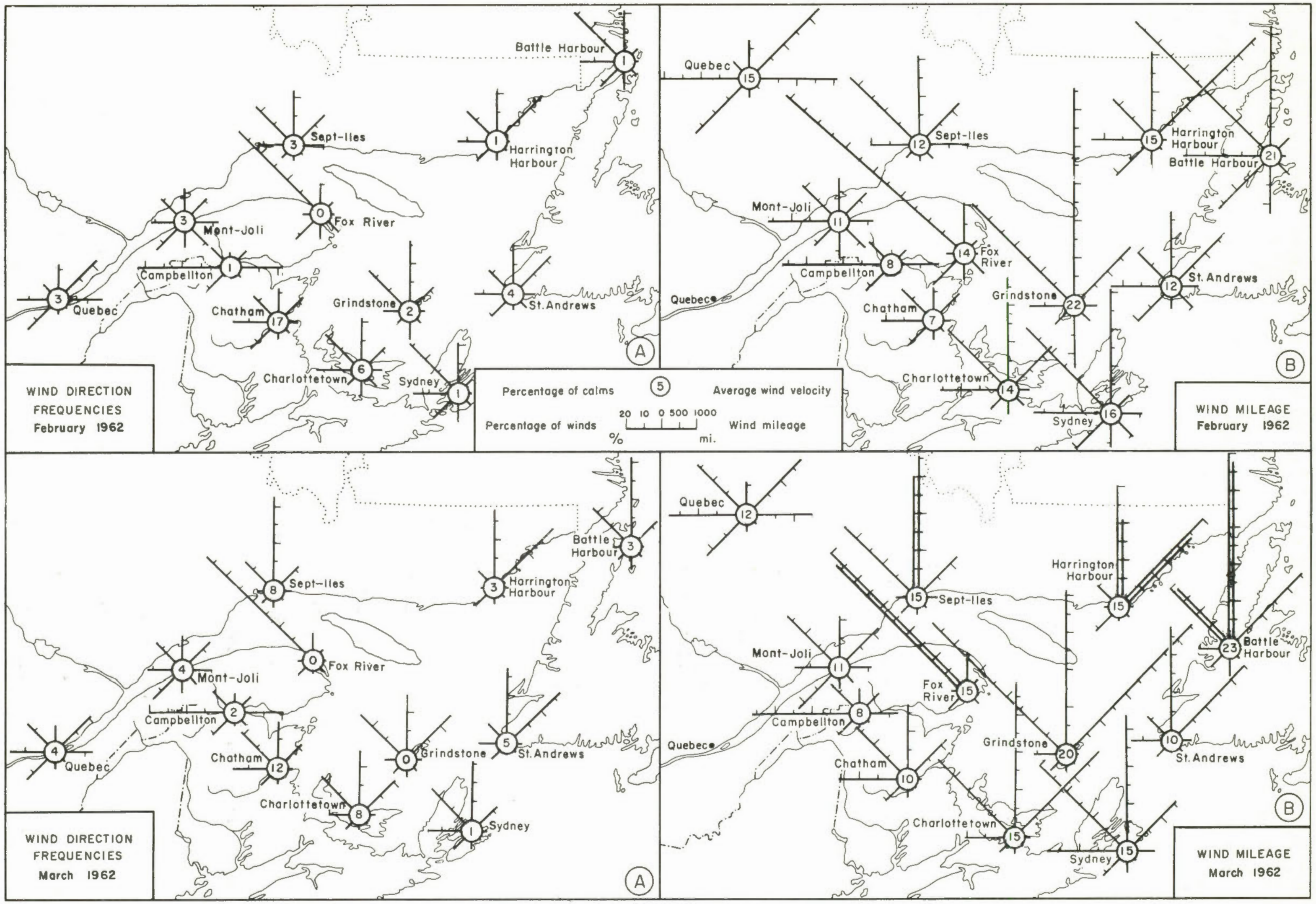

FIGURE 3 (A). Wind-direction frequencies, December 1961 to March 1962.

FIGURE 3 (B). Wind mileage, December 1961 to March 1962.

variations that occur are usually small. The departure of wind frequency from wind mileage varied from -3.4 to +3.8 per cent in December, from -2.0 to +4.8 in January, from -1.2 to +3.6 in February, from -2.4 to +5.9 in March and from -1.3 to +2.2 in April. The greatest difference between the two is associated with the N and NW winds, for which the percentage of wind mileage is greater than that of wind frequency. An examination of Table III shows that a high proportion of wind mileage from a given direction often resulted in a high average wind speed from the same direction. Thus, prevailing winds that travel long mileages tend to have higher velocities than short-mileage components and, because of both their sustained mileage and their velocity, are therefore considerably more effective in moving icefields. Short-mileage winds with high velocities are usually associated with short, violent storms.

TABLE III

Mean wind mileage and velocity,
Gulf of St. Lawrence, December 1961 to April 1962

	December (per cent:m.p.h.)	January (per cent:m.p.h.)	February (per cent:m.p.h.)	March (per cent:m.p.h.)	April (per cent:m.p.h.)
N	13.9:17.8	3.3:10.0	21.4:16.6	31.2:17.4	11.7:14.9
NE	9.6:14.1	3.7:11.4	13.6:13.9	20.6:15.8	13.5:14.8
E	4.6:10.6	2.8:12.1	6.0:11.3	3.4: 9.1	7.1:12.8
SE	8.0:19.2	3.9:16.5	3.2:10.7	0.7: 5.9	4.4:12.0
S	5.2:15.1	8.8:15.1	5.5:13.9	1.7: 8.9	6.9:13.8
SW	13.9:12.1	22.7:16.5	9.7:12.6	5.7: 9.8	23.2:13.3
W	20.9:14.7	31.5:16.8	16.2:13.0	10.3:11.9	15.6:12.3
NW	23.9:17.8	23.3:20.6	24.4:16.0	26.4:16.8	17.6:15.1
Total Average, m.p.h.	100:15.3	100:16.4	100:14.3	100:14.7	100:13.7

Velocity and sustained wind mileage varied considerably throughout the gulf region during the winter months (Figure 3B). Velocities were consistently higher in the central gulf and Strait of Belle Isle areas, the winds in both areas exceeding 21 m.p.h. In the rest of the gulf, velocities ranged from 10 to 17 m.p.h. during December and January and from 7 to 16 m.p.h. in February and March. April winds varied from 8 to 19 m.p.h., velocities being greatest in the central gulf region.

Special local ice conditions arise in certain parts of the Gulf of St. Lawrence region, namely: Gaspé Passage, through which St. Lawrence estuary ice passes into the gulf; the Strait of Belle Isle, through which Labrador ice enters the gulf; the central gulf region, where the icefields are exposed to the unbroken sweep of the prevailing wind; the southern gulf region, which as a catchment basin is often icecongested; and Cabot Strait,through which the icefields leave the gulf. The mean frequency of winds prevailing in these areas is given in Table IV.

TABLE IV

Mean wind frequencies,* exceeding 8.5 per cent, for selected areas, February (F.), March (M.) and April (A.), 1962

	Gaspé Passage			Belle Isle			Central gulf			Southern gulf			Cabot Strait		
Wind	F.	M.	A.	F.	M.	A.	F.	M.	A.	F.	M.	A.	F.	M.	A.
N	10	9	9	20	43	23	32	29	13	22	29	-	25	31	-
NE	-	-	-	-	15	13	13	29	-	11	20	-	-	12	-
E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SE	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-
S	-	-	-	9	-	10	10	-	12	-	-	9	-	-	14
SW	13	-	16	14	-	13	-	-	14	-	-	26	12	-	36
W	-	-	-	18	-	13	-	-	18	19	10	22	18	18	16
NW	57	75	42	31	24	17	25	28	28	21	23	10	24	25	10
Total per cent	80	84	77	92	82	89	80	86	85	73	82	67	79	86	76

*Mean hourly wind frequency, given in per cent, to nearest whole number.

In the Gaspé Passage, strongly developed NW wind components accounted for 42 to 75 per cent of the prevailing wind frequencies from February to April. The main drift of the icefields was southeastward parallel to the Gaspé coast and toward the Magdalen Islands. The NW component, at its peak in March, readily explains why in that month the ice drifts into the catchment basin and the open water in this part of the gulf expands so rapidly.

Strongly developed SW, W and NW quadrant winds (77 per cent) were a major factor in retarding the January inflow of Labrador ice through the Strait of Belle Isle. In February these winds, though reduced in frequency, accounted for 63 per cent of the total in that area. The rapid advance of the Labrador icefields into the gulf during March was associated with the prevalence of N and NE wind components, which, combined, accounted for 58 per cent of the March wind frequencies. One of the main effects of a well-developed NW component is to cause the ice entering the strait to swing to the south coast, thereby leaving the north coast of the strait relatively ice-free. In April, N and NE component winds accounted for 46 per cent of the wind frequencies and NW, W and SW for 43 per cent. The result was a decrease in the amount of ice entering the gulf.

In the central gulf region the winds prevailing during January were SW, W and NW, and these made up 84 per cent of the wind frequencies for the month. With the rapid fall in temperatures that occurred in the latter half of January, they quickly extended the icefields across the gulf. During February and March respectively, NW, N and NE winds accounted for 70 and 86 per cent of the wind frequencies and seemed effective in holding the ice in the catchment basin, establishing the ice barrier and causing the ice to flow from the gulf erratically. In April SW and NW winds predominated and had the general effect of offsetting each other and releasing the ice in small quantities into Cabot Strait.

S, SW and W winds prevailed during January in the southern gulf region and accounted for 83 per cent of the wind frequencies for the month. During February, the well-developed W quadrant winds, making up 62 per cent, established extensive icefields in the southern gulf. The reduction, in March, of the W quadrant and an increase in the NE quadrant winds maintained the icefields in the catchment basin and retarded the flow of ice from the southern gulf region. In April, the weakening of the NW and the gradual dominance of the SW wind, which made up 26 per cent of the wind frequencies for the month, contributed largely to the small but steady flow of ice from the catchment basin into Cabot Strait.

Although Cabot Strait was mainly ice-free during January, the offshore winds (NW, W and SW components) accounted for 78 per cent of the wind frequencies. During February, strongly developed NW and N winds amounting to 49 per cent of the frequency caused the ice to drift to the southeast and lie across the Sydney bight. March brought an intensification of the N wind and a gradual increase of the NE wind, and their combined frequencies reached 43 per cent. The result was the establishment of an effective ice barrier across the bight from St. Ann's Bay to Cape Percé. A relaxation of the ice barrier developed in April, resulting mainly from the dominance of the SW wind. The SW wind together with the W and S winds, with which it constituted 66 per cent of the frequency, tended to hold the icefields away from Cape Breton Island's east coast.

GULF ICE DISTRIBUTION

The type of ice and the concentration, distribution and duration of the ice cover vary with the severity of the winter. As already pointed out, air temperatures over the gulf region during November were well above normal and continued so into December. A light ice year was thus to be expected. The advance of winter and the rapid fall in temperature associated with outbreaks of arctic continental air established the physical conditions necessary for the rapid development and expansion of icefields over the waters of the gulf.

The suitability of air temperatures for ice-forming processes is shown in the mean of monthly degree-days of frost (Table V). The mean of degree-days for November (-9), December (+1), March (-1) and April (-5) was below normal for the gulf region, but in April the air temperatures were unfavorable for ice formation. January and February, on the other hand, with a mean of 14 and 18 mean degree-days of frost respectively, were favorable for the development of an extensive ice cover.

TABLE V

Mean monthly degree-days of frost,* 1961-62

Area	Nov. M.	Nov. N.**	Dec. M.	Dec. N.	Jan. M.	Jan. N.	Feb. M.	Feb. N.	Mar. M.	Mar. N.	Apr. M.	Apr. N.
St. Lawrence estuary	-7	-1	6	12	21	19	23	17	-1	6	-7	-6
North Shore	-5	1	5	15	22	22	25	20	-2	10	-2	-1
Strait of Belle Isle	-5	1	1	10	18	18	19	19	0	10	2	2
Gaspé-Chaleur	-7	-2	3	10	18	17	20	16	-2	6	-7	-5
Eastern gulf	-12	-7	-2	2	8	9	14	11	-4	4	-8	-5
Central gulf	-12	-7	-1	3	9	10	16	13	1	5	-5	-3
Southern gulf	-11	-7	-1	3	11	12	18	13	0	3	-8	-8
Cabot Strait	-14	-9	-3	0	6	6	12	9	-3	2	-7	-7
Average for gulf	-9	-4	1	7	14	14	18	15	-1	6	-5	-4

*A degree-day of frost is defined as a day with a mean temperature $1^{\circ}F$ below the freezing point of sea water (29°).

**M. - mean; N. - normal.

The conditions for ice growth and expansion in the gulf region were variable. In December, the most favorable conditions existed in the northern parts of the gulf, the least in the southern areas. The mean of degree-days of frost in January, +18 to +22, shows that the northern half of the gulf was having freezing temperatures, with conditions most satisfactory for ice formation (Figures 8, 9 and 10). February, with abnormally low temperatures ($11^{\circ}F$), produced effective conditions for the development of an extensive ice surface; the monthly mean of degree-days of frost ranged from +19 to +25 in the northern parts of the gulf, and from +12 to +18 in the southern parts. The entire gulf region, therefore, was an effective ice-forming reservoir. The change in the air-circulation pattern that developed at the beginning of March reduced the effectiveness of ice-forming processes to the minimum daily temperature periods. The fact that much of the gulf lay between the $30^{\circ}F$ and $35^{\circ}F$ isotherms (Figure 1A) indicates that air temperature as a factor contributing to the ice-formation process was declining at an equal rate throughout the region.

The type of ice, as determined by the distribution of new, young and winter types, is an important feature of the ice cover. These types, together with topographic details of relief, are intimately related to the oceanographic as well as the climatic factors. Only climatic data, together with observed conditions, are available; surface oceanographic conditions conducive to heat loss must be interpolated.

Examination of Figure 1A indicates that the formation of ice in December would first occur in the St. Lawrence estuary, Chaleur Bay and the western inlets of the gulf and that by mid-January, with further heat loss, a large area of the western and northern gulf waters would reach the freezing point and thus generate new-ice types (Figures 7, 8 and 9). By the end of January, with air-temperature conditions conducive to severe heat loss over the entire gulf region, the formation of new and young ice had expanded rapidly. The icefields so formed occupied the southwestern half of the gulf and a large part of the northeast arm. The last area of open water remaining at the end of January extended from Anticosti Island to the west coast of Newfoundland. By February 7, this area had became ice-covered.

The development of winter ice requires a sustained loss of heat over a considerable period of time beginning in the early part of winter or continuing into late spring. The growth of the icefields in the Gulf of St. Lawrence began late, the greater part of the area becoming covered between January 18 and February 7 with ice that was mainly new and young. Three weeks later, however, on March 1, the retreat of the icefields began. The period of sustained low temperatures was not long enough for the development of massive fields of winter ice like those encountered in the gulf during the 1961 season. Thus the area of greatest winter-ice concentration was reached about February 28 (Figures 11 and 12) and thereafter steadily declined. New and young ice dominated the northern, western and central regions of the gulf during February and March and were a major constituent of the April icefields.

The development and growth of open-water areas in the first week of March indicated that ice-forming processes were giving way to factors conducive to the deterioration of the icefields. From this time onward, the formation of new ice within the ice pack occurred only where favorable microthermal conditions existed. The development of the open-water areas seemed to have an oceanographic basis that coincided with higher air temperatures. The slow reduction of the icefields in the southern and northeastern parts of the gulf may therefore be closely related to the low temperatures of the water in those areas.

The main areas of winter ice were the St. Lawrence estuary, Chaleur Bay and the southern parts of the gulf, where the heat loss was sufficient to develop this heavier ice type. Strong winds resulting in pressure-ridging aided in the growth of winter ice and the provision of a continuing supply of it from these sources. Both young and winter icefields, on entering Cabot Strait, were subjected to strong wind and wave action that made ice wreckage and pressure ridges a substantial part of the ice surface. The icefields, when subjected to compaction and consolidation in low freezing temperatures, formed heavy, massive concentrations. The Labrador ice entering the Strait of Belle Isle was also churned into extensive, heavily pressure-ridged icefields which,on consolidation, formed a massive barrier. For the topographic details of the winter icefields in the Gulf of St. Lawrence see Figures 7 to 16.

GULF ICE DRIFT

Wind direction, velocity and sustained wind mileage are important factors affecting the distribution of the Gulf of St. Lawrence icefields. Shuleykin's ratio of ice drift to wind speed (1:25, Armstrong, 1955) provides a practical estimate of the rate at which ice drifts with the wind. The rate of free-ice drift for the various parts of the gulf is given by sector in Table VI.

TABLE VI

Free-ice drift per day in miles, by quadrant, December 1961 to March 1962

Area	WEST (SW - W - NW) D.: J.: F.: M.				NORTH (NW - N - NE) D.: J.: F.: M.				EAST (NE - E - SE) D.: J.: F.: M.				SOUTH (SE - S - SW) D.: J.: F.: M.			
St. Lawrence estuary	10:	11:	6:	6	2:	2:	5:	5	3:	2:	5:	4	3:	4:	3:	2
North Shore	5:	11:	5:	3	9:	6:	9:	14	6:	2:	5:	5	2:	3:	1:	1
Strait of Belle Isle	10:	16:	12:	6	13:	3:	16:	20	3:	2:	1:	3	5:	9:	5:	1
Western gulf	8:	10:	7:	8	5:	3:	5:	7	2:	1:	1:	1	4:	5:	2:	1
Northumberland Strait	9:	8:	5:	5	3:	2:	6:	9	2:	1:	2:	3	5:	8:	2:	1
Central gulf	10:	22:	7:	8	14:	15:	16:	18	5:	2:	4:	6	5:	7:	3:	1
Eastern gulf	6:	12:	5:	2	6:	5:	6:	8	4:	2:	4:	4	5:	5:	3:	0
Cabot Strait	8:	13:	7:	6	7:	4:	8:	9	3:	1:	3:	3	5:	6:	3:	1
Mean free-ice drift	8:	13:	7:	6	7:	5:	9:	11	4:	2:	3:	4	4:	6:	3:	1

Westerly winds were particularly strong during January and provided a daily average free-ice drift of 13 miles. Although the rate of ice drift from the west declined after that month, the winds that caused it continued to be particularly strong in the Strait of Belle Isle. The maximum drift rate reached in January in the central area was 22 miles a day. Northerly winds, weaker in most parts of the gulf, provided a greater rate of free-ice drift in the Strait of Belle Isle and central-gulf areas than winds from the westerly quadrant. With the approach of spring, there was a general decline in the rate of ice drift for most winds in all except these two areas.

The mileage of effective ice drift is found by deducting the ice-drift mileage caused by winds from the opposing quadrant. The extensive ice cover that developed in the southern gulf was mainly the result of powerful westerly and northerly winds in the central and southern regions that were opposed by relatively weak winds. In the central gulf during January, westerly winds driving the ice east at 22 miles a day were opposed by 2-mile-a-day easterly winds; and northerly winds driving the ice southward at 15 miles a day were opposed by south winds driving the ice northward at a rate of 7 miles a day. The combined effect was that the icefields were driven into the southeastern areas. The sustained strength of N quadrant winds is shown by the fact that the effective daily southward drift of the ice in the central region was 13 miles in February and 17 miles in March; the effective rate of eastward ice drift was 3 and 7 miles a day for February and March respectively. A major factor in the long duration of the southern-gulf icefields was the strength, particularly in the eastern-gulf region, of the northerly winds, which impeded the flow of ice out of the gulf.

The mean daily effective drive of westerly and southerly component winds in the Strait of Belle Isle for January was 14 and 6 miles respectively. Since the effective drift was to the northeast, the strait was ice-free in mid-January and free from Labrador ice at the end of the month (Figures 9 and 10). The effective drift in February was 11 miles a day from the north and 11 miles from the west. The ice drift thus tended to be toward the southeast, but small quantities of locally formed 'shore' ice entered the gulf at irregular intervals. The main invasion of the northeast arm of the gulf by Labrador ice began about February 19 and increased rapidly thereafter. In March the effective ice drift was 3 miles a day from the west and 19 miles a day from the north. Because of the southwest-northeast trend of the Strait of Belle Isle in relation to the prevailing southward drift of the ice, the icefields were funnelled into the gulf. In addition, the main mass of the Labrador ice shifted from the west to the east coast of the northeast arm of the gulf.

In Cabot Strait the effective daily rate of ice drift for February was 4 miles eastward and 5 southward; for March it was 3 miles eastward and 8 southward. The effect was heavy ice congestion off Cape Breton Island's east coast.

The effect the prevailing winds had during March and April is vividly illustrated in the ice charts for those months. The dominance of the N, NE and NW winds was a major cause of the heavy ice congestion that occurred in March off the west coast of Cape Breton Island. In the southern gulf these winds held the icefields together in a compact mass. In April they were much weaker, but a powerfully developed SW wind in the southeastern gulf was an important factor in shifting the icefields from the southern area into Cabot Strait.

The general direction of ice drift as observed during the winter of 1962 is shown in Figure 4. An examination of these movements shows that the direction of drift was more variable in some places than in others. The greatest variability appeared in the pronounced oscillation of the outflow of ice from Chaleur Bay, Jacques Cartier Passage and Cabot Strait. Along leeward coasts, the icefields tended to keep offshore and follow a mainly southerly course. The general direction of ice movements along windward coasts was toward Cabot Strait. The movement of ice drift toward Cabot Strait reached its greatest development in February, the month that coincided with the maximum of ice formation. With the icefields in the central and eastern gulf reduced but with ice supplies available from such smaller reservoirs as Chaleur Bay, the St. Lawrence estuary and Jacques Cartier Passage, the trend toward the south again became pronounced. The icefields that evacuate the St. Lawrence estuary spread at the river mouth and then, continuing eastward, flatten against the Gaspé coast. In 1962 they carried heavier winter ice and, for the most part, swung to the southeast past Bonaventure Island or turned inward toward Chaleur Bay before bending toward the east. The rest of the icefields that occupied Gaspé Passage continued in a southeasterly direction and were marked at times by pronounced surges. The ice passing out of Chaleur Bay also exhibited this phenomenon but on a smaller scale.

In the southeastern parts of the gulf the icefields north of Prince Edward Island and those from Northumberland Strait converged northeastward toward Cabot Strait. The icefields from the north-central part of the gulf pushed southeastward past Brion Island, also toward Cabot Strait. Joining these two masses were icefields containing a large amount of young or new ice that originated on the leeward side of the Magdalen Islands. The position of this ice indicated that pressure on the icefields from north and south varied considerably; the variation undoubtedly accounted for the fact that the icefields pushed past Cape North in intermittent surges, the duration of which varied according to the direction of the prevailing wind.

The icefields moving from the Strait of Belle Isle into the northeast arm generally followed a course parallel to the Newfoundland coast. In the Strait of Belle Isle, the general movement of Labrador ice was inward from the northeast entrance and outward from the southeast entrance.

The expansion and growth of the icefields during 1962 is shown by the advance of the ice fronts (Figure 5). By December 28 the ice front had reached the mouth of the Saguenay River and by January 17 the mouth of the St. Lawrence estuary. In the western gulf the ice front that extended from the entrance of

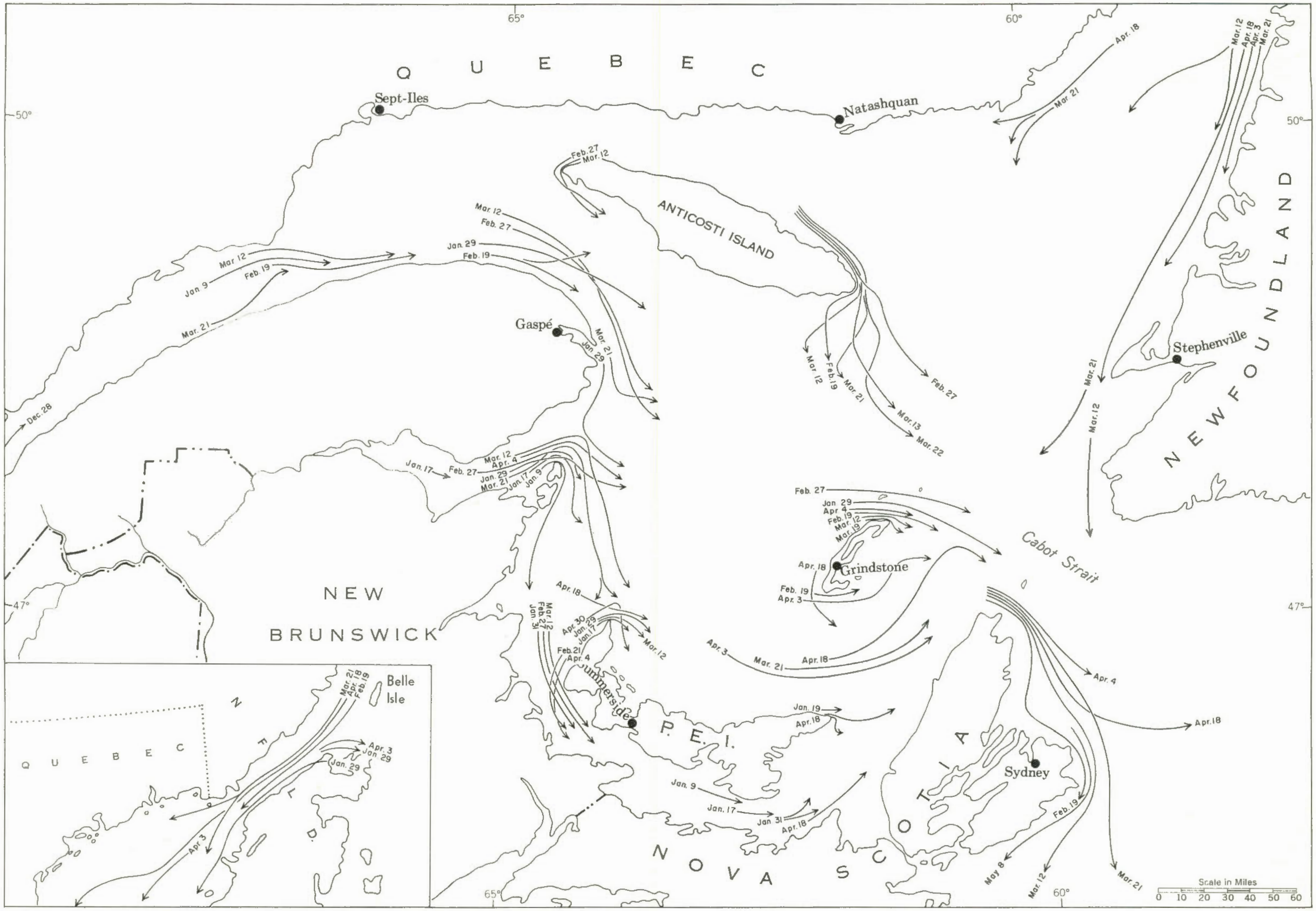

FIGURE 4. Ice movements, Gulf of St. Lawrence, winter 1962.

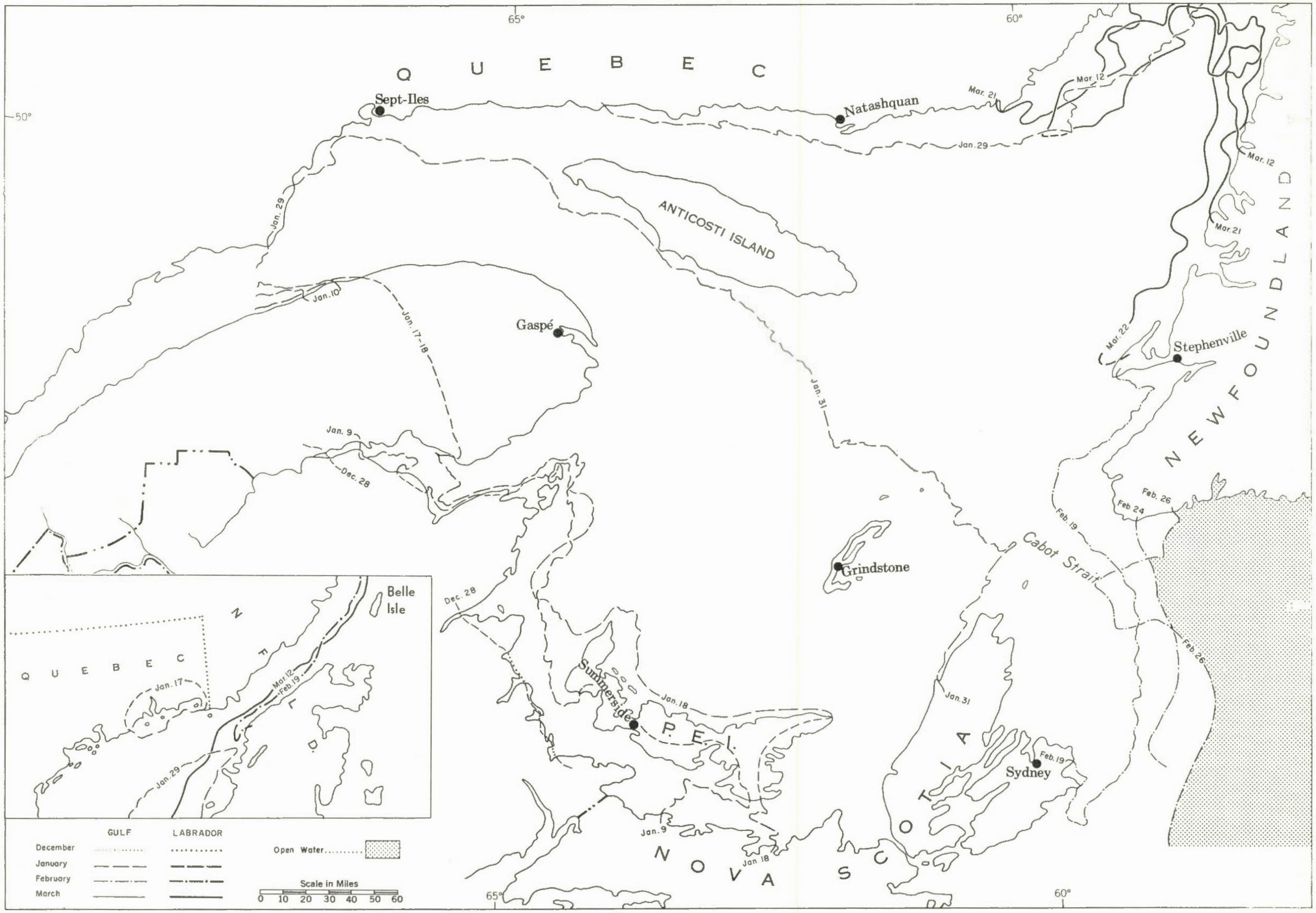

FIGURE 5. Advance of the ice fronts in the Gulf of St. Lawrence, winter 1962.

Chaleur Bay into the eastern half of Northumberland Strait on January 9 advanced eastward at an average rate of 4 miles a day and by January 18 extended beyond Pictou Island. Then it made its most spectacular advance and in the following 13 days almost reached St. Paul Island. In its eastward movement from Miscou Island, at the mouth of Chaleur Bay, the ice front averaged 14.4 miles a day. The expansion of the gulf icefields at this time resulted from low temperatures and strong westerly winds associated with an invasion of cold, continental Arctic air. After January 29 the ice fronts advanced south from the North Shore and east from the Magdalen Islands, and on February 7 they reached Cabot Strait and closed in the eastern half of the gulf. The icefields, pushing into the strait from the north and west, reached their greatest eastward extent about February 26.

Labrador ice, which was entering the Strait of Belle Isle on February 19, advanced rapidly into the gulf during March. The main tongue pushed southward along the west coast of Newfoundland and, by the end of March, it had spread to the middle of the northeast arm. About March 22 it reached Red Island, opposite Stephenville. Although at this date the Labrador ice had advanced to its maximum, strings and patches of it were easily recognizable within the gulf ice farther south. Four small icebergs, in fact, after drifting south from the strait, grounded about the end of the month on Cape Anguille. The maximum advance of the main body of the Labrador ice pack occurred on April 4, after it had extended from the northeast arm into the main gulf area.

The retreat of the gulf ice is shown in Figure 6. Extensive icefields covered the gulf from February 19 to March 1. The first breach developed in early March; between March 6 and 8, three areas of open water developed independently. The first was south of Anticosti Island, the second north of Anticosti and the third off the coast of Newfoundland. These three open-water areas were separated by an ice barrier that extended from the Strait of Belle Isle to the Magdalen Islands and from the latter into Cabot Strait.

The ice barrier was breached and the three open-water areas were merged about March 23, 18 days earlier than in the 1961 season. Between March 12 and 21 the St. Lawrence estuary became ice-free. With the enlargement of the open-water area off the west coast of Newfoundland after March 8, the open water was expected to extend westward and merge with the open-water areas that existed to the north and south of Anticosti Island. The icefields, however, advanced eastward to the Newfoundland coast. Thus, on March 12 the open-water area between Anticosti Island and the North Shore extended eastward in a broad arc toward the Bay of Islands, and an ice barrier separated it from Cabot Strait. This barrier was breached about March 21. Two major areas of ice, one in the northeastern part of the gulf and the second in the

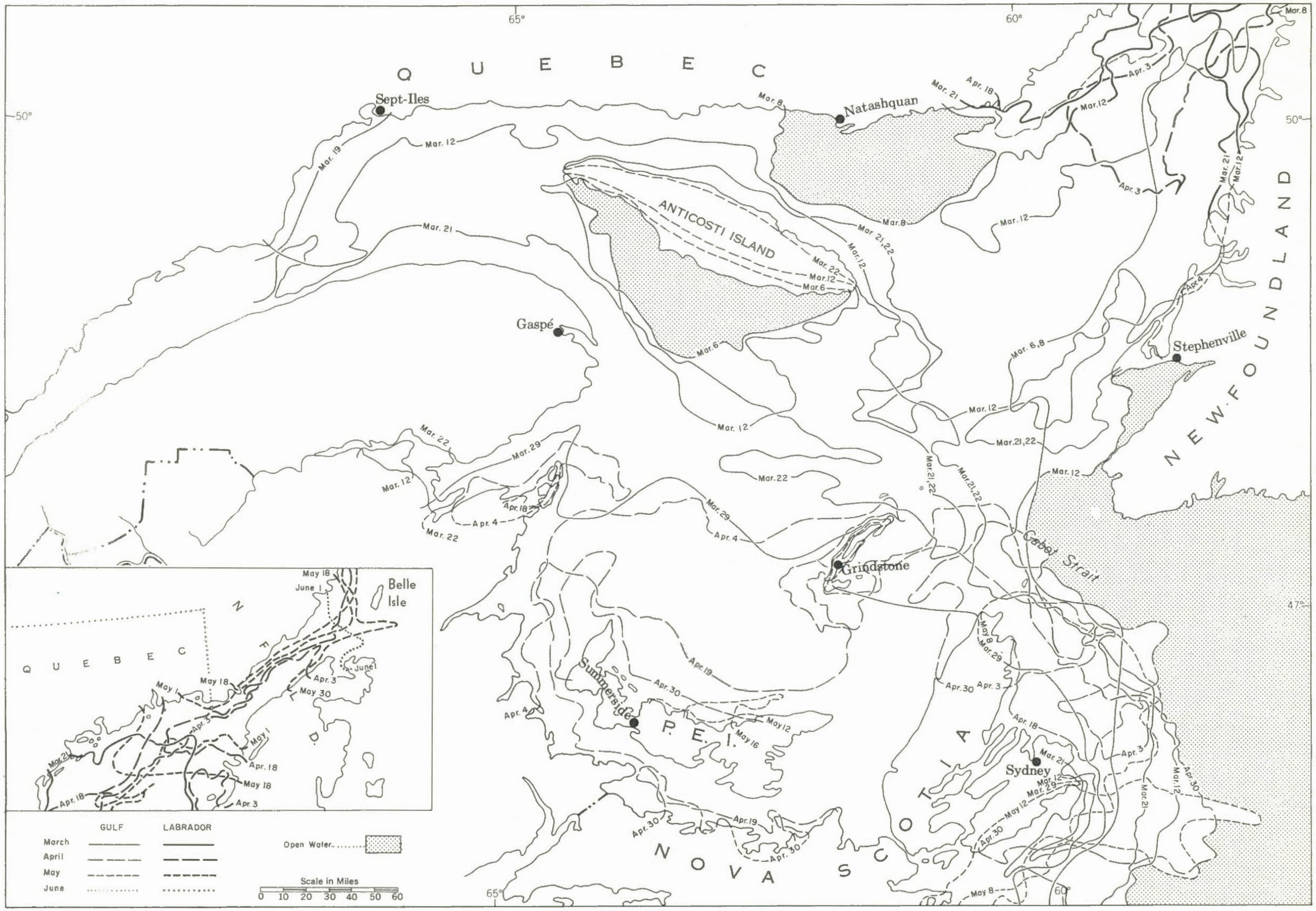

FIGURE 6. Retreat of the ice fronts in the Gulf of St. Lawrence, spring 1962.

southern, continued to diminish slowly.

In the western gulf, from March 22* to April 19, the icefields retreated southward at 8.5 miles a day. The icefields, responding to Coriolis force, moved eastward between the Magdalen Islands and Prince Edward Island to discharge into Cabot Strait at a reduced rate of between 1.5 and 2.0 miles a day. By April 30, leaving only small areas of ice off the north coast of Prince Edward Island and in Northumberland Strait, the main ice pack had pushed out of the southern gulf region into Cabot Strait. The ice barrier established off Sydney about February 10 continued almost unbroken until May 8; but its front was in a continuous state of readjustment. After this date the icefields drifted to the south and southwest of Scatari Island and about May 16, together with remnants of the ice pack in the southern gulf, finally disappeared.

The retreat of the Labrador ice in the northeastern arm of the gulf began after April 3 and, averaging about 2 miles a day, was remarkably steady until May 1. Thereafter, because of new supplies of ice, it became erratic. On June 1 the ice front lay at the eastern entrance to the strait. Labrador ice, however, continued its invasions, and on June 9 heavy concentrations were again pouring into the northeast arm of the gulf. It was not until June 27 that the strait, with the exception of small bergs and growlers, became free of the Labrador ice pack.

GULF ICE-DISTRIBUTION MAPS

The principal features of ice distribution that have been discussed and were observed in the course of the 1961-62 ice reconnaissance survey are shown graphically in Figures 7 to 16. These maps cover a period of changing ice conditions from December 28, 1961, to April 19, 1962. For the period from the end of April to mid-May, when the icefields were deteriorating rapidly, Figures 17 to 19, produced by the Meteorological Branch, Department of Transport, are included.

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*The new ice surface that covered open-water areas in the central and northwestern parts of the gulf on March 22 (Figure 14) resulted from a recent cold spell.

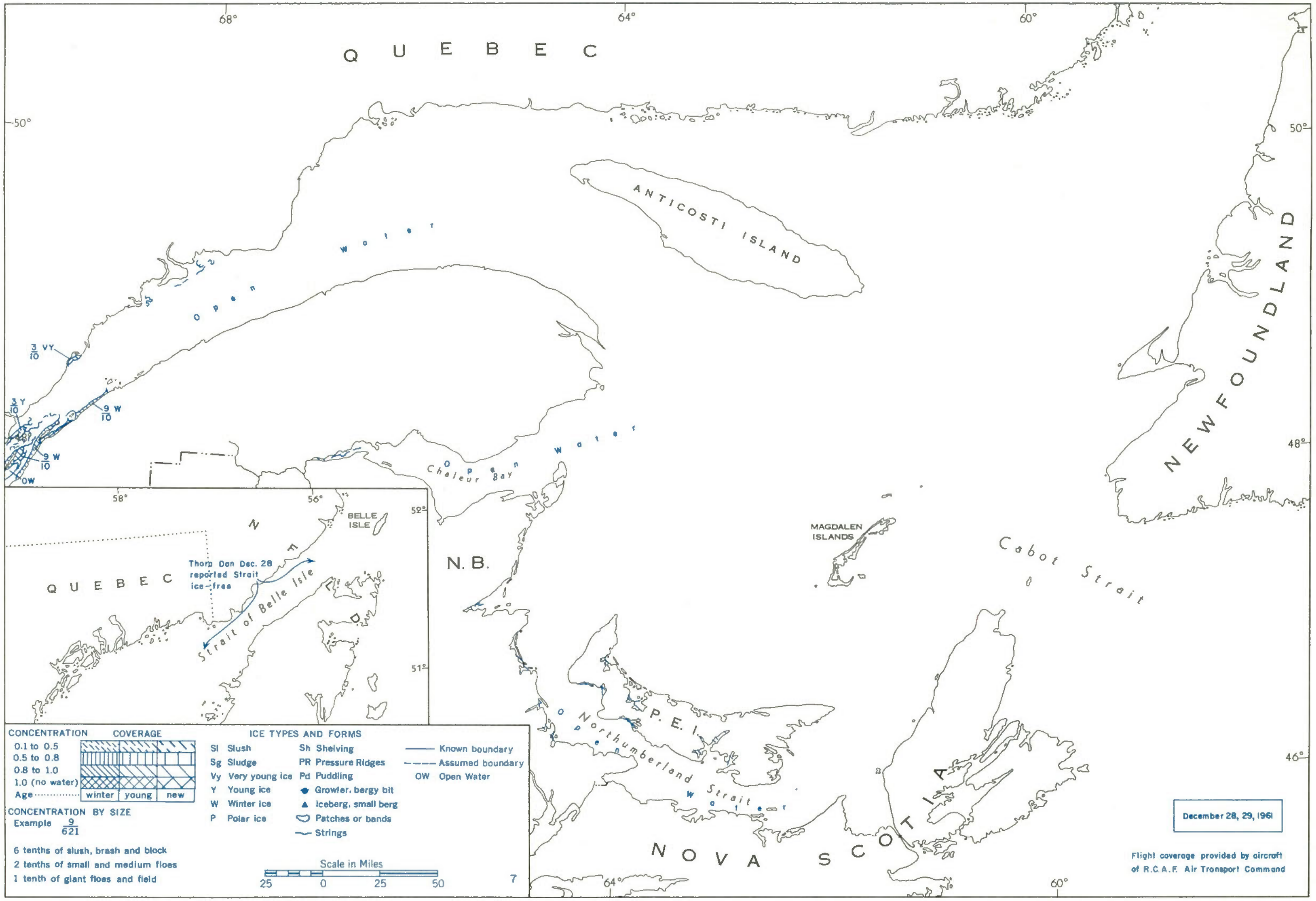

FIGURE 7. Ice distribution, Gulf of St. Lawrence, December 28 and 29, 1961.

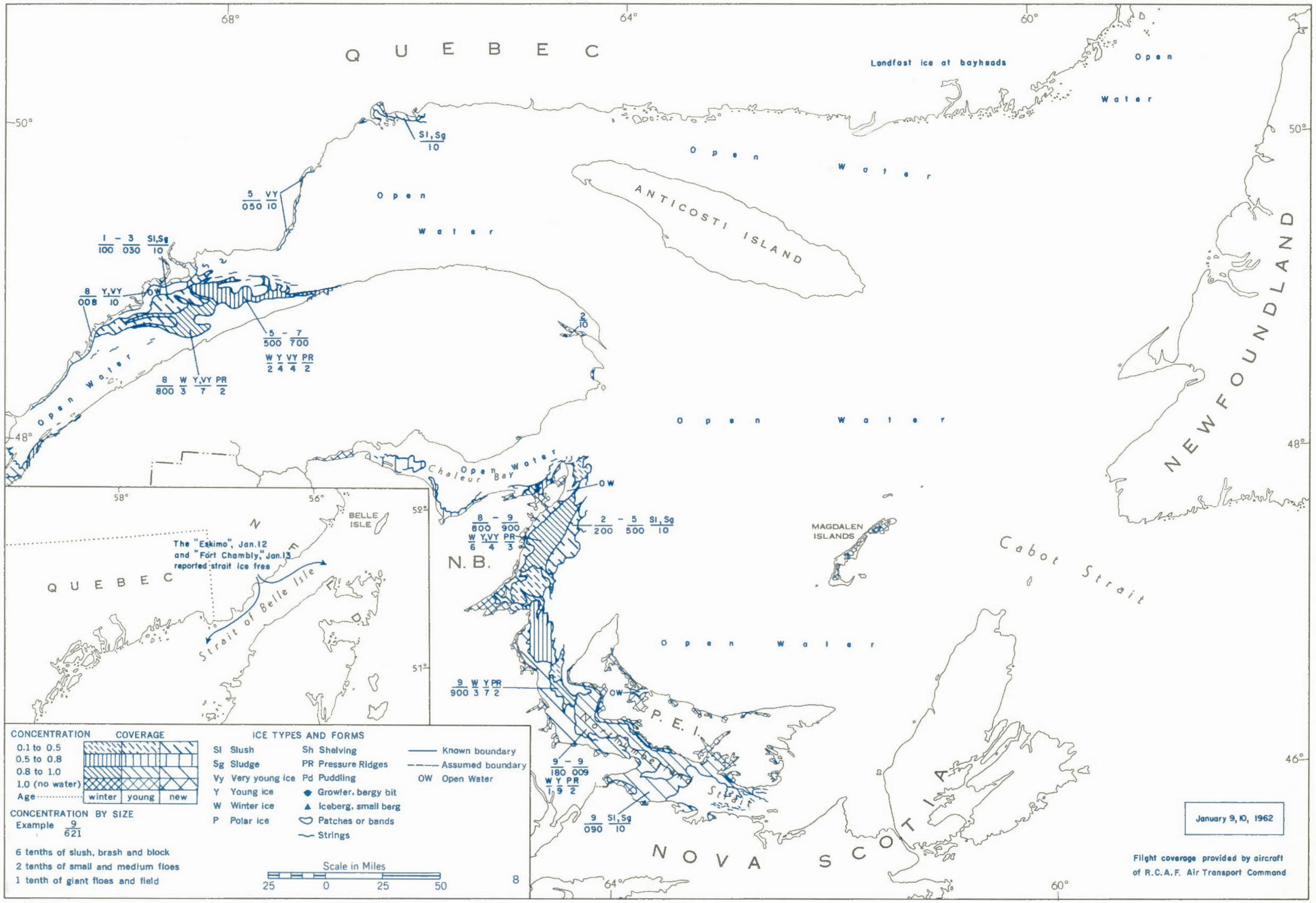

FIGURE 8. Ice distribution, Gulf of St. Lawrence, January 9 and 10, 1962.

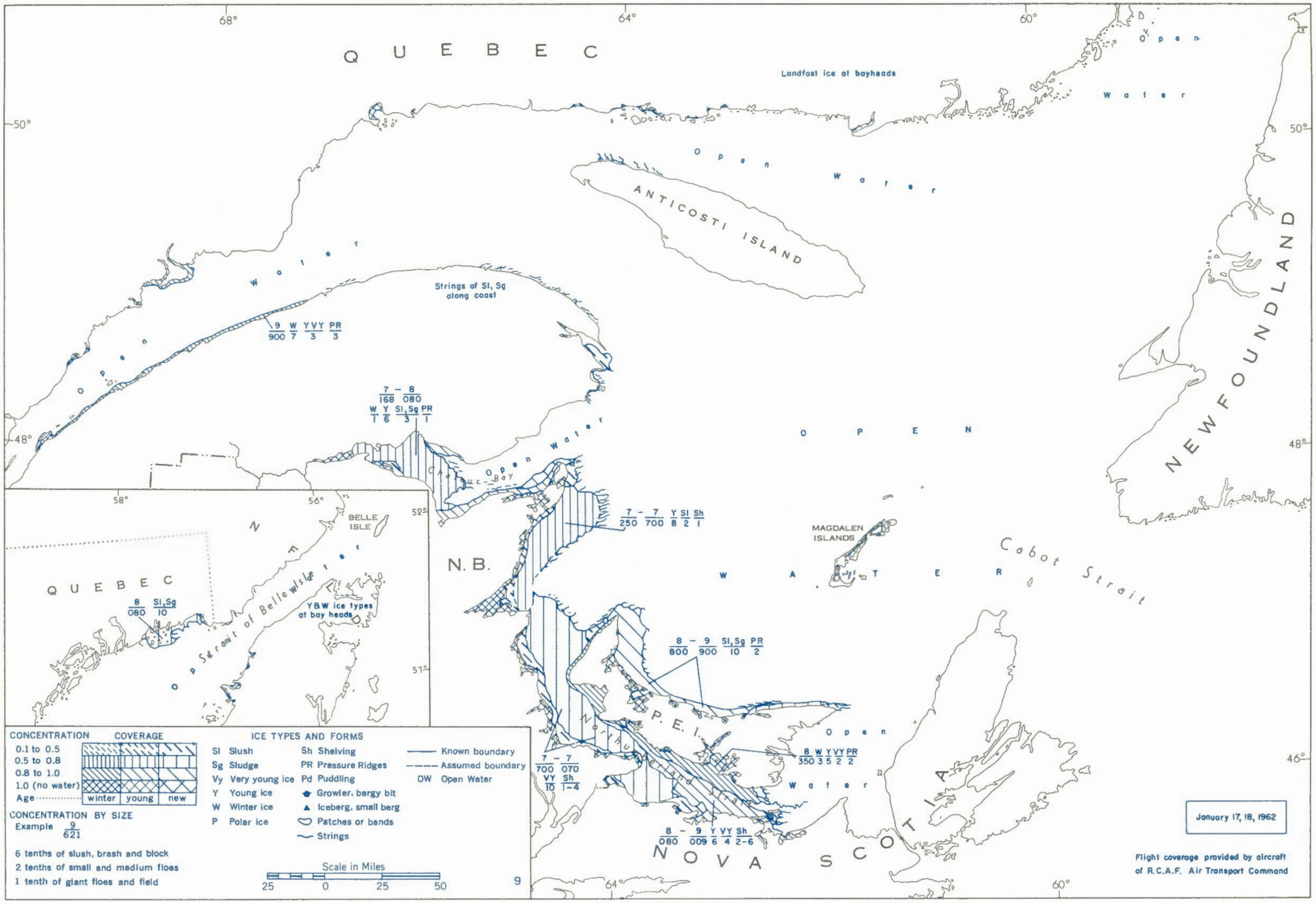

FIGURE 9. Ice distribution, Gulf of St. Lawrence, January 17 and 18, 1962.

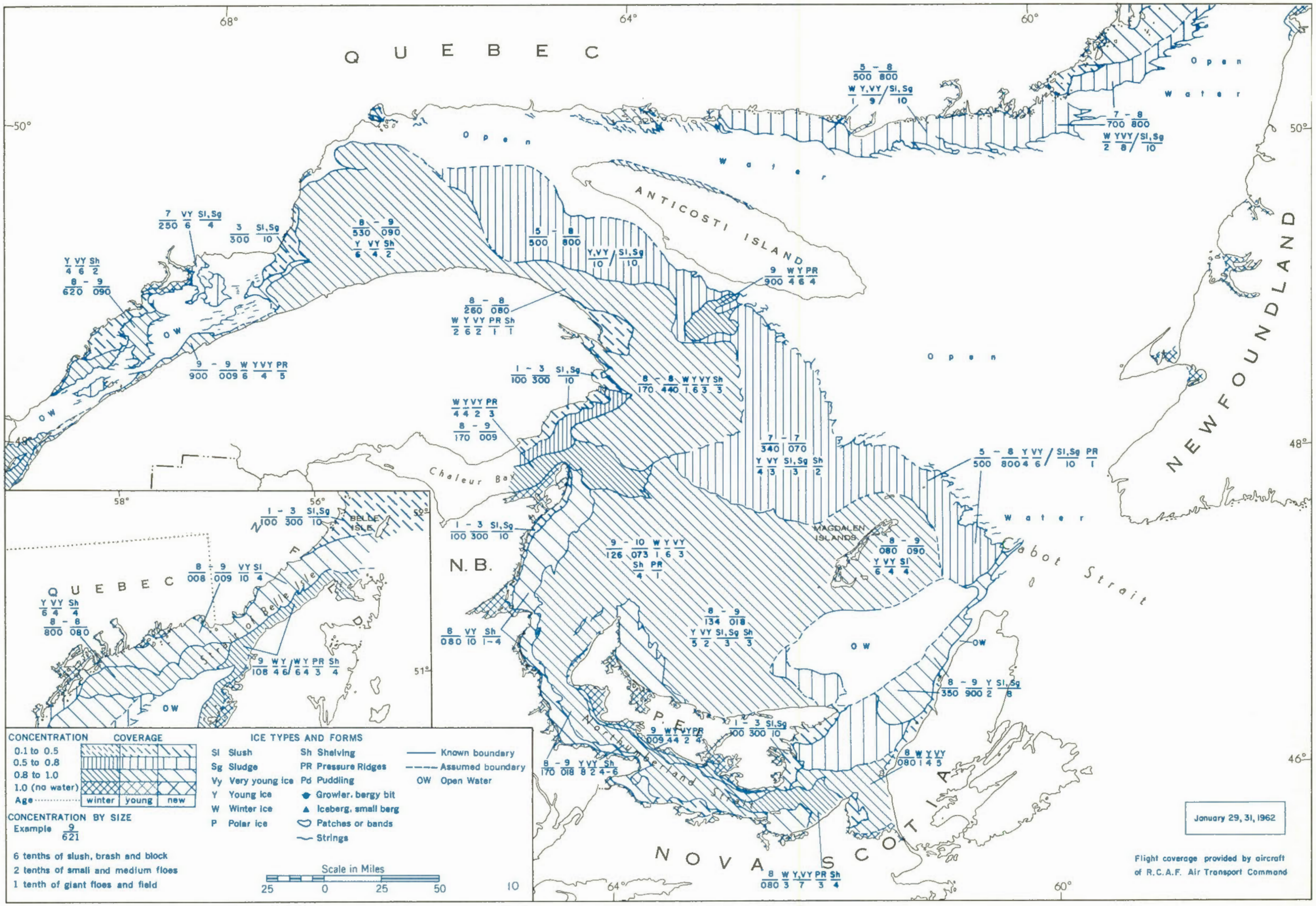

FIGURE 10. Ice distribution, Gulf of St. Lawrence, January 29 and 31, 1962.

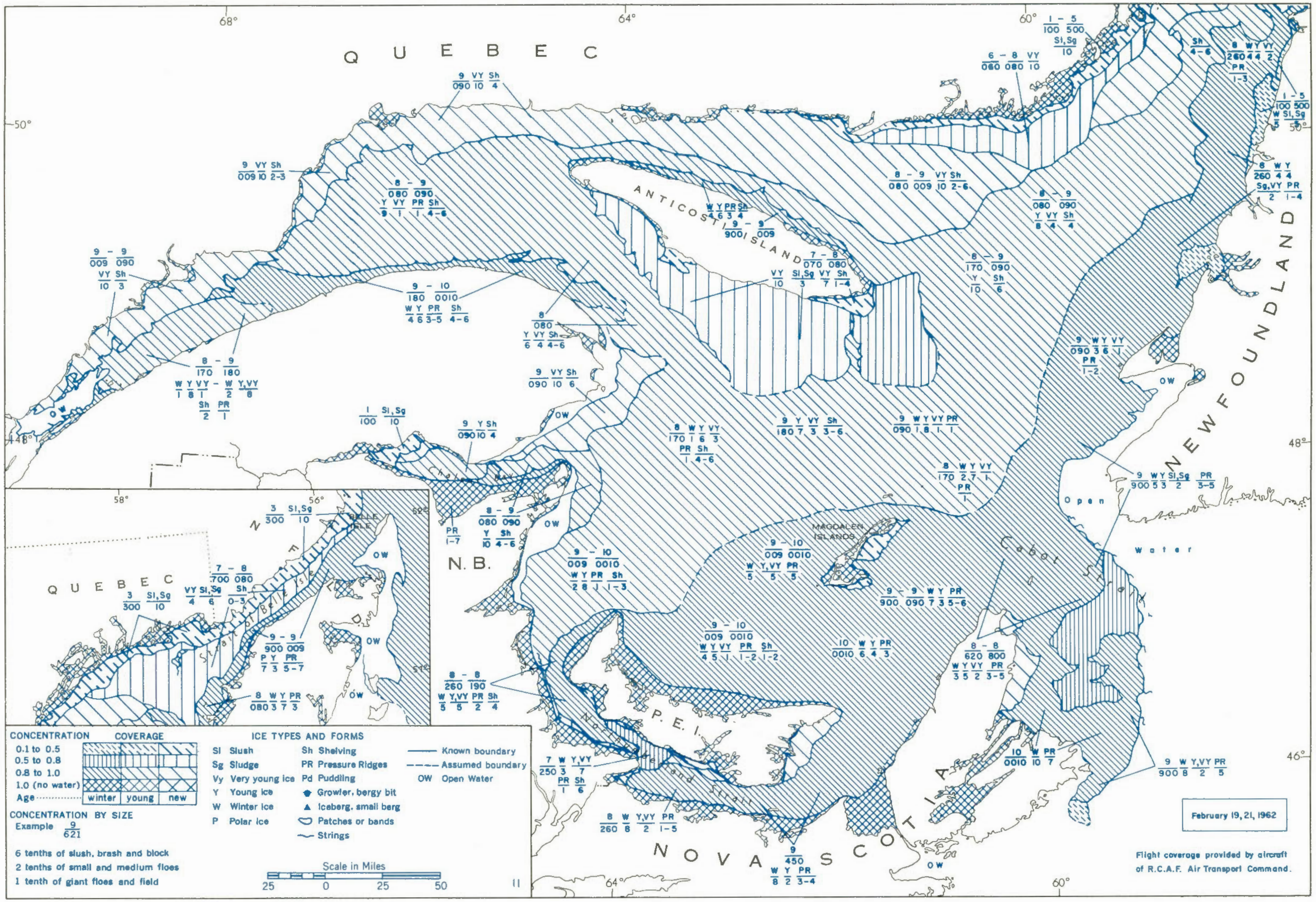

FIGURE 11. Ice distribution, Gulf of St. Lawrence, February 19 and 21, 1962.

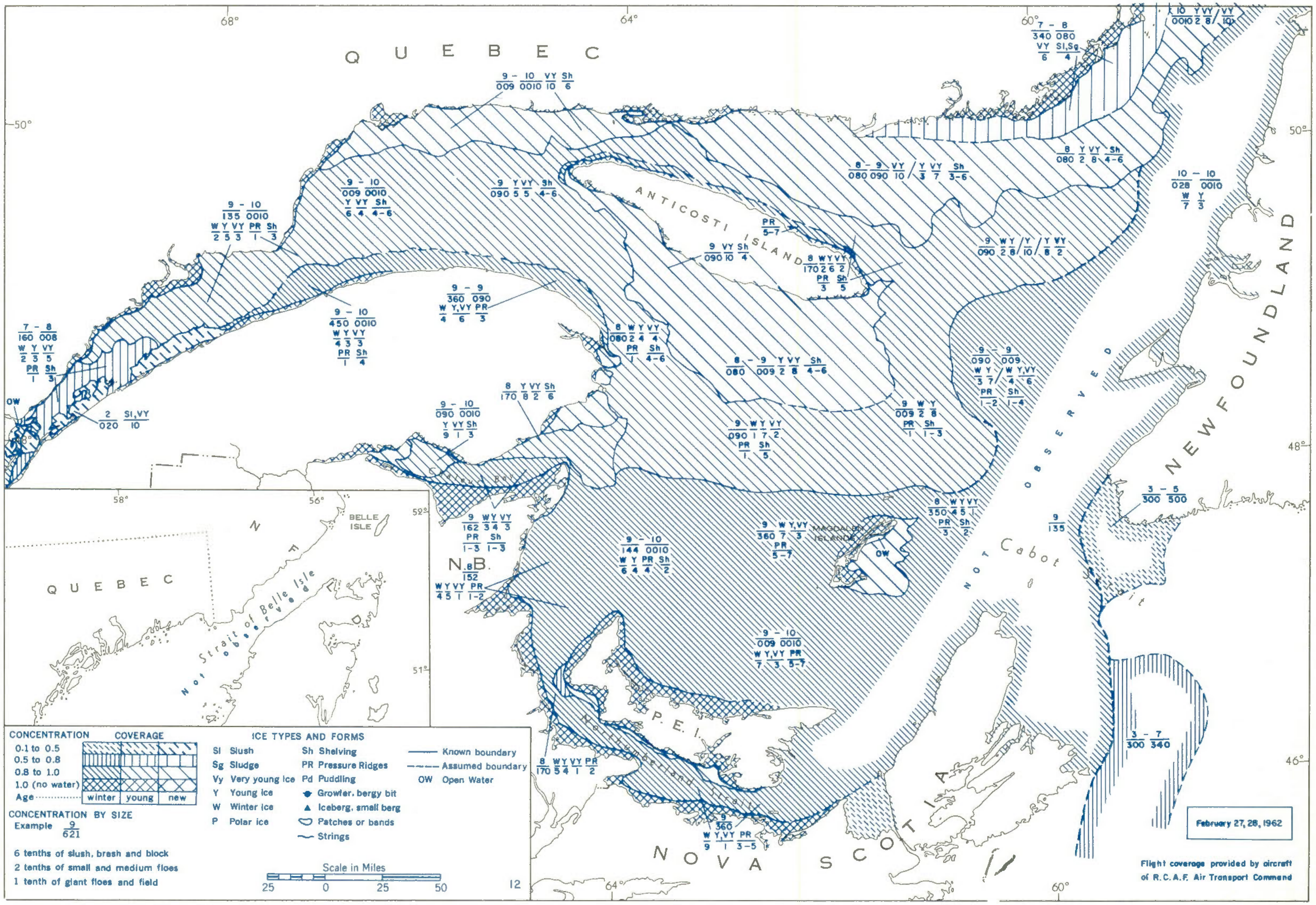

FIGURE 12. Ice distribution, Gulf of St. Lawrence, February 27 and 28, 1962.

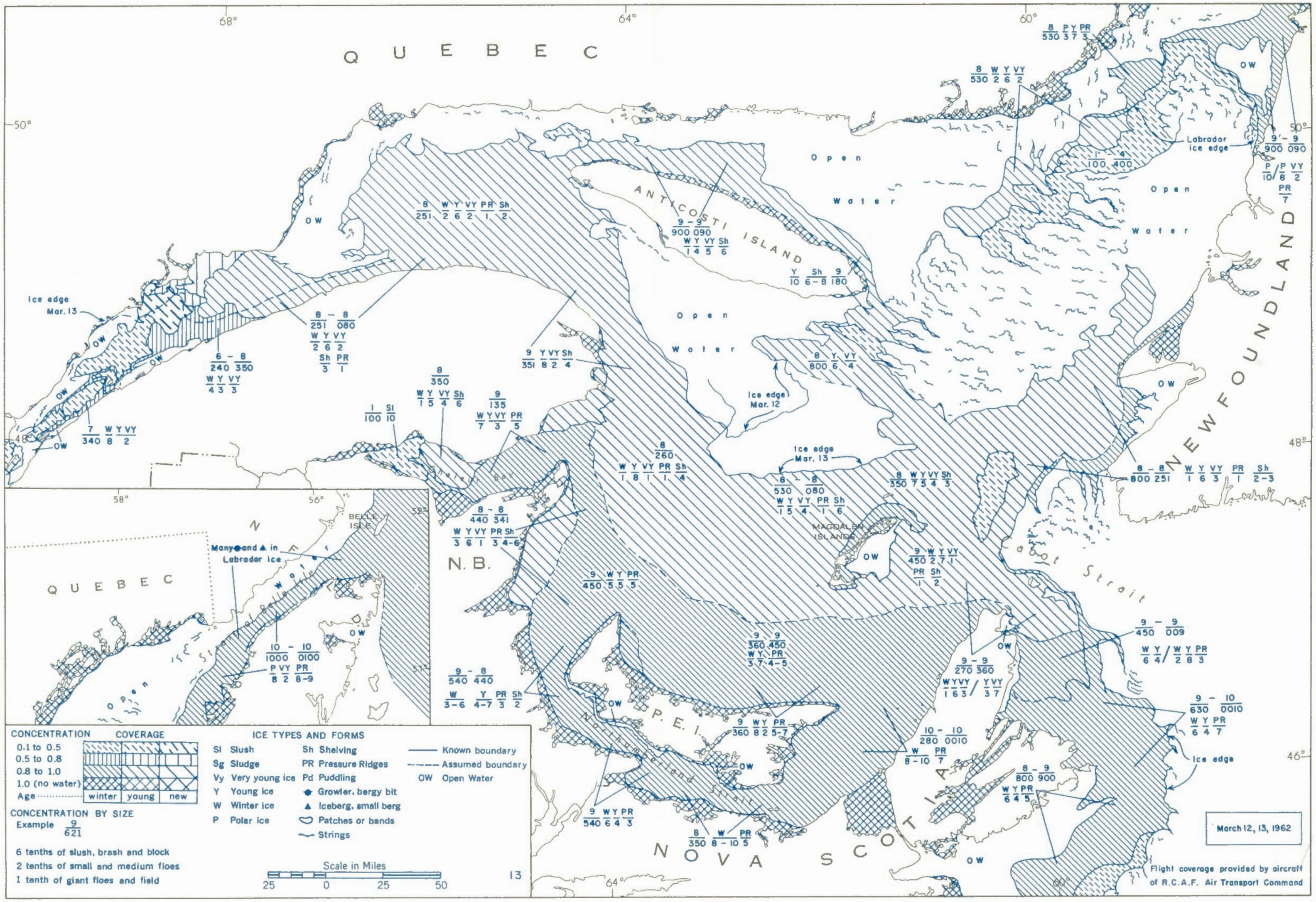

FIGURE 13. Ice distribution, Gulf of St. Lawrence, March 12 and 13, 1962.

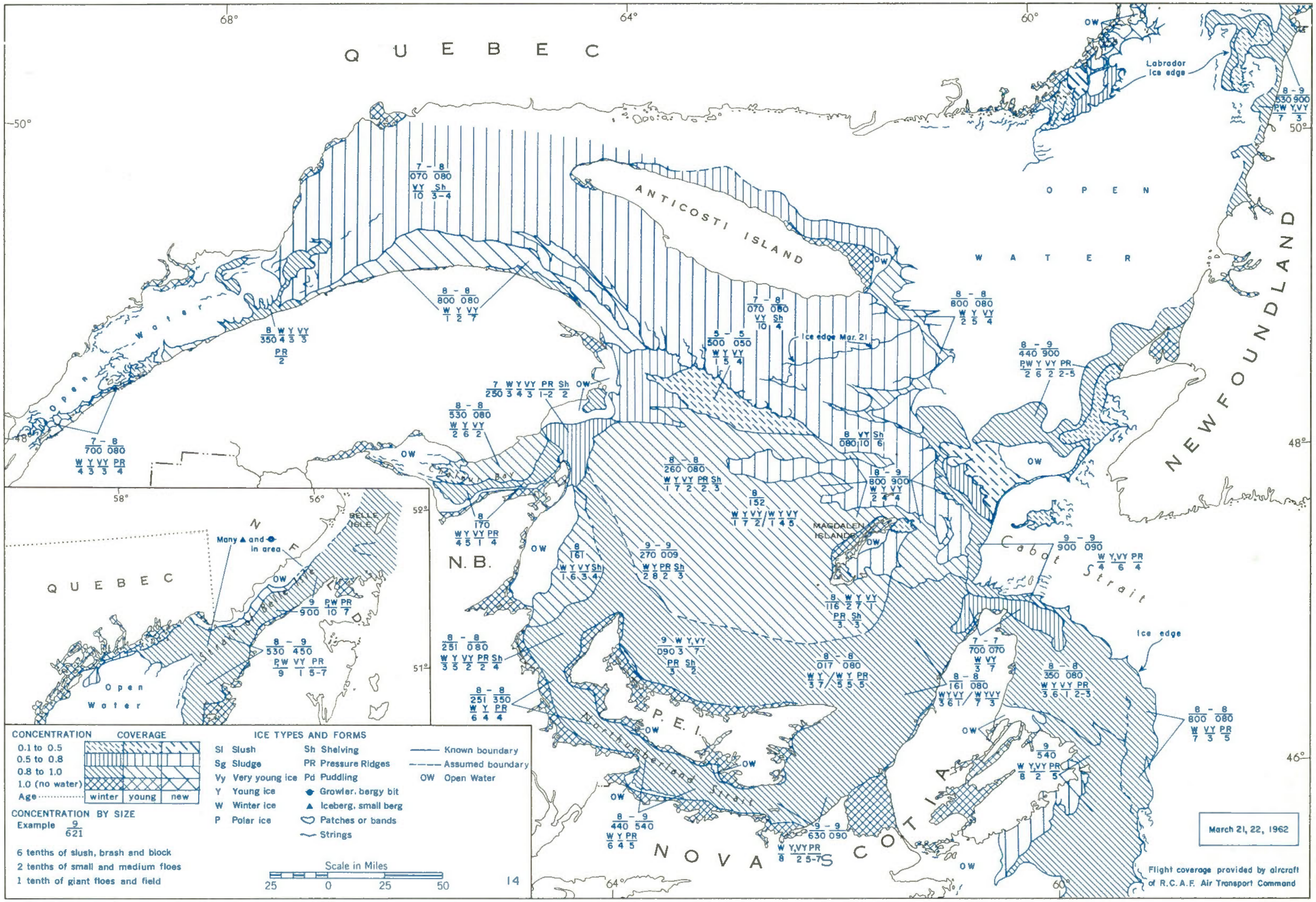

FIGURE 14. Ice distribution, Gulf of St. Lawrence, March 21 and 22, 1962.

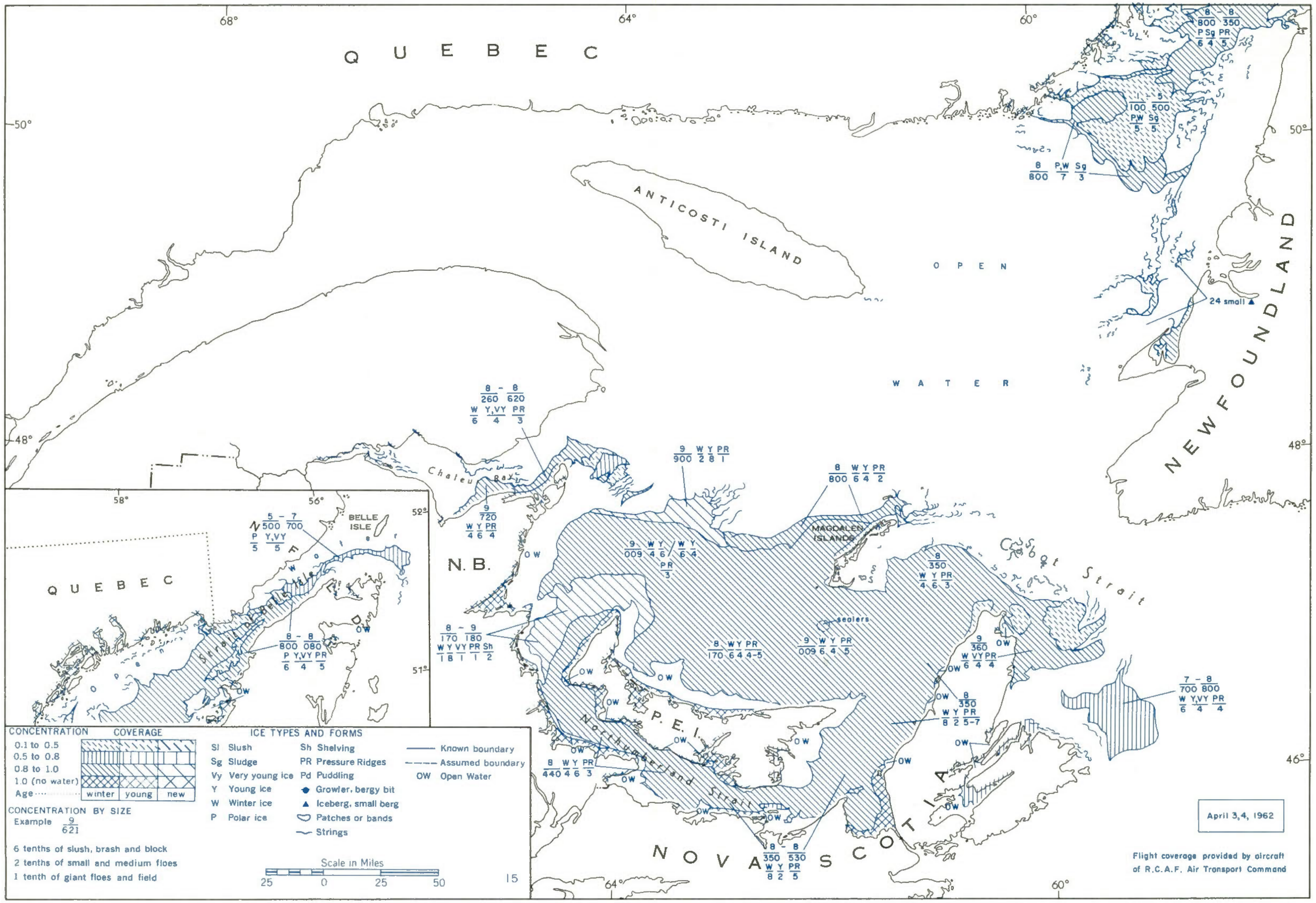

FIGURE 15. Ice distribution, Gulf of St. Lawrence, April 3 and 4, 1962.

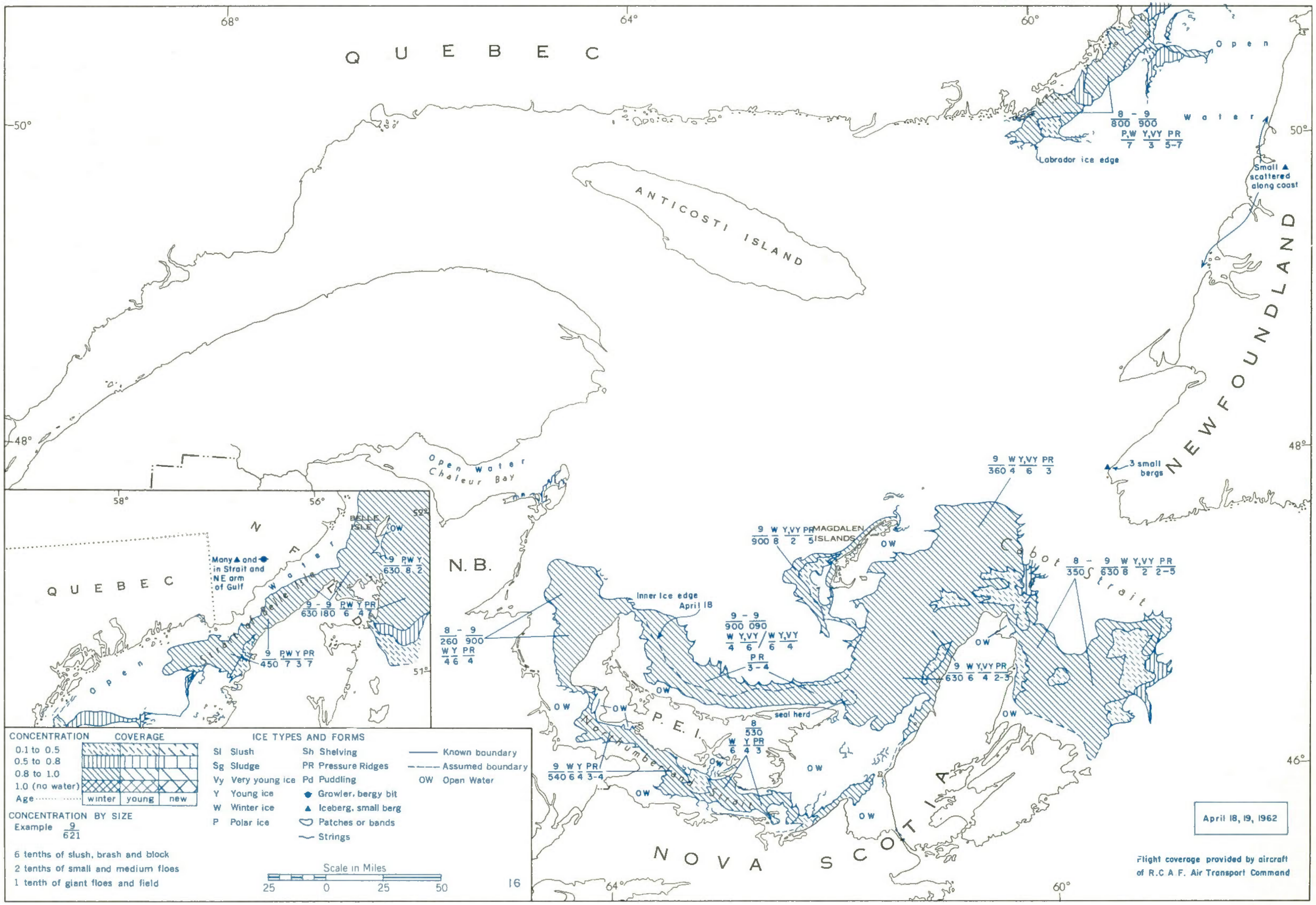

FIGURE 16. Ice distribution, Gulf of St. Lawrence, April 18 and 19, 1962.

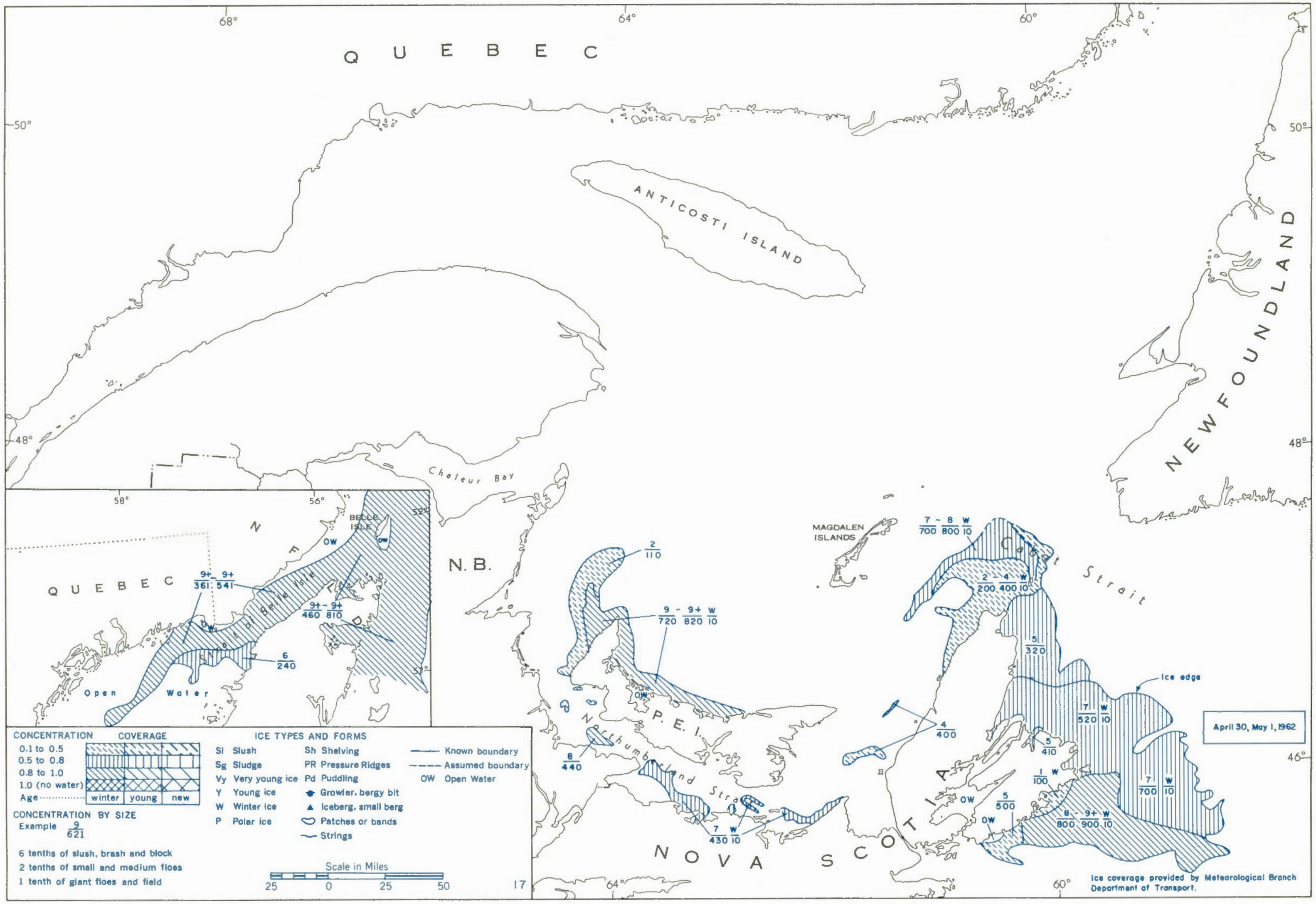

FIGURE 17. Ice distribution, Gulf of St. Lawrence, April 30 and May 1, 1962.

FIGURE 18. Ice distribution, Gulf of St. Lawrence, May 8, 1962.

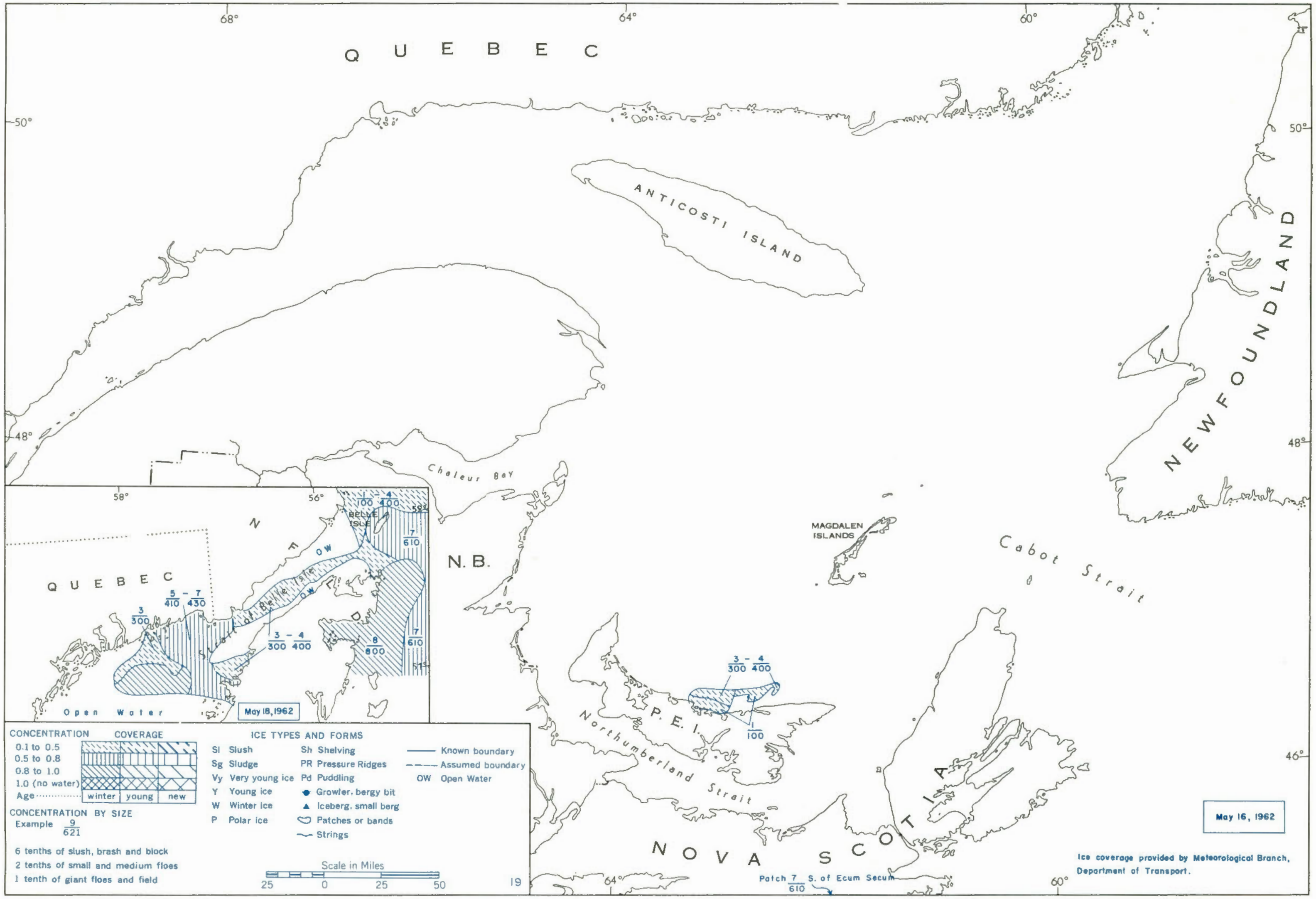

FIGURE 19. Ice distribution, Gulf of St. Lawrence, May 16, 1962.

PART II

THE ST. LAWRENCE RIVER

The middle St. Lawrence River for the purpose of this report extends from Lake St. Louis to the Island of Orleans; the upper estuary of the St. Lawrence River extends from the Island of Orleans to the Saguenay River. The ice charts (Figures 21 to 26) cover these two parts of the St. Lawrence River.

WEATHER CONDITIONS

November was mild in the St. Lawrence valley, with mean temperatures ranging from 34 to 37°F and reaching 3 degrees above normal; and December, with a mean temperature of 22°F, or 4 degrees above normal, seemed to herald a mild winter. In the latter half of December conditions favorable for ice formation and growth existed, and shorefast ice became established along each bank and around the islands and shoals of the river. January, at 8°F, and February, at 7°F, or 3 and 5 degrees below normal respectively, had severe winter weather that favored the extensive development of ice conditions. Valley temperatures ranged from 5 to 14 degrees. In March, which had a mean of 29°F, temperatures rose quickly and reached 5 degrees above normal. The shorefast ice began to break rapidly, and its removal was well advanced by the beginning of April.

The difference in temperature between the southwestern and northeastern stretches of the river was greatest during January and February, being 7 degrees. In general, temperatures were remarkably similar over much of the valley, the lowest temperatures, centred in the Lake St. Peter area, occurring in February.

TABLE VII

Mean temperature and related values (F°), middle St. Lawrence River, 1961-62

Category	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Mean temperature	36	22	8	7	29	40
Mean-temperature range	34 to 37	21 to 24	7 to 14	5 to 12	28 to 30	38 to 42
Departure from normal	3	4	-3	-5	5	1
Mean degree-days*	-4	7	21	22	3	-7
Excess of temperatures at Montreal over those at Quebec	0	3	7	7	2	4

*For the formation of ice in fresh water the mean monthly degree-day is based on 32°F.

Ice growth varied during the winter of 1961-62. There was a mean of 7 monthly degree-days of frost at the end of December; thereafter, the formation of ice was rapid, the mean of degree-days being 21 for January and 22 for February. The number of degree-days accumulated at the end of February was 50, or about the same as in the northern parts of the gulf, the result being equal ice-forming activity. The number of degree-days for March indicates that ice-forming activity was more vigorous in the middle of the St. Lawrence River than elsewhere in the gulf region. The rate of melting in April, as expressed by the monthly mean of degree-days, was equal to that taking place in the southern and western parts of the gulf.

RIVER ICE DISTRIBUTION

The St. Lawrence River was ice-free prior to mid-December. By the end of December, the main outline of shorefast ice was established and bordered the islands and both shores of the river; in the upper estuary the rapid cooling of the shallow water gave rise to drifting ice, which advanced downstream to the vicinity of the Saguenay River (Figure 20A) and went on into the gulf.

Throughout January the open water at the mouth of the Saguenay varied greatly in area. Above the mouth, the icefields consisted mainly of unconsolidated floes, with the result that the ice edge was in continuous motion. Below, masses of drifting ice were still passing into the gulf, but not until February was there a continuous and sustained ice cover in the lower estuary. With the prolongation of low temperatures and the rapid expansion of the ice cover, the open-water area continued to shrink until the end of the month. At this time the polynya lay at the mouth of the Saguenay, but formations of light ice, consisting of new and young ice types, bordered the open-water zone.

These severe conditions seem to have continued for a few days in early March; thereafter, the retreat of the icefields was rapid (Figure 20B). The most spectacular reduction occurred on March 12 and 13. Then the icefields again expanded rapidly and were maintained until March 19. The final retreat began about March 20 and continued both upstream and downstream from the mouth of the Saguenay. By the end of March the lower estuary was ice-free, but in the upper estuary streams of river ice continued to discharge through Orleans Channel, east of Quebec City, before disappearing about April 10.

In the upper St. Lawrence estuary shorefast ice bordered almost the entire south coast but only the small protected bays of the north coast (Figures 21 to 26). In the lower estuary shorefast ice was more extensive on the north coast than on the south coast. Ice types and concentration varied considerably in the estuary during the winter months.

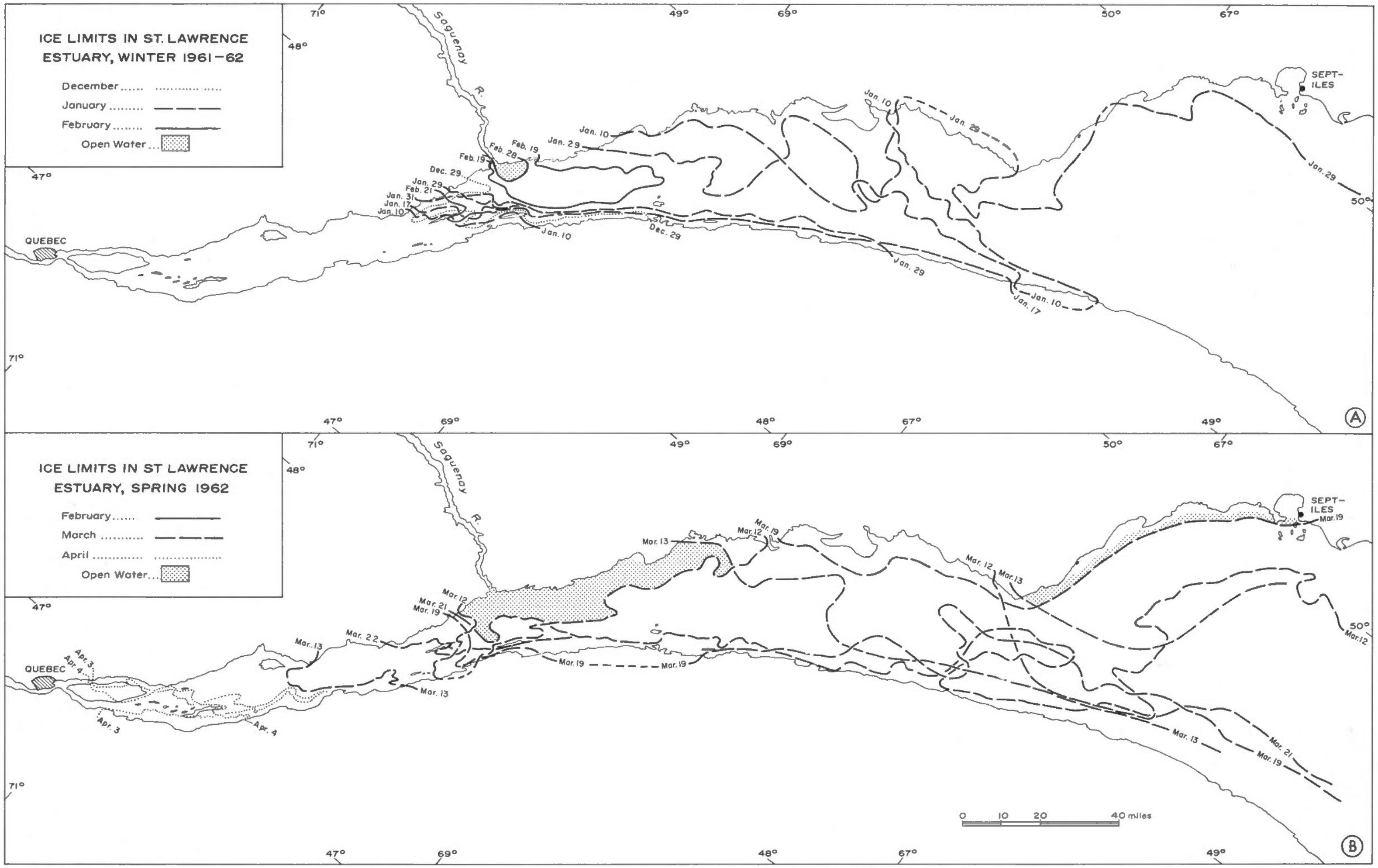

FIGURE 20 (A and B). Movement of the ice fronts, St. Lawrence estuary.

In the middle St. Lawrence River the main outline of shorefast ice was established by the end of December. In the river reach above Sorel, however, its development was not completed until the middle of January, while in the Montreal harbor area it was delayed until the end of that month. The line of piers supporting the new Champlain Bridge, which crosses the basin from Nuns Island, caused the shorefast ice to extend across the basin and back up to the foot of the Lachine Rapids. Open water was now localized largely in the area below the bridge. The main ice bridge above Sorel was established by mid-January and continued into early February until broken by the passage of the icebreaker. After this event the congestion of the river channel became relatively light in the reaches above and below Lake St. Peter. Ice congestion in the lake itself occurred at the end of January and continued until mid-March, when the effectiveness of the ice-forming processes was much reduced. Toward the end of March the channel through the lake widened rapidly.

The ice that formed in the river between the bordering shorefast ice generally consisted of a stream of heavy winter ice that was paralleled on one side by new ice and on the other by open water and swung at the bends from one side of the river to the other. This pattern and alternation continued until the ice discharged past the Island of Orleans into the estuary. The drifting winter ice was usually negligible in the upper part of the river, but at Quebec it constituted a large part of the total cover. The channel edge of the shorefast ice coincides closely with the 5-fathom line and, as the bordering ice is always heavily pressure-ridged and massive, this edge may well be anchored to the river bed. The winter ice consists for the most part of ice snapped from the edge of the shorefast ice, which extends beyond the anchored zone and is readily affected by tides and currents or by the wake of a passing ship.

The amount of winter ice in the distribution is usually greatest at the time of break-up, particularly in the reach below Lake St. Peter, where extensive areas of shorefast ice bordered the channel; above Lake St. Peter the amount of winter ice was negligible. The shorefast ice began to break up about mid-March and, discharging through the Orleans Channel, continued to do so until April 10; by April 18 the break-up was virtually complete.

RIVER ICE-DISTRIBUTION MAPS

The various features of the distribution of the St. Lawrence River ice that have been discussed and were observed in the course of the 1961-62 ice reconnaissance survey are snown in Figures 21 to 26. These maps cover the period from December 29, 1961, to April 19, 1962. As the survey covered the area between Cornwall and Montreal, five insets were selected that are representative of ice conditions in this part of the river at the time of freeze-up and break-up. These insets are shown in Figure 26. The graphic and fractional method of showing ice types and ice concentrations is that used in the distribution maps for the gulf, but the flow size has been reduced to a scale in keeping with the natural restrictions imposed by the St. Lawrence River.

PART III

WINTER NAVIGATION

The winter of 1961-62 was the second successive ice season of utmost severity for shipping. In its early stages it seemed to herald a light ice season. Thus on January 14, 1962, the commercial vessel, the M/V Fort Chambly, was routed through the Strait of Belle Isle. Rapidly decreasing temperatures, however, closed the strait to shipping.

On December 1, 1961, the Marine Operations Branch, Department of Transport, later renamed the Canadian Coast Guard Service, established an Ice Information Office at Sydney, N.S. In early January the main icebreaker fleet, including the Coast Guard ships John A. MacDonald and Labrador, assisted by the smaller vessels Sir Humphrey Gilbert and Sir William Alexander, began to assemble at Sydney. The C.C.G.S. d'Iberville operated in the northern sector of the gulf. In the early stages of routing shipping through the icefields, three of the icebreakers operated in the vicinity of Port Cartier and Seven Islands, Que., Dalhousie, N.B., and Corner Brook, Nfld., thereby protecting individual ports and covering the gulf in a north-east-west pattern. In February, as ice conditions worsened, the convoy system was inaugurated, the ships assembling at Cape Ray, Nfld. Vessels were supported individually from this rendezvous as icebreaker support became available. Commercial vessels, on approaching Cabot Strait, were informed by the Ice Information Officer what route to take through the gulf or whether icebreaker support would be needed. The main steamer track through the icefields ran from Cape Ray to Heath Point, Anticosti Island, thence along the south side of the island to West Point, at its other end, from there directly toward Seven Islands and thence coastwise to Baie Comeau. The route to Chaleur Bay ports departed from the main track near Southwest Point, Anticosti Island, proceeded to Chandler, Que., and then went coastwise to Dalhousie. On several occasions shipping was routed from Heath Point to Natashquan, Que., and coastwise to Seven Islands. Decca Navigation proved an invaluable aid. The Meteorological Branch provided aerial tactical support, and in gulf and east Newfoundland waters its three aircraft flew some 527 hours.

In the St. Lawrence estuary the C.C.G.S. Tupper, operating out of Rimouski, Que., throughout the winter, assisted local shipping. In the middle St. Lawrence River, three icebreakers, the C.C.G.S. ships N.B. McLean, Ernest Lapointe and Saurel, operating under the authority of the River St. Lawrence Ship Channel, were engaged in breaking or preventing ice jams on the river.

From December 15, 1961, to April 15, 1962, the closed-season period, 216 deep-sea vessels requested escort or routing from Sydney, and 271 called for and received icebreaker support. From April 16 to May 31, however, 255 vessels requested escort or routing while 75 called for and received icebreaker support. In addition, the icebreakers gave support on 34 occasions to sealing and fishing vessels. Vessels that failed to inform the Ice Information Office of their sailing plans ran into immediate trouble. Most of these ships were beset, some suffered heavy damage, and one was almost stranded before it was rescued through the combined efforts of the RCAF Air-Sea Rescue Service and the C.C.G.S. Labrador.

In the closed season, 203 ships entered gulf waters. Of these, 69 sailed to ports upstream from Baie Comeau, 16 of them during the period from January 1 to March 31. One shipping line sent its ships as far upriver as Three Rivers. On March 13 the M/V Helga Dan became the first overseas vessel to reach Montreal, and on April 18 the German freighter Transpacific became the first ship to enter the St. Lawrence Seaway. The cargoes moved to and from ice-restricted ports during the closed season totalled 2,316,583 tons of which 768,000 tons were ore exported through Port Cartier.

In view of the severity of ice conditions in the Gulf of St. Lawrence, the icebreaker fleet was eminently successful in the routing and convoying of shipping.

PART IV

ICE CONDITIONS AND GLOSSARY

This part comprises a summary and photographic record of ice conditions and a glossary of ice terms.

SUMMARY OF ICE CONDITIONS

The aerial ice-reconnaissance survey of 1961-62 showed that ice conditions in the St. Lawrence River tended to be normal and that those in the Gulf of St. Lawrence, although extensive, were not severe. The mean monthly temperatures were above normal for December and March, normal for January and considerably below normal for February (Table VIII).

The mean temperatures in the gulf region for the winter of 1961-62 ranged from 23 to 32°F for December, 7 to 23°F for January, 4 to 17°F for February and 28 to 33°F for March. In the various parts of the gulf during January and February, mean temperatures varied from 6 to 8°F for the St. Lawrence River, 4 to 11°F for the north, 11 to 20°F for the central and southern region and 17 to 23°F for the Cabot Strait area. Because of the abnormally low temperatures and the westerly-quadrant winds that prevailed in January and the northwesterly-quadrant winds that prevailed in February, the gulf developed an extensive ice cover. The lightest ice formations occurred off leeward coasts, the heaviest concentrations against windward coasts. The northerly-quadrant winds that prevailed in March tended to drive the icefields into the southern parts of the gulf or through Cabot Strait and along the Cape Breton coast.

TABLE VIII

A comparison of mean monthly temperatures (F°), 1957-62

Winter	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1957-58	35	27	24	23	30	38
1958-59	33	14	18	19	19	36
1959-60	34	24	20	26	24	33
1960-61	35	23	11	11	21	35
1961-62	38	28	15	11	30	34
Normal temperatures	32	22	15	14	23	33

At the end of December icefields were limited to the lower St. Lawrence River. They expanded rapidly in January and continued to do so throughout February and in March. Their deterioration consisted in a three-pronged retreat that progressed in its earlier stages from east, northwest and north, and in its later stages from north and south. The St. Lawrence estuary became ice-free after March 21, and the river before April 18. The shipping lane through the gulf south of Anticosti Island became ice-free after March 22. At the end of March, the southern part of the gulf and the northeast arm were the two main areas of ice congestion; secondary areas included Cabot Strait, Chaleur Bay and the middle St. Lawrence River. In the northeast arm much of the heavier ice was of the polar, or Labrador, variety, which had entered the gulf mainly after mid-February. This type of ice reached its maximum advance about March 21. Its retreat in April was steady, but frequent invasions kept pouring into the northeast arm so that the Strait of Belle Isle was not free of ice congestion until about June 24.

The gulf became ice-covered mainly between January 18 and February 7. At this time the icefields consisted mainly of new and young ice. The winter icefields reached their greatest extent about the end of February, and about March 1 they began to retreat. Throughout the winter, shelving in new and young ice and pressure-ridging in winter and Labrador ice constituted a large part of the ice cover.

As the ice season was relatively mild before mid-January, there was no restriction before that date on the movement of shipping in gulf waters. When a rapid drop in temperatures occurred and was followed by steady expansion of the ice cover, ships were convoyed, escorted or supported through the icefields by the icebreaker fleet. From December 15, 1961, to April 15, 1962, the closed-season period, 216 ships passed through the gulf. In its effect on shipping, the winter season of 1961-62 was as severe as the winter of 1960-61.

PHOTOGRAPHIC RECORD OF ICE CONDITIONS

The photographs selected (Figures 27 to 31) show the nature and distribution of the ice that was observed during the survey and illustrate the conditions encountered by ships using the St. Lawrence winter route in 1961-62.

Requests for photographs should be addressed to the National Air Photo Library, 603 Booth Street, Ottawa. The print, roll number and date, which follow the caption, should be given for each print. It should be noted that the subject matter of these photographs has been selected and cut to meet the physical limitations of this report. Requests for the Tiros IV photograph should be directed to the Officer Commanding, JPIC, RCAF station, Rockcliffe, Ont.

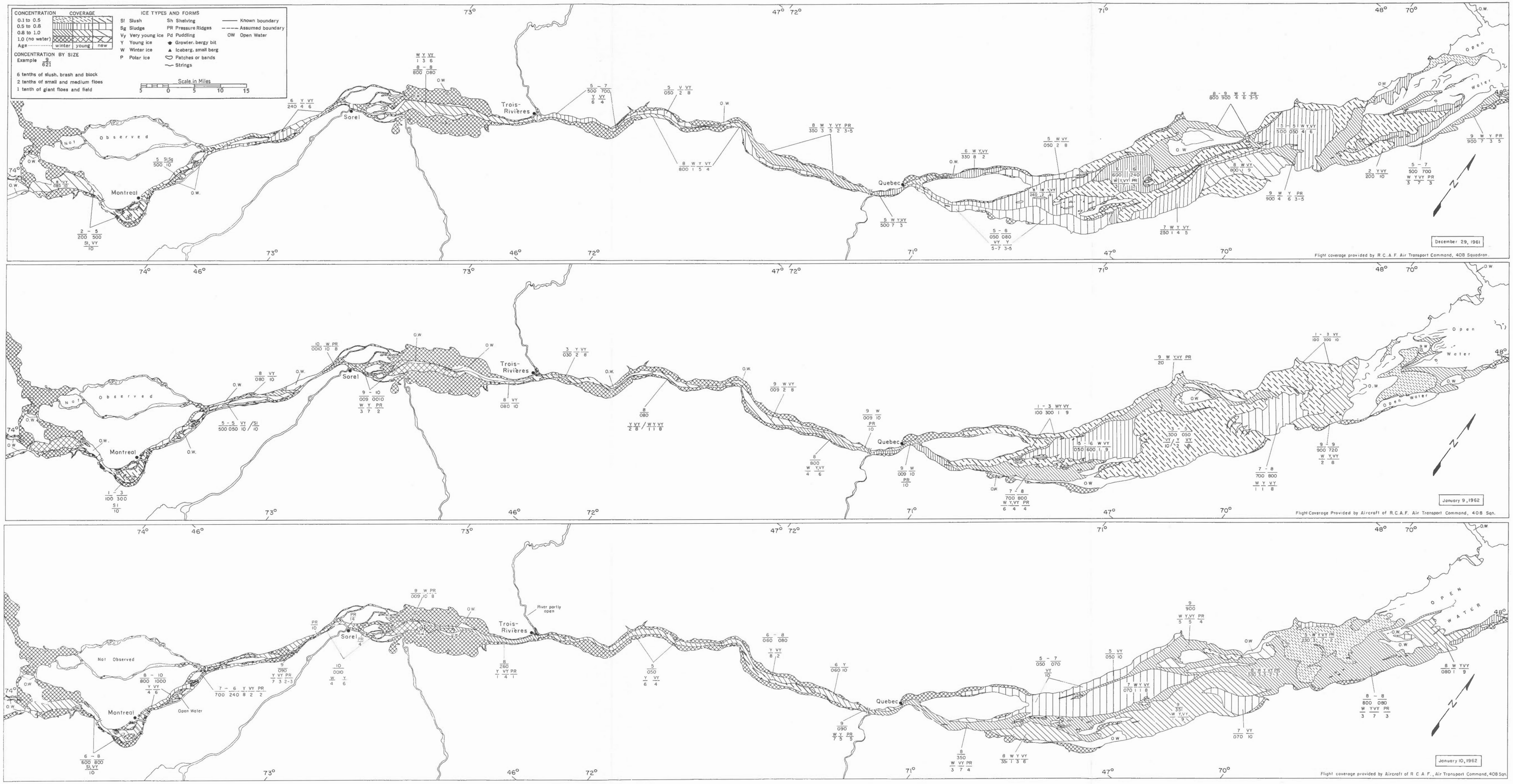

FIGURE 21. Ice distribution, St. Lawrence River, December 29, 1961, and January 9 and 10, 1962.

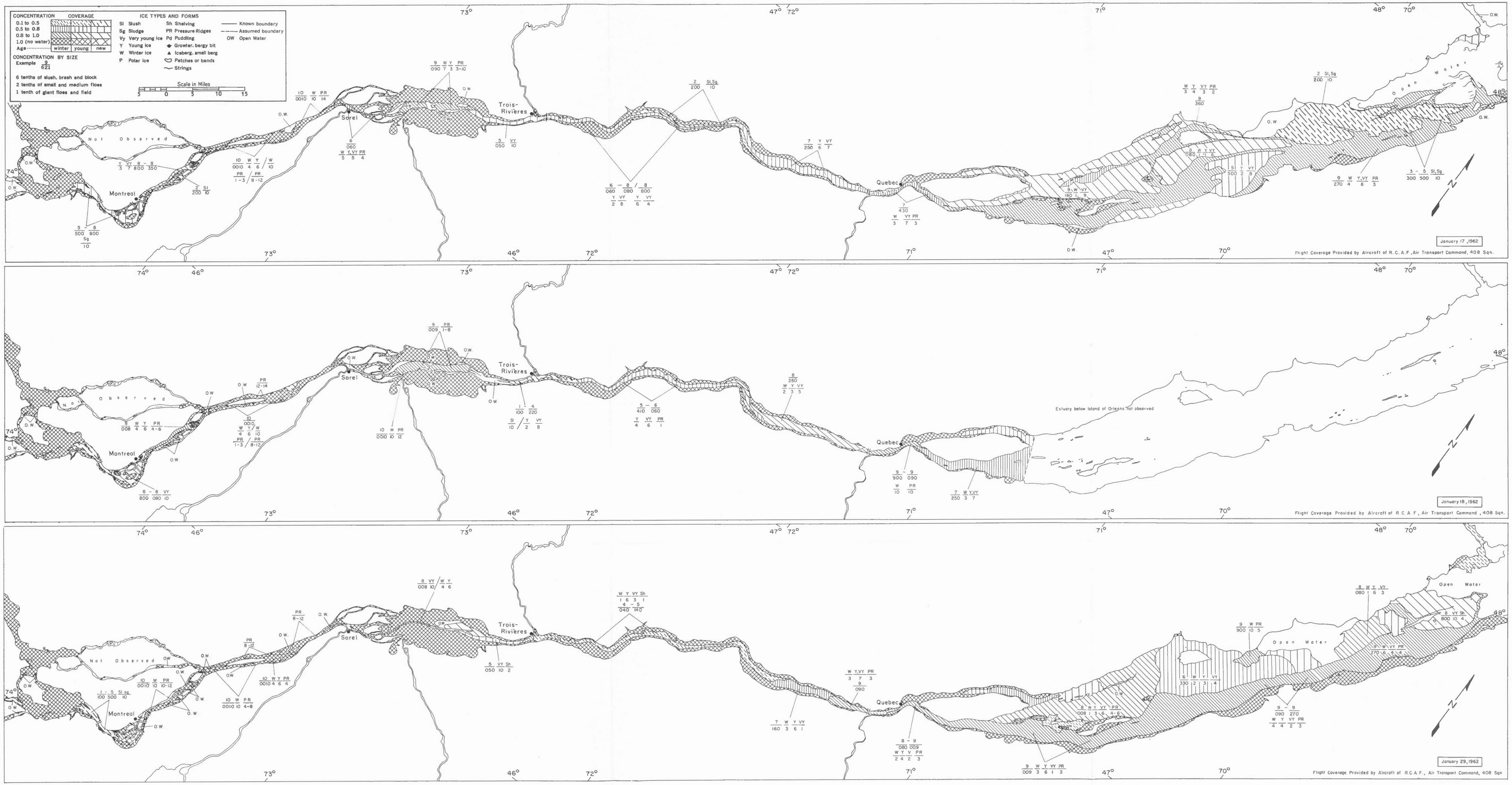

FIGURE 22. Ice distribution, St. Lawrence River, January 17, 18 and 29, 1962.

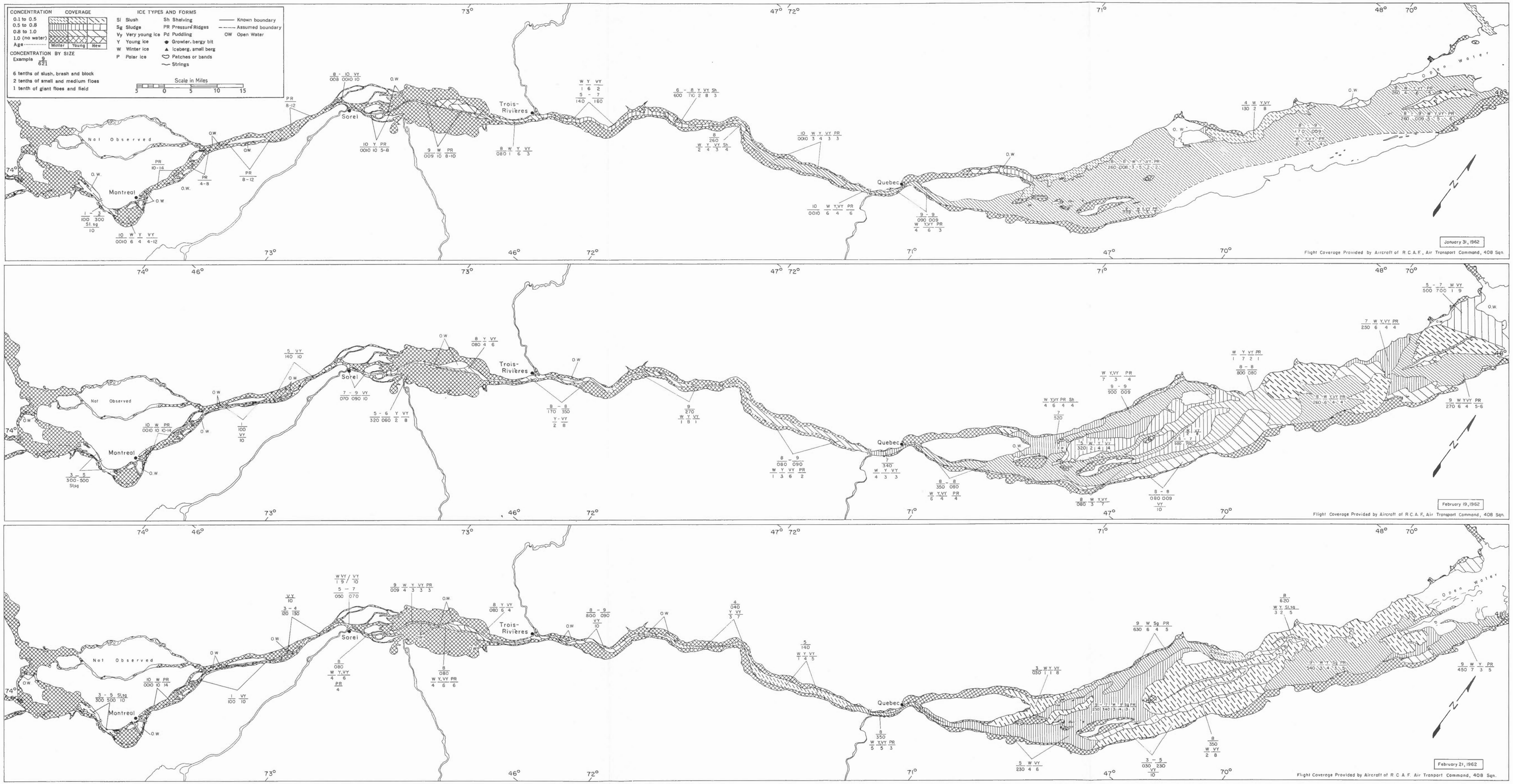

FIGURE 23. Ice distribution, St. Lawrence River, January 31 and February 19 and 21, 1962.

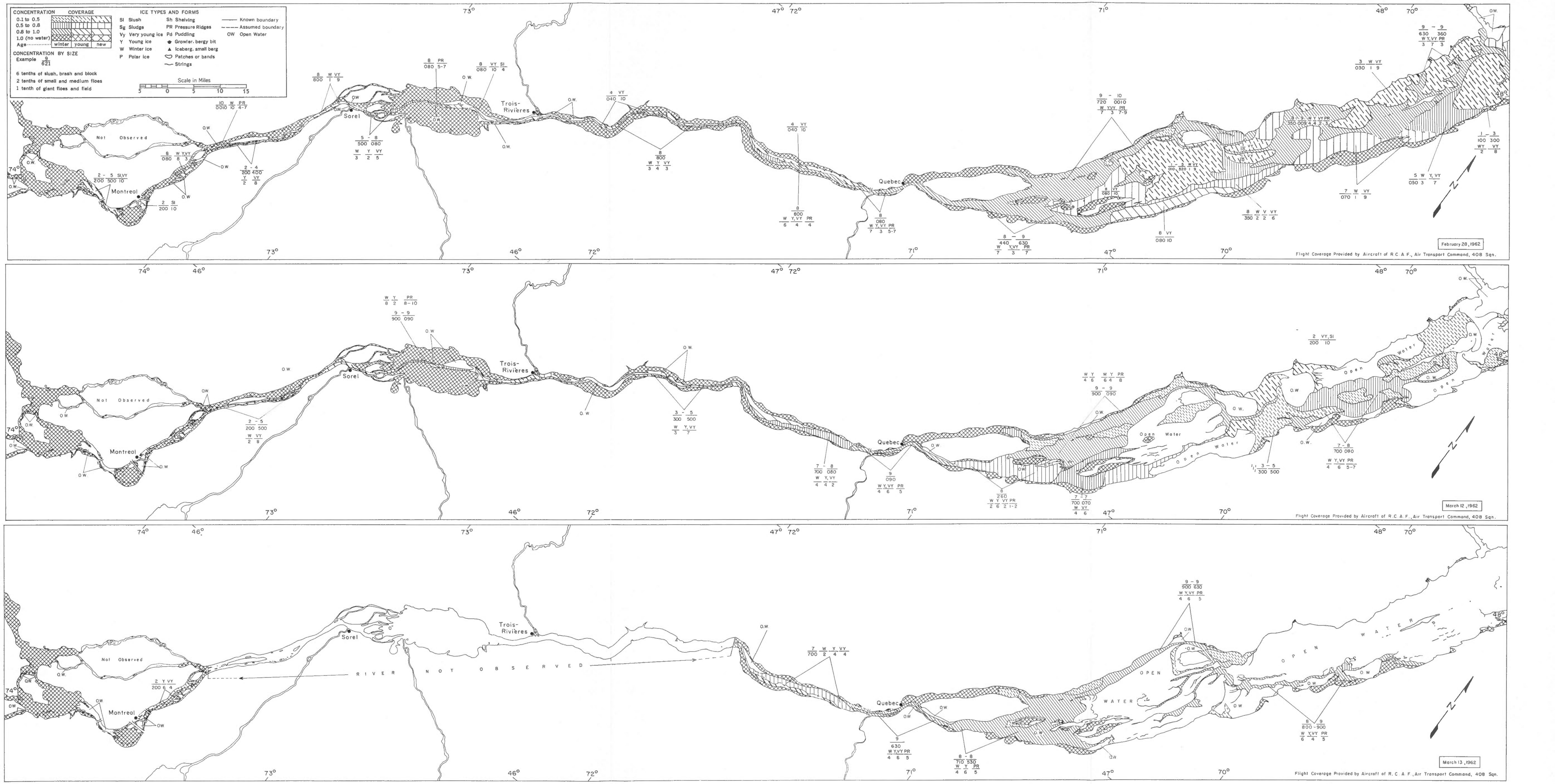

FIGURE 24. Ice distribution, St. Lawrence River, February 28 and March 12 and 13, 1962.

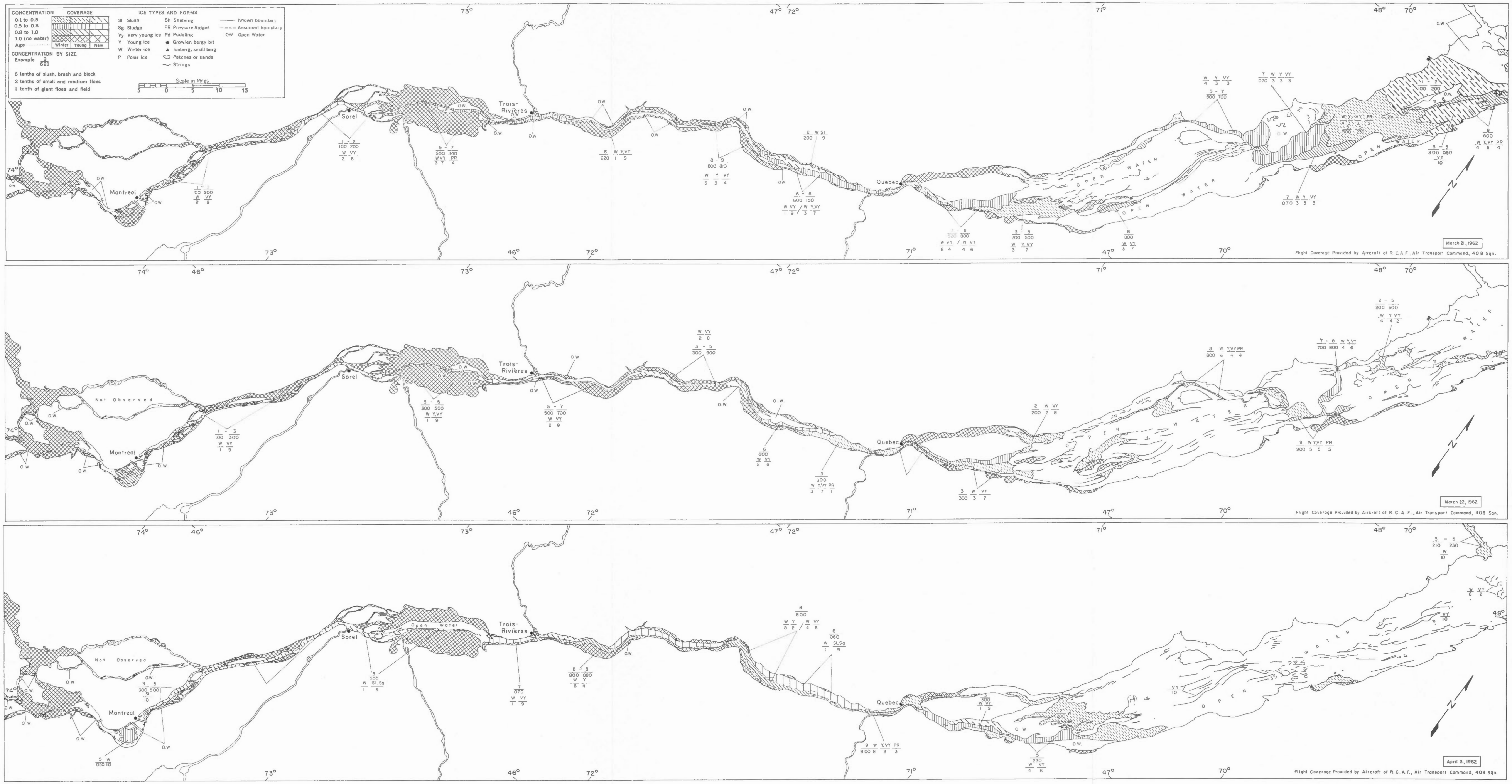

FIGURE 25. Ice distribution, St. Lawrence River, March 21 and 22 and April 3, 1962.

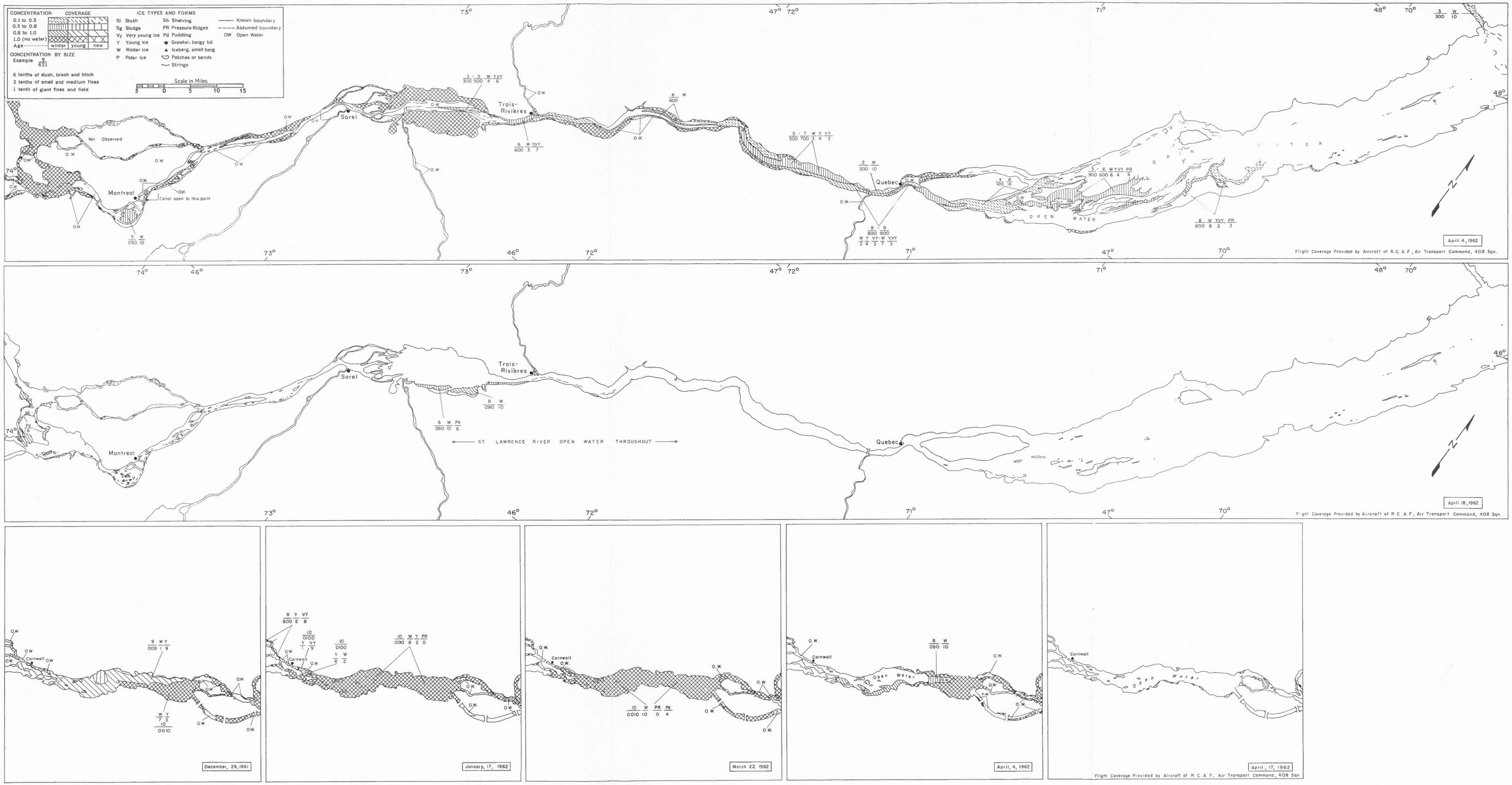

FIGURE 26. Ice distribution, St. Lawrence River, April 4 and 18, 1962. The insets show the ice distribution below Cornwall, Ont., on selected dates.

FIGURE 27

Large quantities of river ice funnel into the ship passage between Ile aux Coudres and Baie St. Paul. The amount of ice that drifts through the passage varies greatly. (6 S (39) RR 2271, Jan. 9, 1962)

FIGURE 28

The icebreaker C.C.G.S. *N. B. McLean* forces a passage through a St. Lawrence River ice jam. This exceedingly rough ice contrasts sharply with the smooth ice covering the river shoals. (2 S (30) RR 2274, Jan. 17, 1962)

FIGURE 29

The MV *Baie Comeau* hove to in an icefield about 30 miles west of Cape St. George, Nfld. The icefield consists of young-ice concentrations of brash and block, but the continued low temperatures and the covering of surface snow are transforming it into winter ice. (6 S (30) RR 2288, Feb. 19, 1962)

FIGURE 30

An eastward view of the ice conditions in Sydney harbor and offshore. The open water at the harbor entrance is the southern extension of the open-water area that extends from St. Ann's Bay to Cape Egmont. (9 S (30) RR 2296, Mar. 21, 1962)

FIGURE 31

This *Tiros IV* photo (No. 2, Apr. 3, 1962), taken at an altitude of 450 miles, shows the outline of the Gulf of St. Lawrence, the icefields, the open-water areas and the cloud cover. The main icefields are in Chaleur Bay, the southern gulf and the northeast arm of the gulf (compare with Figure 15). The cloud cover, extending east of Gaspé, lies north of the southern-gulf icefields and at the eastern entrance to Cabot Strait. (Courtesy JPIC, Department of National Defence, Rockcliffe, Ont.)

GLOSSARY

Block: A fragment of sea ice between 6 and 30 feet across.

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

Consolidated ice: Ice floes of different sizes that are compacted into extensive fields. Consolidation usually progresses quickly under rapid freezing of the sea surface.

Floe: A piece of sea ice. A small floe is from 30 to 600 feet across; a medium floe 600 to 3,000 feet; a large floe 3,000 feet to 5 miles. Qualifying terms such as 'light' and 'heavy' are often used, but they imply thickness or ruggedness rather than areal limit.

Frazil: Ice crystals formed and held in suspension in turbulent water or fast-flowing rivers.

Growler: A piece of ice up to 10 feet across frequently greenish and barely showing above water.

Ice barrier: An extensive area of ice that lies across a shipping route or a ship's course.

Ice bridge: An ice jam that forms in a river and, through consolidation by freezing and compression, binds together the shorefast ice on either bank.

Ice concentration: The ratio of the areal extent of the ice present to that of the ice and water surfaces combined. Concentration is usually measured in tenths: for example, $\frac{9}{621}$ concentration indicates 6/10 brash and block, 2/10 small to medium floes, and 1/10 large to giant floes. The total ice surface is 9/10.

Ice coverage: The distribution of the ice surface shown graphically by concentration and ice type.

Icefield: The largest of sea-ice areas (6 miles or more across), which usually covers hundreds of square miles of sea surface.

Ice forms: The pattern formed by the topographical details of the ice surface.

Ice patch: An area of drifting ice that has become isolated from the main icefield.

Ice string: A long, narrow, whip-like stretch of ice, usually composed of ice wreckage or small fragments and detached from larger areas of ice.

Ice types: Ice classified by age, as new, young, winter and polar.

Landfast ice: Any type of ice attached to the shore, beached, stranded in shoal water or attached to the bottom of shoal areas. It is also known as shorefast ice.

New ice: The most recently formed ice type, which includes such forms as grease, slush, frazil, very young ice and early-stage sludge.

Pack ice: Floating ice covering any substantial area, usually described as open, close or very close pack ice.

Polar ice: In this report, polar ice is defined as ice originating in arctic or subarctic areas outside the Gulf of St. Lawrence region.

Polynya: An open-water gap of varying size that is found in the same area every year. In the gulf, polynyas occur off lee coasts during the winter.

Pressure ridge: A ridge of ice. Wherever pressure ridges form a substantial area of the ice, their coverage may be expressed in tenths. For example, $\frac{PR}{3}$ indicates that 3/10 of the area is made up of pressure ridges. It is also a measure of surface roughness and of the reduction of the ice area through pressure-ridging.

Rafting: The overriding of one floe by another of winter ice.

Shelving: The interlocking rectangular pattern of new and young ice. The area of shelving ice may be expressed in tenths.

Sludge: An accumulation of small pieces of soft ice mixed with slush. The surface of the sludge is usually hardened into an ice crust. Slob ice is a dense form of sludge. Sludge coverage may be expressed in tenths. Thus $\frac{Sg}{4}$ means 4/10 of sludge.

Slush: An accumulation of ice crystals such as would result from snow that has fallen into water that is approximately at freezing temperature. In the water, slush forms a thick, white, soupy mass. The coverage of slush may be expressed in tenths. Thus $\frac{Sl}{5}$ means 5/10 of slush.

Very young ice: Dark ice recently formed in calm water. Its coverage is expressed in tenths. Thus $\frac{VY}{6}$ means 6/10 of very young ice.

Winter ice: Ice produced during the current winter, usually ridged and capable of maintaining a snow cover without the snow's becoming grey from water seepage through the ice. Coverage is expressed in tenths. Thus $\frac{W}{5}$ means 5/10 of winter ice.

Young ice: Newly formed ice that is generally grey and varies from 2 to 6 inches in thickness. It is older than new ice. Coverage is expressed in tenths. Thus $\frac{Y}{7}$ means 7/10 of young ice.

BIBLIOGRAPHY

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

Armstrong, Terence, and Roberts, Brian.
1956 : Illustrated ice glossary. The Polar Record, v. 8, no. 52, 4-12.

Barnes, Howard Turner.
1928 : Ice engineering. Renouf Pub. Co., Montreal, Que.

Forward, C.N.
1954 : Ice distribution in the Gulf of St. Lawrence during the break-up season. Geog. Bull. 6, 45-84.

Hamelin, Louis-Edmond.
1960 : Classification générale des glaces flottantes. Naturaliste Can., v. 87, no. 10, 209-227.

Jarlan, G.E.
1961 : Note on the wind-induced upper layer circulation and subsequent ice-drift phenomena in the Gulf of St. Lawrence. N.R.C., Ottawa.

Jarlan, G.E., and Brochu, M.
1959 : Observations of frazil in the St. Lawrence River (Quebec). Mech. Eng. Rept. MH-86, N.R.C., Ottawa.

Lauzier, L.M.
1957 : A preliminary report of the winter oceanographic survey in the Gulf of St. Lawrence, 1956. Fisheries Res. Bd., Atlantic Oceanog. Group, St. Andrew's, N.B.

1958 : Some aspects of oceanographic conditions in the Gulf of St. Lawrence from autumn 1956 to spring 1957. Ms Rept. Ser. no. 9. Fisheries Res. Bd., Atlantic Oceanog. Group, St. Andrew's, N.B.

Lauzier, L.M., and Graham, R.D.
1958 : Computation of ice potentials and heat budget in the Gulf of St. Lawrence. Ms. Rept. Ser. no. 11. Fisheries Res. Bd., Atlantic Oceanog. Group, St. Andrew's, N.B.

Meteorological Branch. Department of Transport. Canada.
Monthly weather map. November 1961 to May 1962. Toronto, 1961-62.

Meteorological Branch. Department of Transport. Canada.
1959 : Temperature and precipitation normals for Canadian weather stations based on period 1921-1950, CIR 3208, CLI-10, Toronto, 33 p.

Neu, H.A.
1960 : The tide in the St. Lawrence River. Ms., Hydrog. Lab., N.R.C., Ottawa.

1961 : Note about the ice survey in the St. Lawrence River. Report to the Working Group on Ice in Navigable Waters. Ms., Hydrog. Lab., N.R.C., Ottawa.

Neu, H.A., and Clarke, J.R.
1961 : Ice in the St. Lawrence River, its effect on the tide and its movement in the estuary below Orleans Island. Ms., Hydrog. Lab., N.R.C., Ottawa.

United States Navy Hydrographic Office.
1952 : A functional glossary of ice terminology. Hydrog. Office Pub. 609. Government Printing Office, Washington, D.C.

Date Due

Canada. Lands Directorate.
Gulf of St. Lawrence ice
survey, winter, 1962.

GEOGRAPHICAL PAPERS
(Etudes 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, Québec. 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., map, 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 caractéristique des glaces de dérive de l'estuaire et de la partie nord-est du golfe Saint-Laurent, hiver 1957-1958. 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, NWT. G. Falconer. Ottawa, 1962. 58 p., maps, illus. $2.00.
No. 34.	River-ice conditions in the Nelson River drainage system. D.K. MacKay. Ottawa, 1962. 42 p., 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.