C. J. Stevenson

Canada

GEOGRAPHICAL PAPER No. 32

# Gulf of St. Lawrence Ice Survey, Winter 1961

*W. A. Black*

GEOGRAPHICAL BRANCH
Department of Mines and
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*Price: $1.50*

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54491-6—1

Massive St. Lawrence River ice in the vicinity of Deschaillons obstructs the passage of the icebreaker C.M.S. *d'Iberville* (Feb. 2, 1961).

# PREFACE

The Gulf of St. Lawrence ice survey, winter 1961, is a study resulting from the sixth winter aerial ice survey conducted over the Gulf of St. Lawrence region. In addition, a survey of the St. Lawrence River between Montreal and Quebec is included.

It is hoped that this report, together with the previous reports, may 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

# GULF OF ST. LAWRENCE ICE SURVEY, WINTER 1961

## INTRODUCTION AND ACKNOWLEDGEMENTS

The aerial survey of sea ice conditions in the Gulf of St. Lawrence from January to April, 1961 is a continuation of the ice distribution surveys commenced 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 long-term objective is to provide an annual report on the relationships between ice and climate that is of practical value to shipping interests, and of use in ice forecasting for winter navigation.

The ice survey was conducted by the Geographical Branch with the cooperation of Air Transport Command, RCAF, and was co-ordinated by the Geophysical Research Section of the Defence Research Board. Specific acknowledgements are made to T.A. Harwood, Geophysical Research Section, DRB, W/C W.H. MacDonell of 408 (R) Squadron, RCAF, and P.D. McTaggart-Cowan, Meteorological Branch, Department of Transport. The writer wishes to acknowledge the excellent cooperation received from the RCAF officers and crews who carried out the ice survey program.

The operation in 1961 was planned to begin in January and to continue until the end of April; the first flight was made on January 12, and the last on April 27. The squadron provided Lancaster aircraft, and RCAF station Rockcliffe was the base of operations; RCAF station Summerside, Prince Edward Island, was the forward base. Air Transport Command organized eleven flights at approximately 10-day intervals on the following dates: January 12, and 24; February 1, 14, and 22; March 7, 15, and 28; and April 5, 18, and 27. The average duration of each operation was about 2 days with a total flying time of 16 hours. Flights were made at heights up to 10,000 feet, depending on local visibility conditions.

The aerial reconnaissance was conducted so that the St. Lawrence River from Montreal to the Saguenay River was surveyed during the outward and return flights. Cornwall, Ontario formed the western limit of the survey and the Strait of Belle Isle formed the eastern limit. Flight patterns were arranged to permit the greatest possible observation of ice conditions, to avoid unfavourable local weather conditions, and also, to provide ice information of immediate concern to officers of the Marine Operations Branch.

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 Royal Canadian

Air Force.

This report is divided into two parts: Part I includes weather conditions, ice conditions, and ice distribution maps of the Gulf of St. Lawrence region; Part II includes weather and ice conditions, and ice distribution maps of the St. Lawrence River.

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

# PART I

# THE GULF OF ST. LAWRENCE

## WEATHER CONDITIONS

The winter of 1960-61 was severe, with January and February mean temperatures for the gulf region well below normal. As a result, extensive icefields covered the gulf, deteriorated slowly, and continued into late spring.

Mean monthly temperatures varied from 2 to 4 degrees above normal for November, and up to 2 degrees above normal for December. In January, February and March mean monthly temperatures were substantially below normal, being up to 7 degrees lower for January, up to 8 degrees lower for February, and up to 4 degrees lower for March; gulf region temperatures in the southern gulf January and February were the two coldest contiguous months on record with a low mean temperature of 11°F. However, the mean November - December temperature (29°F.) coincided closely with the March - April temperature (28°F.).

Regional variations in mean temperatures are shown in Table I. The St. Lawrence River and North Shore areas experienced lower temperatures in December than did other gulf regions. In January, the northern and northwestern areas of the gulf were the coldest. The St. Lawrence River in February experienced rising temperatures that were comparable with those of the southern and eastern areas of the gulf. In March, the North Shore and the Strait of Belle Isle were the coldest areas of the gulf region. The exceptionally low temperatures of the entire gulf, including Cabot Strait, were conducive to the formation and maintenance of an extensive ice cover. Even in April, ice-forming processes were prevalent in parts of the gulf; only in the northwestern and southeastern areas were conditions unfavourable to sustain ice-fields.

TABLE I

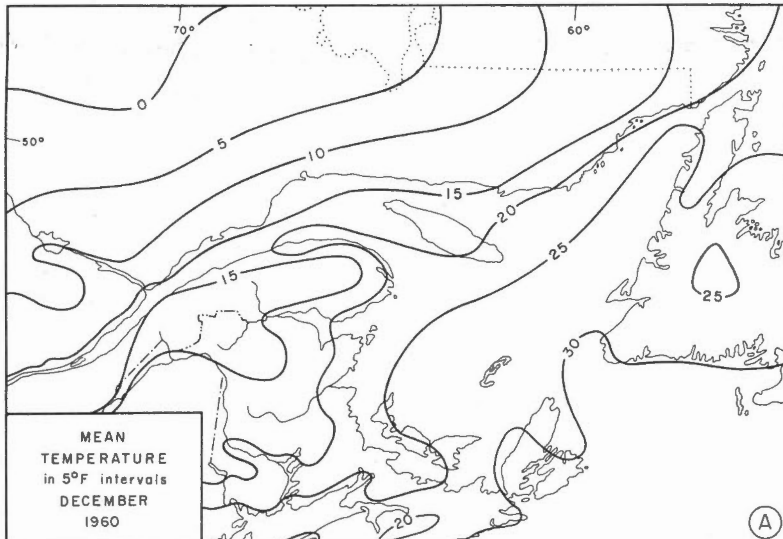
Mean and normal temperatures (F.°) for the gulf region from November 1960 to April 1961

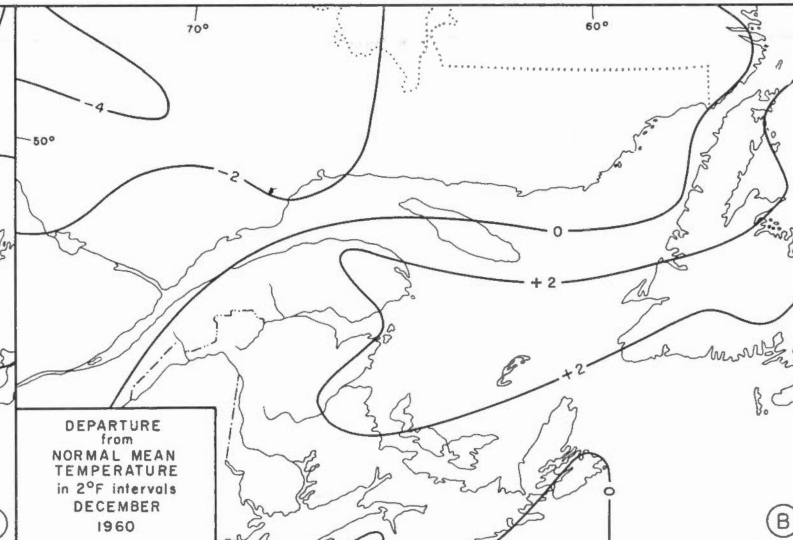
| Area | Nov. M. | Nov. N.* | Dec. M. | Dec. N. | Jan. M. | Jan. N. | Feb. M. | Feb. N. | Mar. M. | Mar. N. | Apr. M. | Apr. N. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| St. Lawrence R. | 34 | 30 | 16 | 17 | 5 | 10 | 13 | 12 | 21 | 23 | 37 | 35 |
| North Shore | 30 | 28 | 15 | 14 | 3 | 7 | 6 | 9 | 17 | 19 | 35 | 30 |
| St. of Belle Isle | 30 | 28 | 20 | 19 | 10 | 11 | 7 | 10 | 17 | 19 | 32 | 27 |
| Gaspé-Chaleur | 34 | 31 | 20 | 19 | 5 | 12 | 11 | 13 | 20 | 23 | 35 | 34 |
| Eastern gulf | 36 | 36 | 28 | 27 | 18 | 20 | 10 | 18 | 22 | 25 | 35 | 34 |
| Central gulf | 38 | 36 | 28 | 26 | 16 | 19 | 12 | 16 | 20 | 24 | 32 | 32 |
| Southern gulf | 38 | 36 | 25 | 26 | 12 | 17 | 14 | 16 | 23 | 26 | 35 | 37 |
| Cabot Strait | 38 | 38 | 30 | 29 | 19 | 23 | 16 | 20 | 25 | 27 | 35 | 36 |
| Av. gulf temps. | 35 | 33 | 23 | 22 | 11 | 15 | 11 | 14 | 21 | 23 | 35 | 33 |

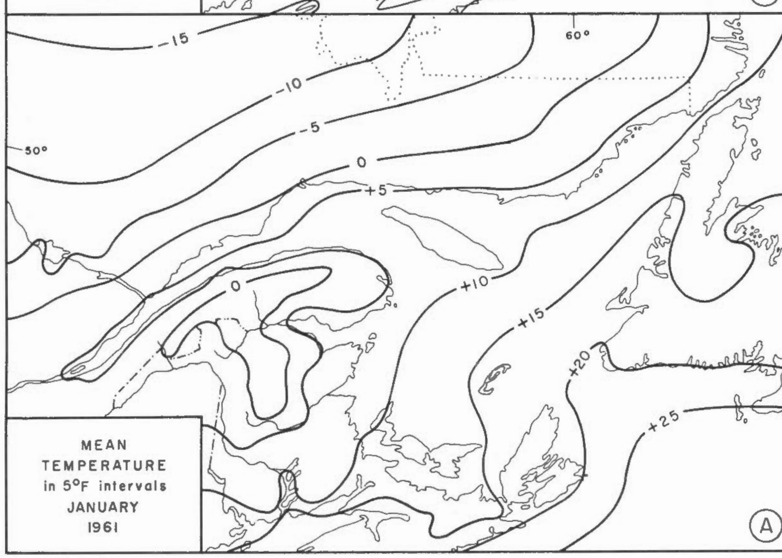
*M mean N normal

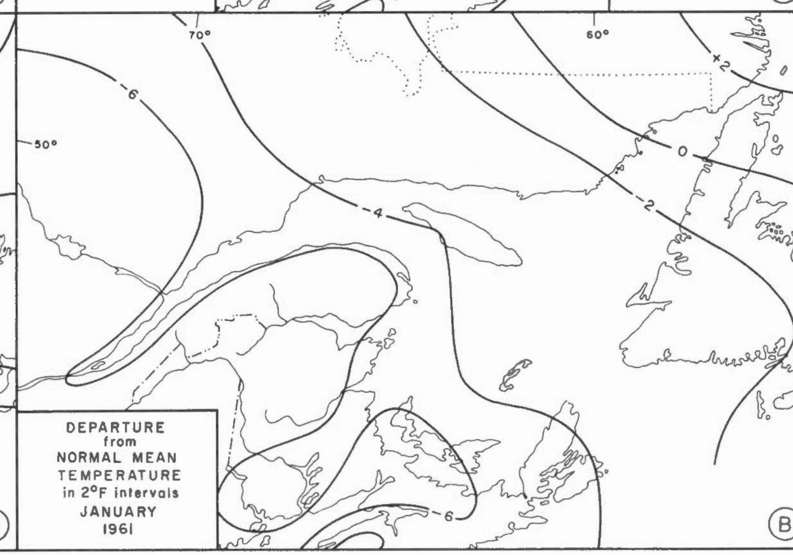
The mean isotherms, December to March, for the gulf region are shown in Figure 1A. The northeast - southwest trend indicates that December and January air temperatures were generally uniform from Quebec to Belle Isle along the North Shore. The trend during February and March was from east to west, Quebec air temperatures being similar to those of the southern gulf region. This change in the trend of the isotherms emphasizes the continental effect of arctic air masses over the gulf; the isotherms also indicate where ice formation first began and where the main ice-forming conditions existed during the winter months. The North Shore, the St. Lawrence estuary, and the Gaspé coast were subjected most to ice formation, followed by Chaleur Bay and the western gulf coast.

Figure 1B, departure from the normal isotherms, shows the extent to which various parts of the gulf differed from normal mean winter temperature conditions. In December, the region lay in the path of southwesterly flows of mild Atlantic air masses so that above-normal temperatures prevailed. The flows of mild Atlantic air continued into the first half of January when the circulation pattern changed


70°
60°
50°
0
5
10
15
20
25
30
15
20
25
MEAN TEMPERATURE in 5°F intervals DECEMBER 1960
A


70°
60°
50°
-4
-2
0
+2
+2
0
DEPARTURE from NORMAL MEAN TEMPERATURE in 2°F intervals DECEMBER 1960
B


70°
60°
50°
-15
-10
-5
0
+5
0
+10
+15
+20
+25
MEAN TEMPERATURE in 5°F intervals JANUARY 1961
A


70°
60°
50°
+2
-6
0
-2
-4
-6
DEPARTURE from NORMAL MEAN TEMPERATURE in 2°F intervals JANUARY 1961
B

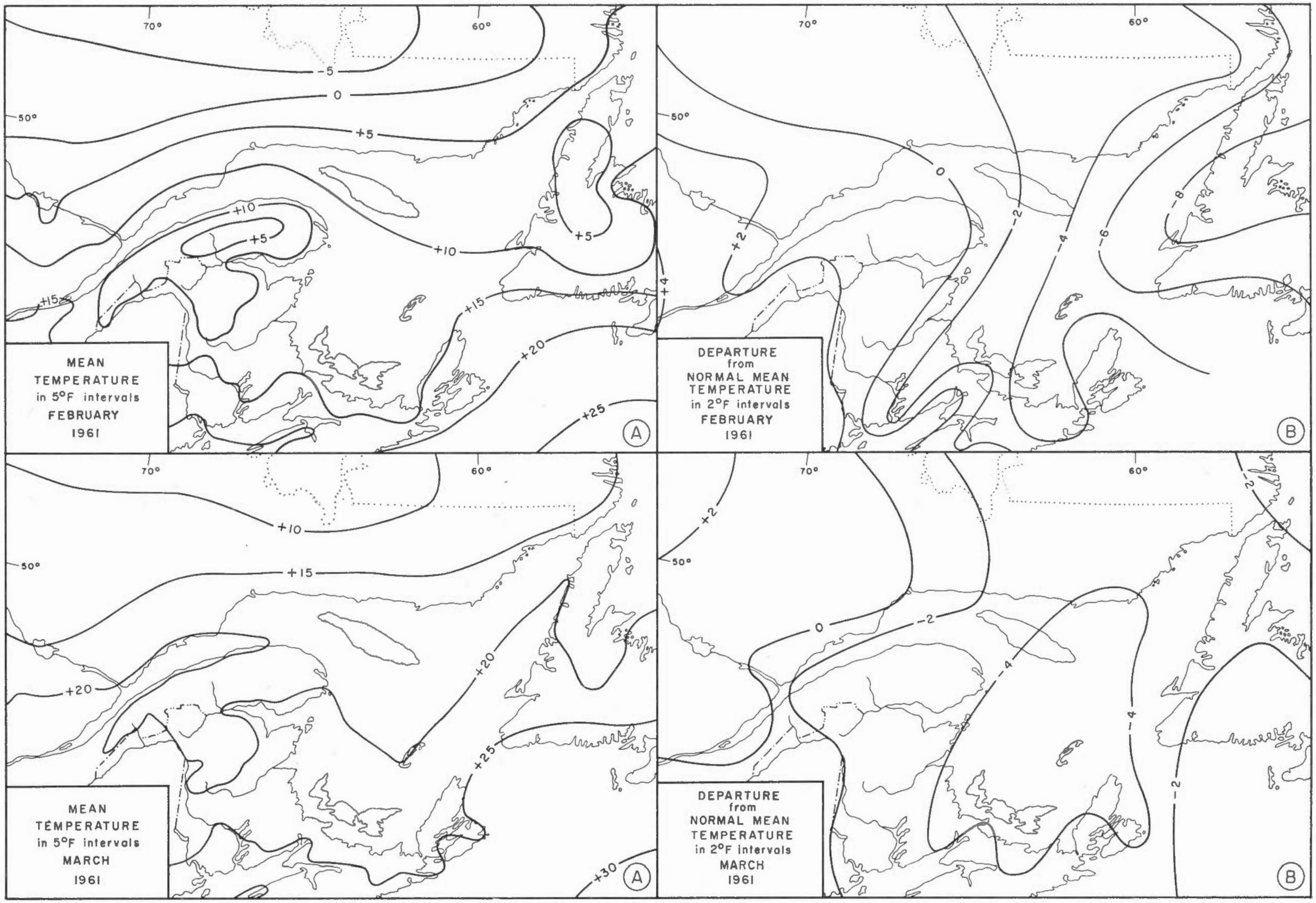



**Figure 1 (A).** Mean temperatures, December 1960 to March 1961.

**Figure 1 (B).** Departure from normal mean temperature, December 1960 to March 1961.

abruptly as cold arctic air swept across the gulf region. Mean temperatures dropped up to 6 degrees below normal in the western gulf region, with near-normal conditions prevailing in the northeast arm of the gulf. Temperatures continued low in February, particularly during the first half of the month; the regions of temperature deficiencies were reversed, with a maximum of 8 degrees below normal in the eastern gulf region, and up to 2 degrees above normal in the St. Lawrence River region. In March a series of storms of Arctic and modified Atlantic air, resulting from a low pressure air mass that prevailed over the eastern Arctic, brought severe weather to the gulf region. Temperature deficiencies of 4 degrees below normal existed in the central and southern parts of the gulf. After the first week of April when temperatures begin to rise, storms of cold Atlantic air swept across the region and resulted in temperatures that were 2 to 4 degrees below normal in the central and North Shore areas, and 2 degrees below normal in the southern gulf region.

Temperatures most suitable for ice growth prevailed in the northern and western gulf throughout the winter months, but in the southern gulf these temperatures were not reached until February. The severity of the winter produced massive icefields and a constant supply of ice that drifted southeast through Cabot Strait. Because of the direction in the passage of storms across the region 162 inches of snow fell, adding substantially to the thickness of the ice.

Winter Winds

The prevailing winds were associated with the flow of the continental Arctic or the maritime Atlantic air masses that swept over the gulf region. The former gave rise to northerly sector winds, and the latter to milder southerly winds. Thus with abnormally low temperatures throughout the region favouring the development of an extensive ice cover, the distribution of the ice depended largely on the shifts of the prevailing winds (Figure 2A).

In December, prevailing winds over the gulf region were westerly; components of easterly and southerly winds were weak. Local areas were marked by strongly developed winds from specific sectors. In January, a similar pattern prevailed, but on the North Shore northerly winds were strong. February was marked by strong northerly and westerly sector winds, with strong northeasterly winds in the eastern part of the gulf. March winds were more variable, with northerly and westerly sector winds predominating except in the eastern gulf region. The main effect of the dominance of northerly and westerly sector winds throughout the winter months was to sustain the drift of ice into the southern part of the gulf, and also, into Cabot Strait. The effect of the prolonged northerly and northwesterly sector winds during March and April was to drive the ice into the southeastern shore of Northumberland Strait. A major effect of predominantly westerly winds in the western gulf and of easterly winds in the eastern gulf was to establish an ice barrier southwest from the Strait of Belle Isle to the Magdalen Islands.

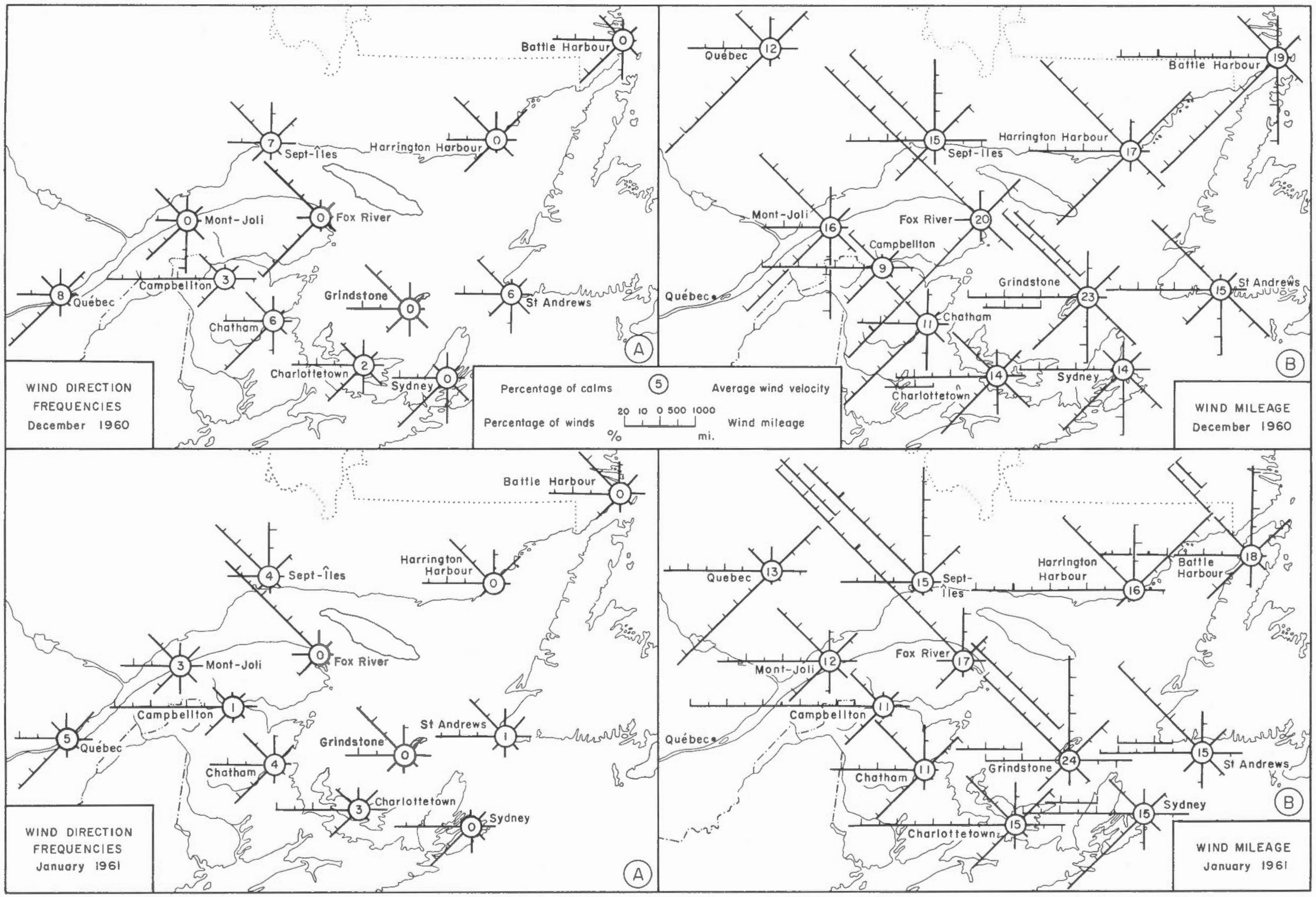
Wind velocities for December were higher in the central and northern parts of the gulf and averaged from 15 to 23 mph; in the southern half of the gulf they averaged 9 to 15 mph. January wind velocities continued high, whereas February was marked by a reduced velocity in wind speeds averaging from 9 to 18 mph. The central gulf and the Strait of Belle Isle area experienced stronger wind velocities than elsewhere in the area. Calm periods were most pronounced in the northwestern and southwestern gulf areas. Wind speeds continued high for March with stronger winds occurring in the central gulf region than elsewhere in the gulf.

Prolonged high velocity winds led to the formation of pressure ridges that comprised from 1/10 of the ice in the western gulf to 8/10 in the southeastern gulf. In the Strait of Belle Isle, the northeast arm, the St. Lawrence estuary and Northumberland Strait, tidal action and ocean currents also contributed to the formation of pressure-ridged ice. The effect of prolonged winds may be gauged from the fact that ice off Sydney was reported to be 30 feet thick. In the ice-congested area of Northumberland Strait, where tidal action was effective as a builder of pressure ridges, the sea ice was over 20 feet thick. Exceptionally high tides during storms in February and March piled ice into ridges 50 feet high against parts of the Northumberland coasts.

## Gulf Ice Drift

Direction, velocity and sustained wind mileage are important factors affecting the distribution of sea ice. A comparison of figures 2A and 2B for each month reveals that wind frequency and wind mileage tend to coincide. The strength of the winds as expressed by sustained wind mileage (Figure 2B) indicates the wind sectors that were most effective in moving the ice down-wind, and producing wind-induced surface currents.

Shuleykin's (Armstrong, 1955) ratio of ice drift to wind speed (1:25) provides a practical estimate of the rate that ice drifts with the wind (Table II). Westerly winds were particularly strong during December and January and provided a daily average free ice drift of 10 miles. Northerly sector winds were also strong in the central gulf region and provided a free ice drift southward of 10 to 14 miles per day. In the North Shore and Strait of Belle Isle areas northerly winds in January provided a southward drift of 10 miles per day respectively. February brought a change in rate of free ice drift; westerly and northerly sector


WIND DIRECTION FREQUENCIES
December 1960
A
Battle Harbour
Sept-Îles
Harrington Harbour
Mont-Joli
Fox River
Campbellton
Québec
Grindstone
St Andrews
Chatham
Charlottetown
Sydney
Percentage of calms
Average wind velocity
Percentage of winds
Wind mileage
20 10 0 500 1000
%
mi.
WIND MILEAGE
December 1960
B
WIND DIRECTION FREQUENCIES
January 1961
WIND MILEAGE
January 1961
Quebec

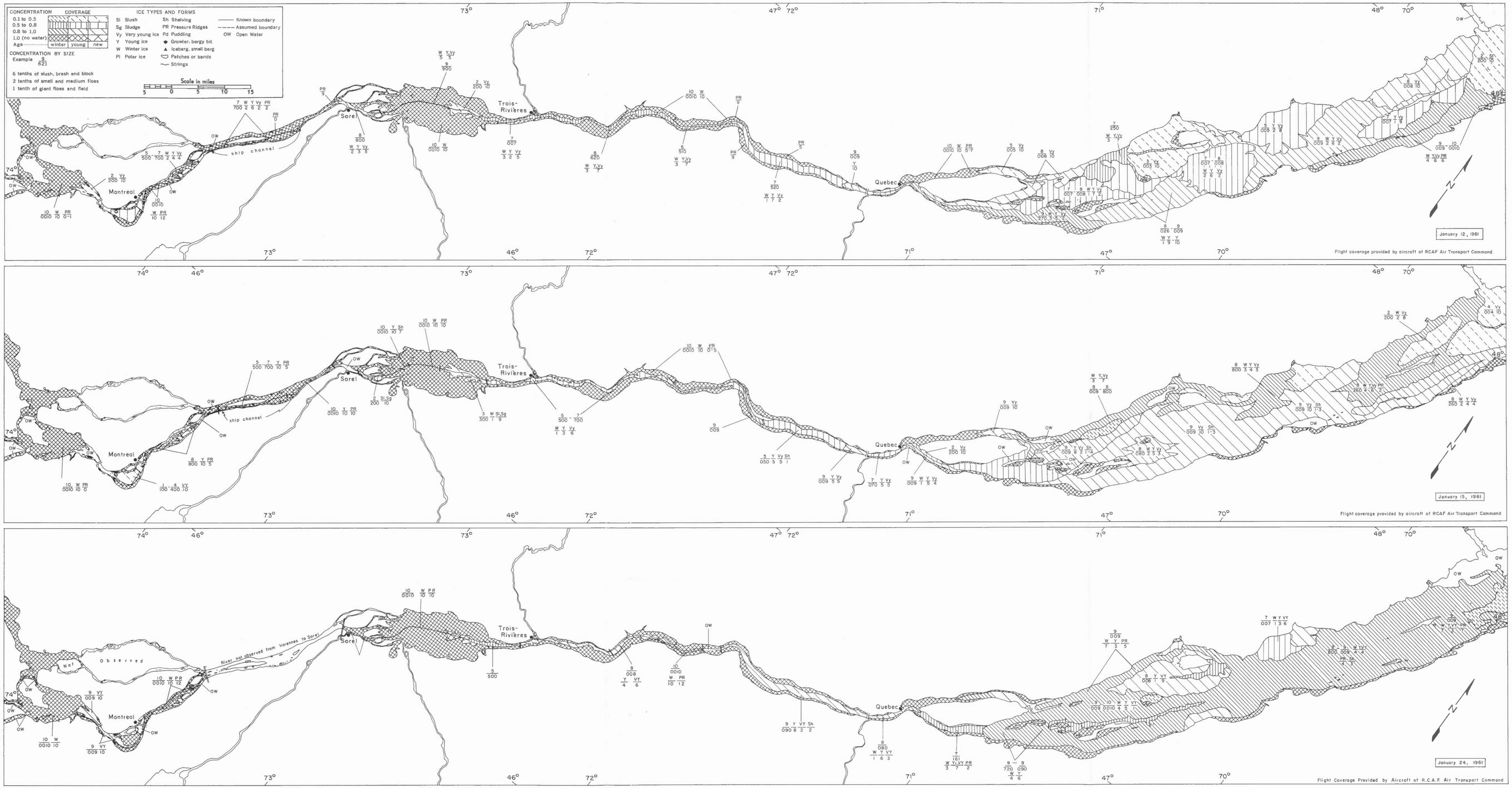



**Figure 20.** Ice distribution, St. Lawrence River, January 12, 15, 24, 1961.

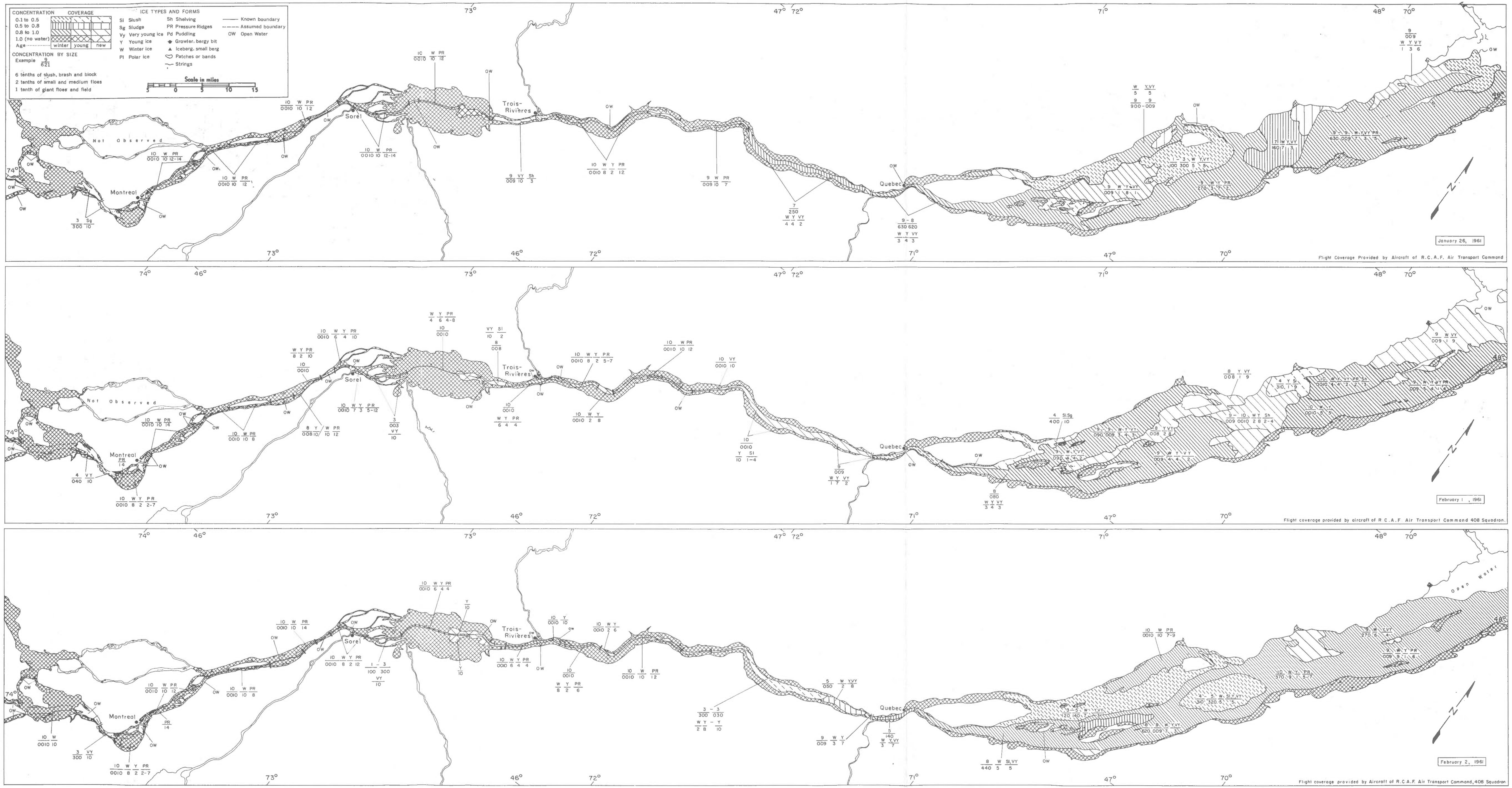



**Figure 21.** Ice distribution, St. Lawrence River, January 26; February 1, 2, 1961.

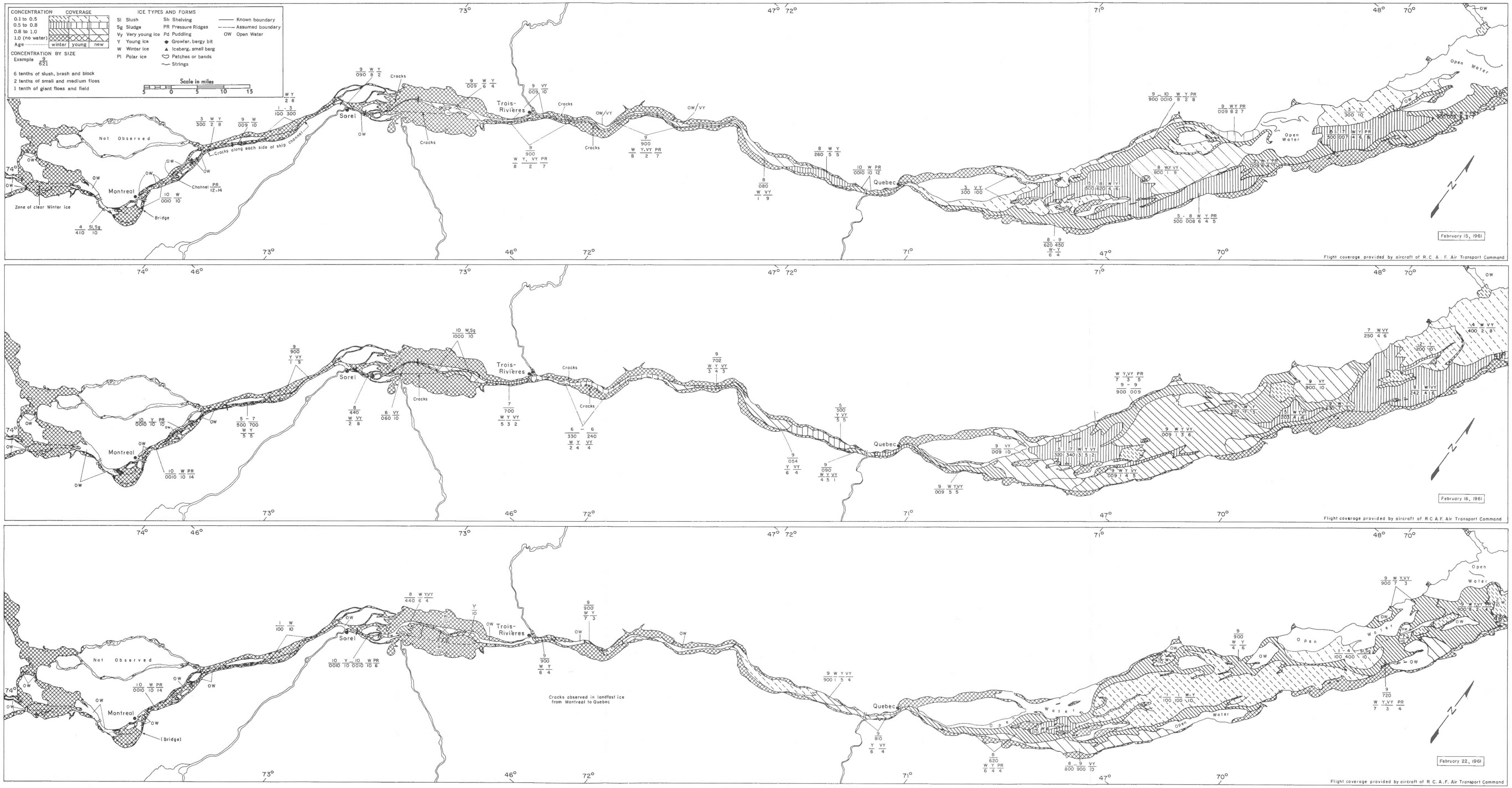



**Figure 22.** Ice distribution, St. Lawrence River, February 15, 16, 22, 1961.

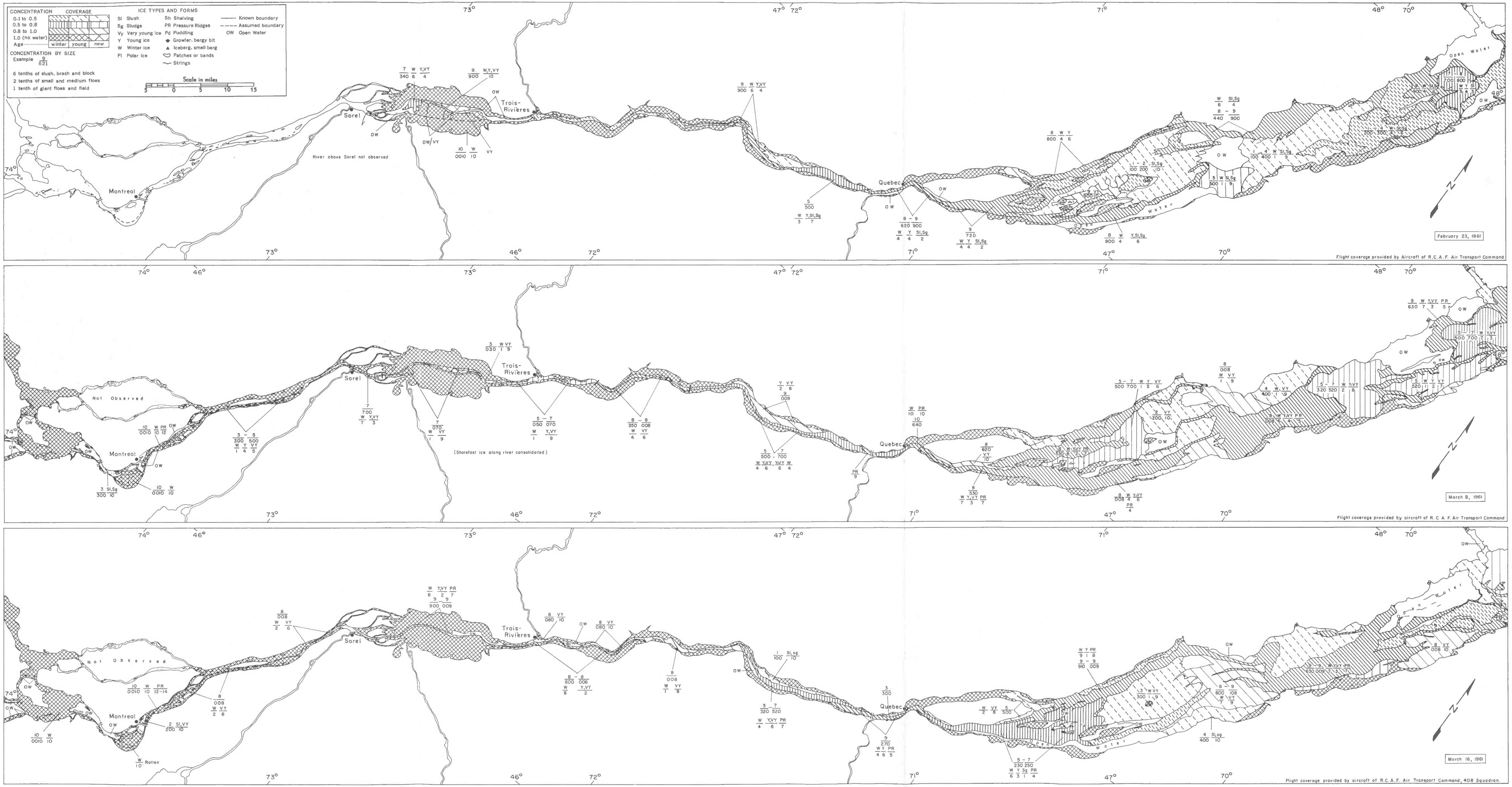



Figure 23. Ice distribution, St. Lawrence River, February 23; March 8, 16, 1961.

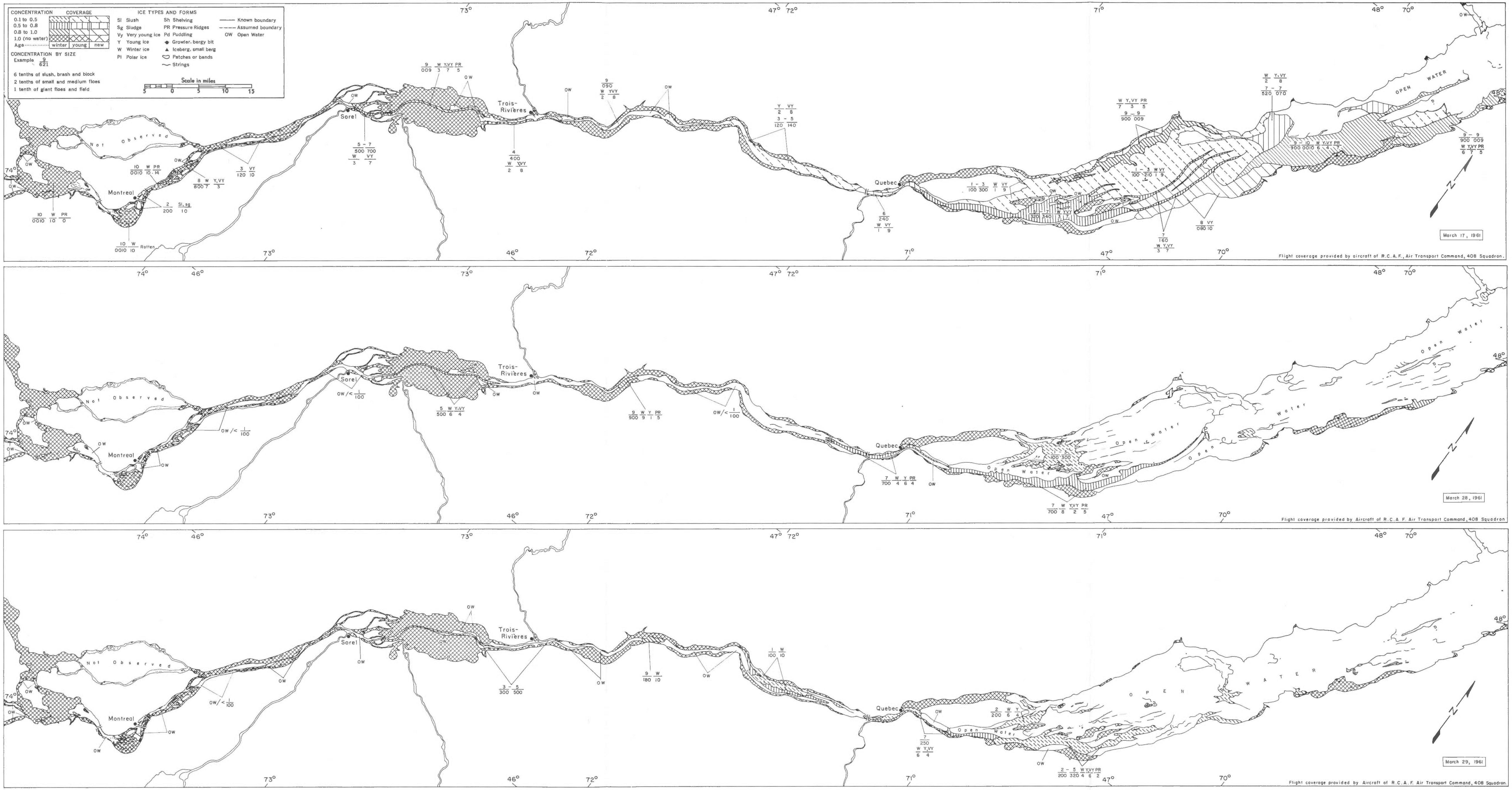



**Figure 24.** Ice distribution, St. Lawrence River, March 17, 28, 29, 1961.

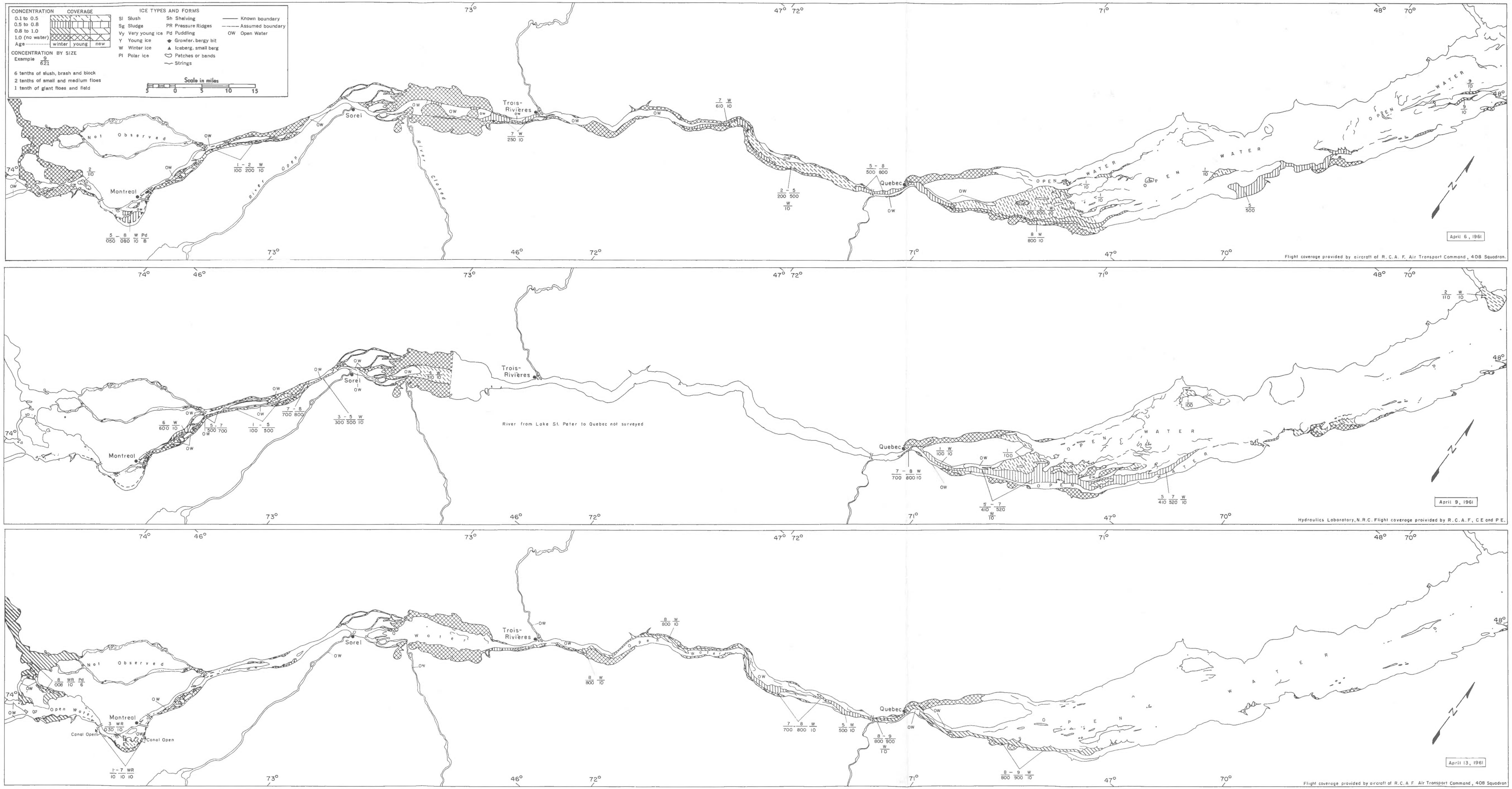



Figure 25. Ice distribution, St. Lawrence River, April 6, 9, 13, 1961.

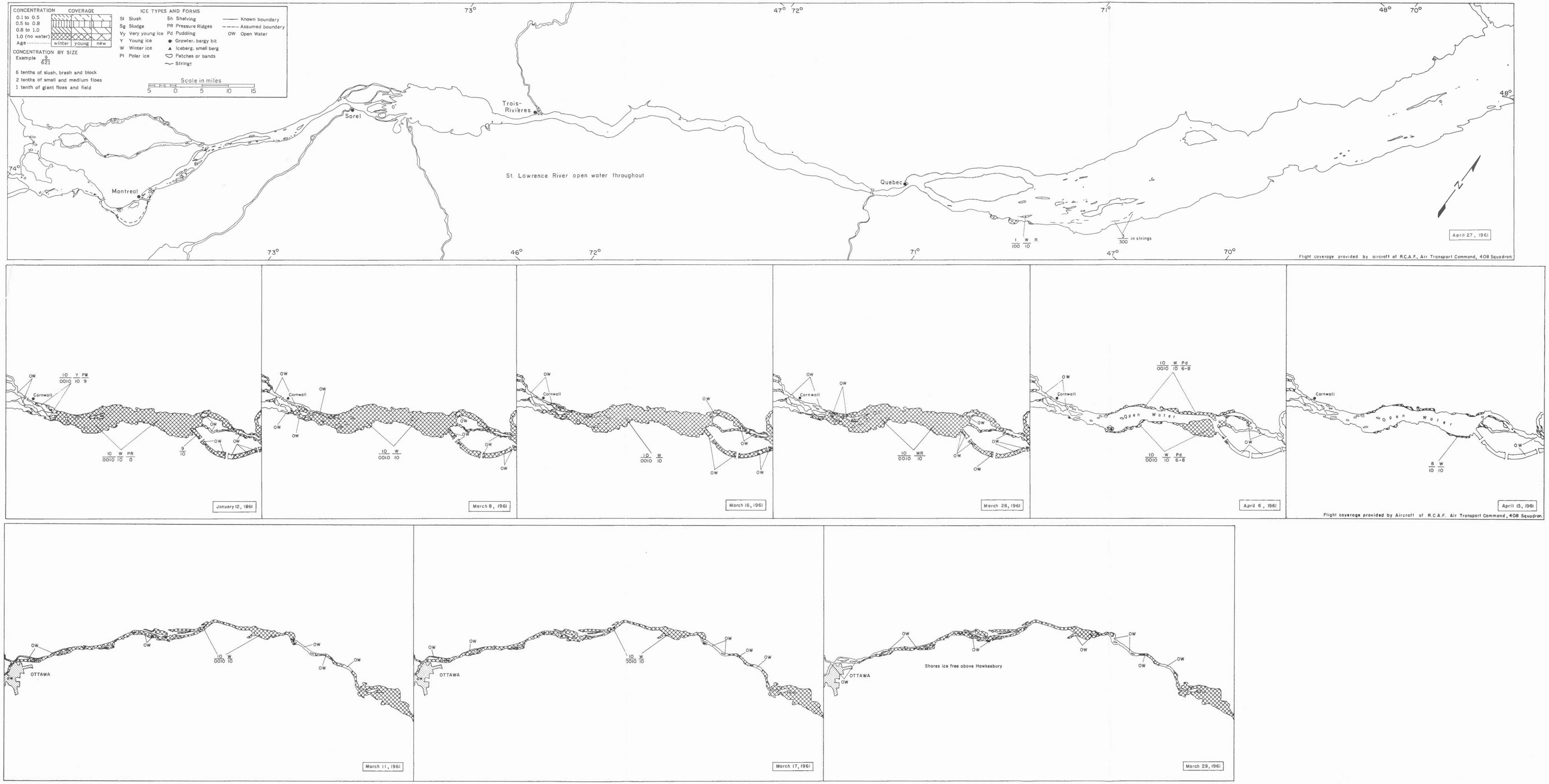



**Figure 26.** Ice distribution, St. Lawrence River, April 27, 1961. Insets show the distribution below Cornwall and below Ottawa on selected dates.

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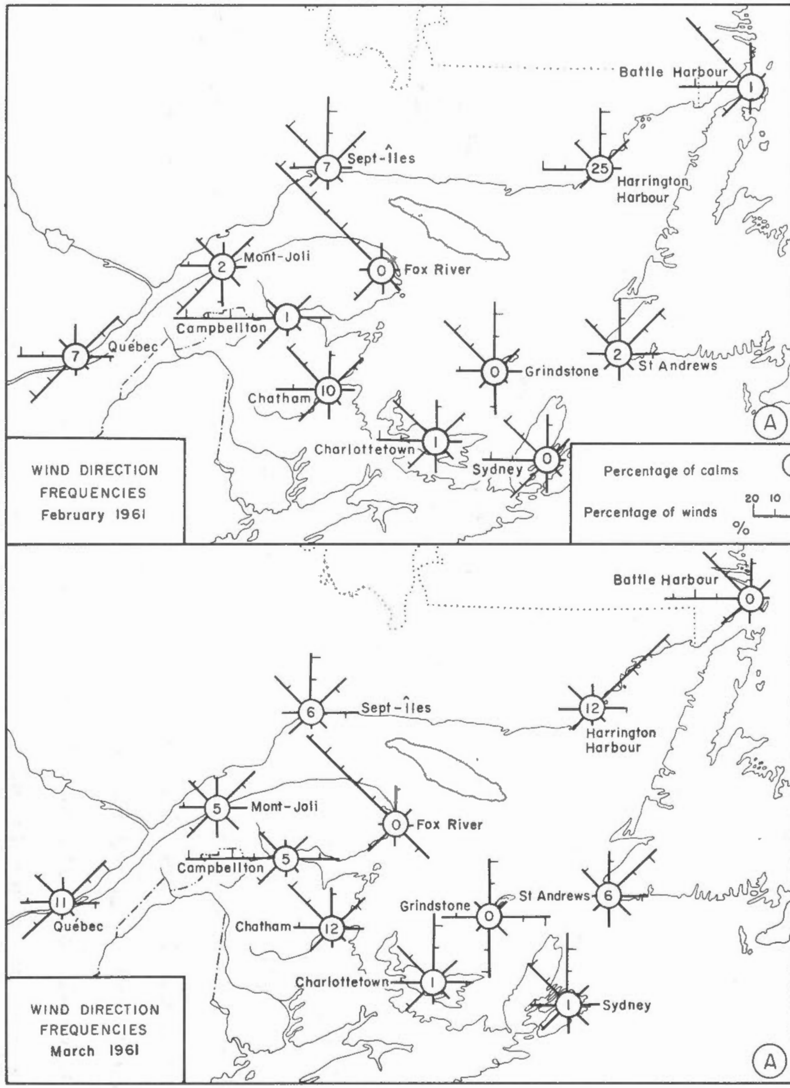


Figure 2 (A). Wind direction frequencies, December 1960 to March 1961.

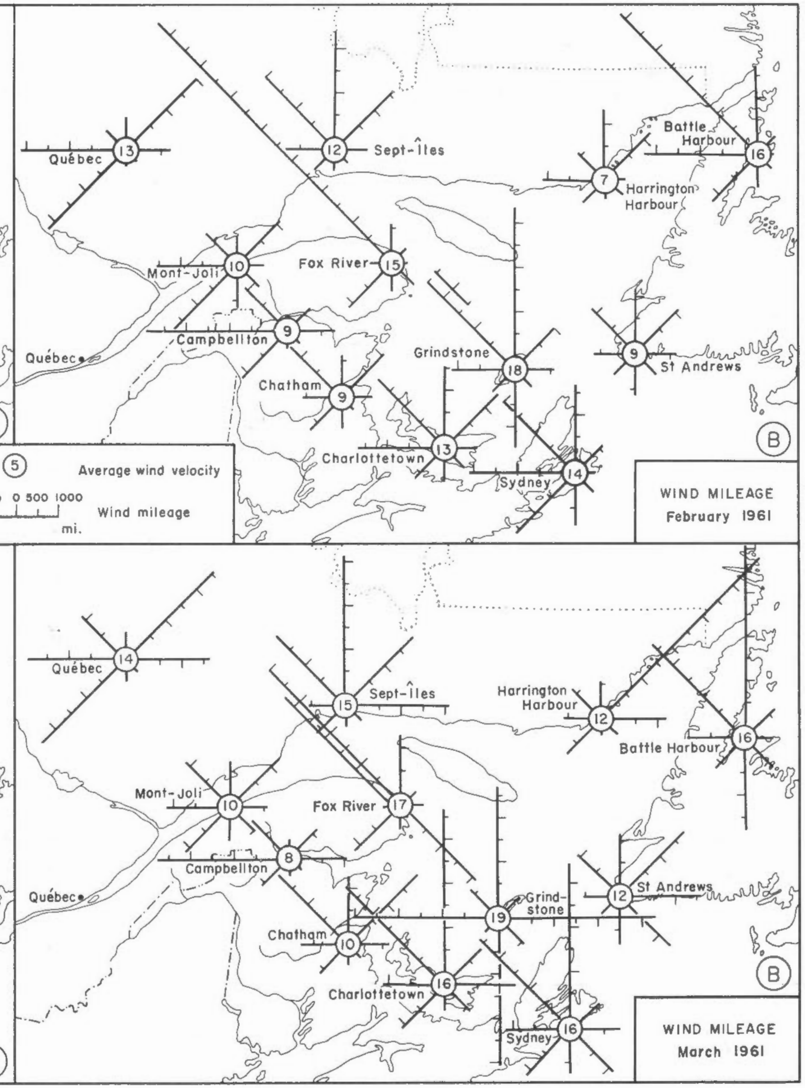


Figure 2 (B). Wind mileage, December 1960 to March 1961.

winds supported a drift of 7 miles per day, easterly and northerly winds 3 miles per day. March drift figures were marked by a weakening of the westerly and northerly components, whereas, the easterly and southerly components remained similar to those of the previous months.

The actual mileage of effective ice drift is found by deducting the ice-drift miles from the opposing wind sector. The general drift of the ice in the St. Lawrence estuary from west to east diagonally across the river to the south shore provides a partial explanation for the ice congestion that is experienced along the south shore and along the Gaspé coast. The effectiveness of assisting winds is considerably reduced by opposing winds and by the trend of the coast. The extensive ice cover that developed in the southern gulf during January and February clearly illustrates this principle. Powerful westerly and northerly winds in the central gulf region that drove the ice into the southern gulf were opposed by relatively weak winds. In February, westerly winds driving the ice east at 7 miles per day were opposed by easterly winds at 3 miles per day; northerly winds driving the ice southward at 12 miles per day were opposed by southerly winds at 3 miles per day. The March drift figures indicate a reduced rate of ice flow from the gulf basin through Cabot Strait.

The December and January drift values from west and north sector winds provided a strong daily rate of ice drift to the southeast, as the east and south drift values were relatively weak. The effective mean daily ice drift rate of these winds for January was 3 miles on the St. Lawrence River, and about 8 miles along the North Shore. The strongest daily rate of ice drift occurred in the central gulf. In this area the daily effective southeastward drift of the ice was 11.5 miles for January and 6.5 miles for February; in the western gulf the daily effective drift of the ice was 7 miles for January and 5 miles for February. The main effect of such drift values was the rapid extension of the ice surface over the gulf waters during January and February (see Figure 3). Effective ice drift is also a measure of the pressure that wind exerts on a floating mass of ice, and therefore has a bearing on the formation of ice shelving and pressure ridging.

The mean daily effective drive of westerly and northerly component winds in the Strait of Belle Isle was 8.5 miles for January and 8.8 miles for February and accounted in large part for the ice being usually observed on the south side of the strait. The effective drift for March was 5.5 miles per day. This figure seems to be reaching a critical value where oceanographic controls exert an increasing effect upon the drifting ice. In mid-March for example, there was extensive movement of Labrador ice through the strait into the northeast arm of the gulf against the flow of the prevailing wind. In Cabot Strait the mean effective outward flow by wind action, for March, was 1.5 miles per day.

TABLE II

Free ice drift per day in miles by sector, December 1960 to March 1961*

| 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 R. | 9 : 8 : 6 : 6 | 4 : 4 : 4 : 5 | 2 : 2 : 4 : 4 | 7 : 4 : 4 : 3 |
| North Shore | 10 : 9 : 4 : 4 | 8 : 10 : 7 : 9 | 4 : 3 : 3 : 4 | 4 : 1 : 1 : 1 |
| St. of Belle Isle | 13 : 12 : 12 : 6 | 3 : 10 : 9 : 10 | 2 : 2 : 0 : 2 | 9 : 3 : 3 : 3 |
| Western gulf | 10 : 10 : 8 : 7 | 5 : 7 : 6 : 7 | 2 : 1 : 2 : 3 | 5 : 2 : 2 : 2 |
| Northumberland SE | 8 : 9 : 5 : 4 | 3 : 5 : 6 : 8 | 2 : 2 : 3 : 3 | 5 : 3 : 2 : 4 |
| Central gulf | 16 : 15 : 7 : 5 | 10 : 14 : 12 : 5 | 3 : 4 : 3 : 6 | 7 : 2 : 3 : 5 |
| Cabot Strait | 7 : 10 : 6 : 5 | 3 : 4 : 6 : 7 | 3 : 3 : 2 : 5 | 7 : 4 : 3 : 4 |
| Mean free ice drift | 10 : 10 : 7 : 5 | 5 : 8 : 7 : 7 | 2 : 3 : 3 : 4 | 6 : 3 : 3 : 3 |

*Ice drift to the nearest whole number

The expansion of the icefields continued throughout the winter. The first break in the extensive ice cover came with the retreat of the ice from the northwestern arm, the northern gulf and the eastern gulf regions. These areas of open water developed in March and expanded in April. In March, in the northern and western parts of gulf, effective southeastward drift of the ice varied from 4 miles to 4.5 miles per day; however, in the eastern part of the gulf easterly sector winds combined with northerly winds provided an effective southwesterly drift of the ice of 1.5 miles per day. The effect of the prevailing winds at this time upon the gulf icefields is vividly illustrated in the March and April ice charts.

During April and May, westerly and northerly sector winds were particularly effective in containing the ice in the catchment basin of the southern gulf. Other factors, such as extensive pressure ridges which add substantially to the thickness of the ice, slowed down the melting of the ice fields in this area.

## GULF ICE DISTRIBUTION

The extent of ice coverage varies with the severity of the winter. December temperatures in the northern and northwestern gulf areas were favourable for ice formation; elsewhere in the gulf region conditions were not so favourable. With the advance of winter, the continued low temperatures (Table III) and strong winds from westerly and northerly sectors provided effective physical conditions throughout the gulf region for the expansion and preservation of the icefields. The result was perhaps the severest ice conditions in the gulf region in recent times.

The mean monthly degree-days of frost for November, December and April for the gulf region are near normal (Table III). The values for January, February and March are from 2.6 to 3.9 mean monthly degree-days of frost greater than normal. Air temperatures were unfavourable as an ice-forming

TABLE III

Mean Monthly Degree-days of Frost,* 1960-1961

| | Nov. M. : N.** | Dec. M. : N. | Jan. M. : N. | Feb. M. : N. | Mar. M. : N. | Apr. M. : N. |
|---|---|---|---|---|---|---|
| St. Lawrence R. | -5 : -1 | 13 : 12 | 24 : 19 | 16 : 17 | 8 : 6 | -8 : -6 |
| North Shore | -1 : 1 | 14 : 15 | 26 : 22 | 23 : 20 | 13 : 10 | -6 : -1 |
| St. of Belle Isle | -1 : 1 | 9 : 10 | 19 : 18 | 22 : 19 | 12 : 10 | -3 : 2 |
| Gaspé-Chaleur | -5 : -2 | 9 : 10 | 24 : 17 | 18 : 16 | 9 : 6 | -6 : -5 |
| Eastern gulf | -7 : -7 | 1 : 2 | 11 : 9 | 17 : 11 | 7 : 4 | -6 : -5 |
| Central gulf | -9 : -7 | 1 : 3 | 13 : 10 | 17 : 13 | 9 : 5 | -3 : -3 |
| Southern gulf | -9 : -7 | 4 : 3 | 17 : 12 | 15 : 13 | 6 : 3 | -6 : -8 |
| Cabot Strait | -9 : -9 | -1 : 0 | 10 : 6 | 13 : 9 | 4 : 2 | -6 : -7 |
| Average for gulf area | -5.7:-3.9 | 6.2:6.9 | 18.0:14.1 | 17.6:14.8 | 8.4:5.8 | -5.5:-4.1 |

*The freezing point of salt water (29°F.) is used as a basis for the mean monthly degree-day values.

**M Mean N Normal

factor in November and April.

Variable conditions for ice formation existed in the gulf region for December; the most favourable conditions existed in the northern parts of the gulf, the least in the southeastern areas of the gulf. The change in the circulation pattern in mid-January that resulted in cold arctic air sweeping the region brought abnormally low temperatures that continued throughout February. Thus as an indicator of ice-forming effectiveness, the mean monthly degree-days of frost show that conditions were most effective for ice formation in January in the St. Lawrence River, North Shore, Gaspé-Chaleur and the southern gulf regions and in February in the Strait of Belle Isle, eastern gulf, central gulf and Cabot Strait regions. The effectiveness of such conditions for ice formation may be shown as follows: The mean monthly degree-days of frost value for January was twice that for January 1960, February's value was almost six times that of the previous February, and the March value was also substantially higher than the previous March. An examination of the mean monthly degree-days of frost for various parts of the gulf for January, February and March indicate that the region was a vast ice-forming reservoir.

One of the most important features of an ice cover is its age as determined by the distribution of new, young and winter ice types. These features are intimately related to oceanographic as well as to climatic factors. As only climatic data was available, the areas where heat loss first became sufficient to form ice must be interpolated. It is observed from Figure 1A that the formation of ice would first occur in the St. Lawrence estuary and off the North Shore followed later by the Gaspé-Chaleur Bay area. From Figure 5 (January 12 to 15), it can be observed that with further loss of heat a substantial area of the northern and western gulf waters reached freezing point and led to the formation of new ice forms; further heat loss aided by shelving gave rise to young ice. Winter-ice development along the Gaspé Coast indicates a greater loss of heat in that area than elsewhere in the gulf. The large quantities of winter ice in Northumberland Strait suggest that the ice was increased in thickness by tidal action as it drifted into the area rather than being formed locally.

The distribution of the ice in the gulf toward the end of January (Figure 6) indicated a rapid loss of heat in order to bring about the concentrations of winter ice that extended across the Magdalen Shallows from the Gaspé coast to the Magdalen Islands. The southwest coast of Newfoundland was the last area where ice formed. By the first of February (Figure 7) the gulf was mainly covered with young ice that resulted from the rapid cooling of the entire gulf under low air temperatures. With continuous heat loss from gulf waters the area of winter ice gradually extended, reaching a maximum about March 8 (Figure 10) when the northwest arm of the gulf became covered with winter ice.

The ice retreat, which first began off the west of Newfoundland, seems to have had an oceanographic basis as indicated by the trend of the 20-degree isotherm for March. A similar basis seems to explain the extensive areas of gulf water that developed and expanded south of Anticosti Island and off the North Shore with mean air temperatures between 15 and 20 degrees. Microthermal conditions appear to have existed within the gulf ice barrier during April as indicated by the formation of new and young ice. Lauzier (1957, p. 16)has shown that large volumes of the gulf's cold-water layer in spring are related to severe ice conditions of the previous winter; thus, the slow reduction of the icefields in the southern and central gulf are thereby closely related to the low temperatures of the waters in these areas, as mild air temperatures at this time prevailed.

## Gulf Ice Cover

The expansion of the Gulf of St. Lawrence icefields in the winter of 1961 is shown by the advance of the ice fronts (Figure 3). The upper St. Lawrence estuary was ice-covered by December 18. The ice front lay across the mouth of the St. Lawrence estuary on December 28, and across the western entrance to Gaspé Passage on January 10. By January 12-15, the ice front lay off Brion Island, and off St. Paul Island by January 25; by February 1, it had extended across the entrance to Cabot Strait. The most advanced position of the ice front was reached about February 23.

The advance of the Labrador ice through the Strait of Belle Isle was as erratic as in previous years. In mid-January, a tongue of Labrador ice extended through the western entrance of the strait;

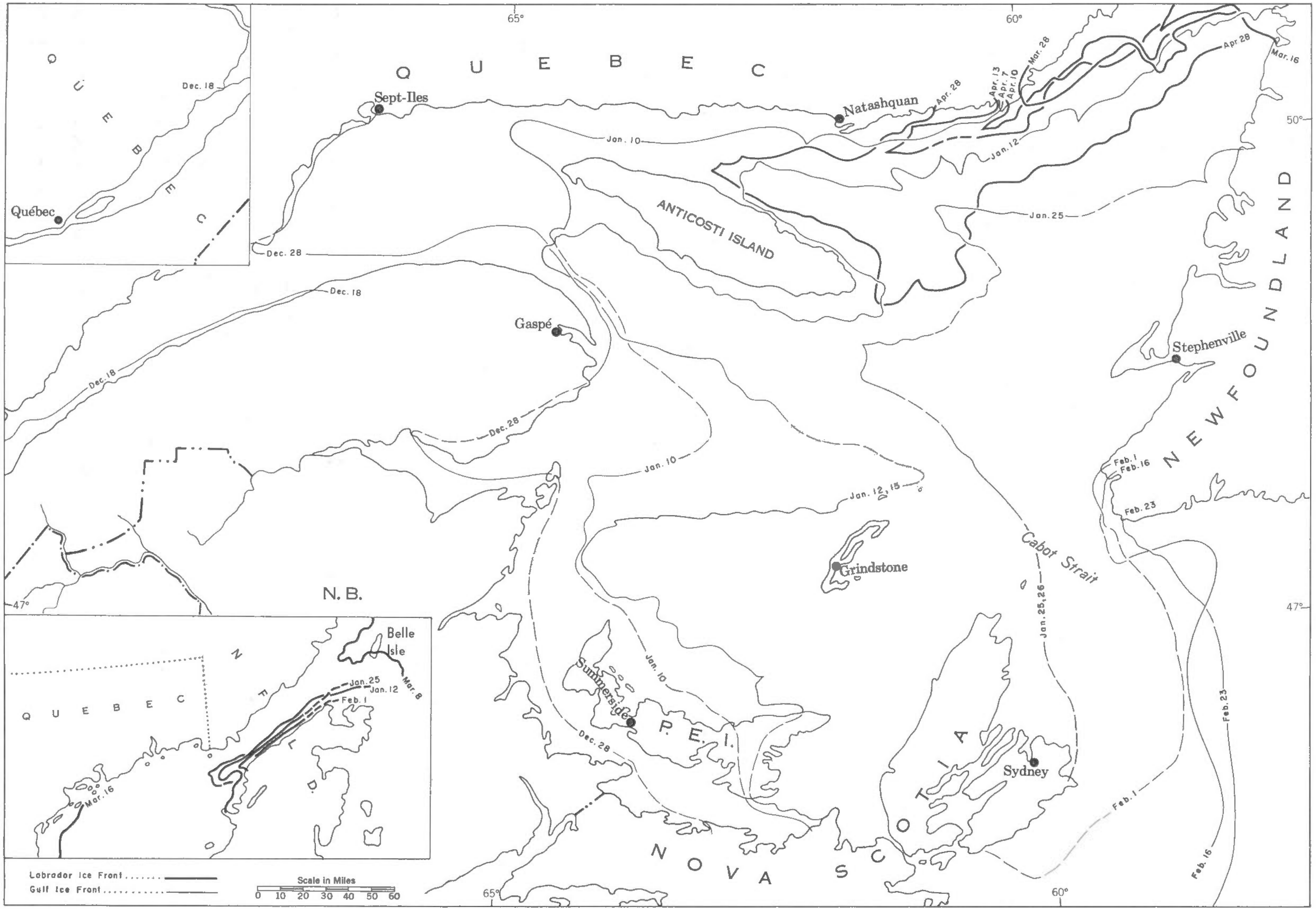


**Figure 3.** Advance of the ice fronts in the Gulf of St. Lawrence, Winter 1961.

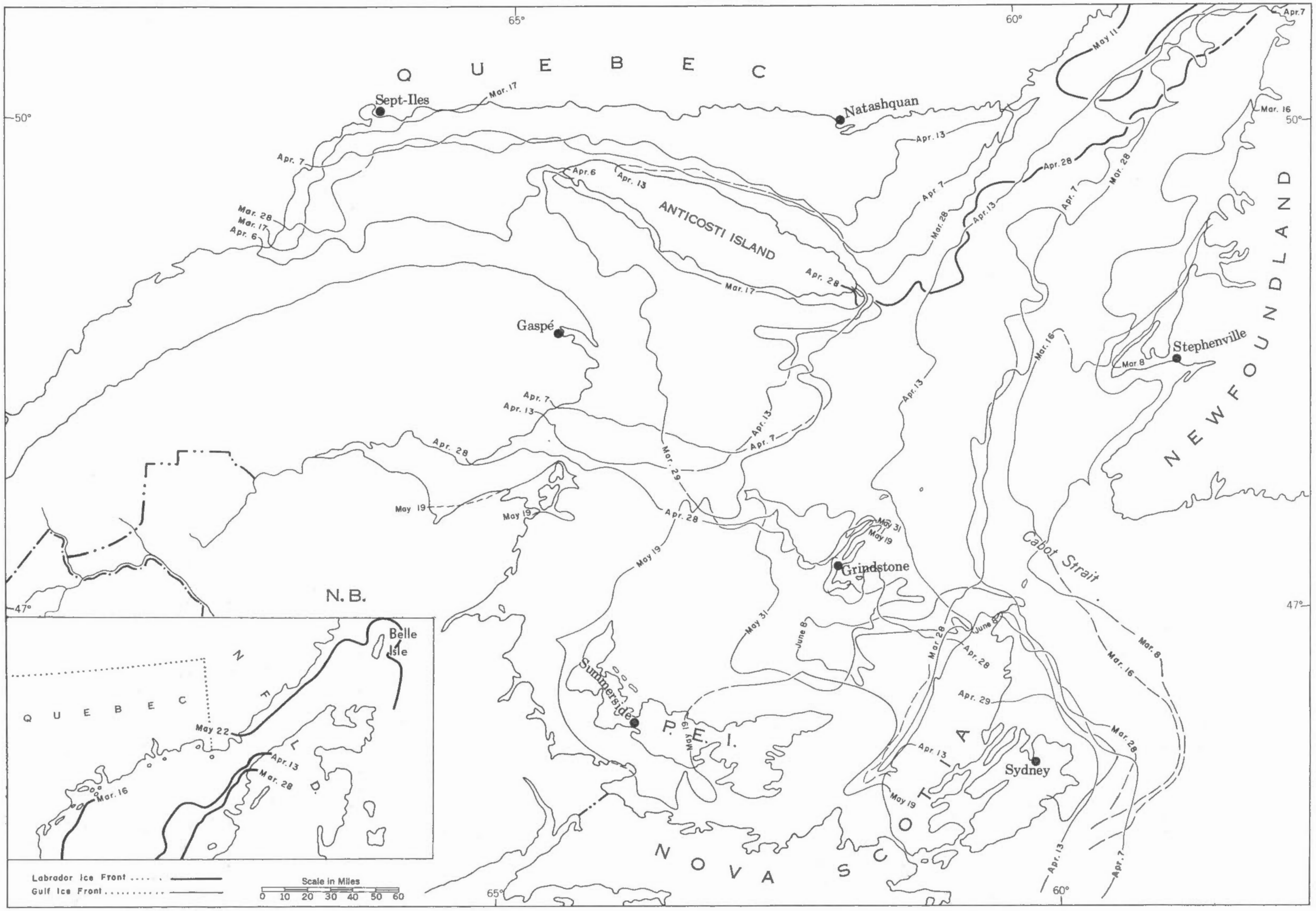


Figure 4. Retreat of the ice fronts in the Gulf of St. Lawrence, Spring 1961.

thereafter, this ice slowly retreated and it seems to have disappeared from the strait about mid-February. On March 8, Labrador ice appeared at the northeastern entrance to the strait, and extended rapidly westward bordering the northern side of the northeast arm of the gulf. By March 28, the leading edge of the ice lay off Cape Whittle, and by April 28, it had reached Anticosti Island. In the area south of Cape Whittle, the Labrador ice was a constitutent in the extensive formations of gulf ice.

The retreat of the gulf ice is shown on Figure 4. Extensive icefields covered the gulf from February 1 to March 17. The first breach in the gulf icefields developed in the St. Lawrence estuary about March 16; thereafter, the area of open water continued to extend eastward. Two large areas of open water developed independently of the St. Lawrence estuary open water, south of Anticosti Island and off the North Shore. These three areas of open water merged about April 10. A second major breach, beginning about March 8, developed off the coast of Newfoundland and gradually extended northward and westward. The barrier of ice that now extended from the Strait of Belle Isle to the Magdalen Islands narrowed slowly, and began to thin out in the area to the northeast of Anticosti Island about March 28. By April 15, this barrier was breached, and the two major areas of ice, one in the northeastern part of the gulf and the second in the southern gulf, continued to diminish.

In the area east of Cape Breton Island, the gulf ice had reached its greatest extent about February 23; thereafter, its retreat was marked by continuous readjustment of the ice front. Although these icefields were cut off from the main supply of gulf ice about March 28, intermittent supplies of ice continued to spill around Cape North until May 25. The ice disappeared from this area about May 29.

Ice in the southern gulf continued to diminish slowly in May, the ice front being in a continuous state of readjustment. Northumberland Strait became ice-free about May 30. About May 25, the extensive icefields, lying off the north coast of Prince Edward Island, gradually shifted towards the west side of the Magdalen Islands, thence, rotated anti-clockwise to the southeast of the islands. From this position the icefields deteriorated rapidly, the last remnants disappearing off Cape North shortly after June 8.

The retreat of the Labrador ice in the northeastern arm of the gulf did not begin until about April 28; its retreat after this date was remarkably steady. As there was no renewal of ice through the Strait of Belle Isle, the ice front by May 22 had retreated towards the eastern entrance of the strait. Except for small bergs and growlers the strait became free of sea ice shortly after this date.

## Ice Types and Concentration

In the winter of 1961 new and young ice types were the major constitutent in the gulf icefields until mid-February; thereafter, they constituted the main element of the ice cover on the leeward coasts of the gulf. In seaward areas storms and rough seas churned this ice into sludge and slob, the latter being the familiar pancake ice. With invasions of cold air, new ice formed rapidly and through extensive shelving, gave way to young ice, and the latter, farther removed from the leeward coast, gave way to winter ice. Because of strong winds and low temperatures, the level winter ice was turned into heavily pressure-ridged icefields, the area of which expanded with the advance of the season. Pressure ridging was particularly severe on windward coasts. The ice in the central and southern gulf region generally varied in concentrations of 009 to 0010, of which 8/10 was winter ice and the remainder new and young ice types (see map legend). The symbol, 009-00(10), thus expressed, and the fact that young and new ice forms were observed indicates that consolidation processes were in effect.

A remarkable feature of the St. Lawrence River ice was observed in the nature of its distribution as it emptied into the gulf past the Gaspé coast. The surface of this ice was rough in detail and yellowish in colour; therefore its distribution could be observed. The ice on the north side of the St. Lawrence River ice stream continued southeastward to the Magdalen Islands, but the river ice hugging the Gaspé coast, gradually bent southward towards Chaleur Bay. By April, when the surface snow had melted, this ice extended along the north side of Prince Edward Island.

Two areas, namely, the Strait of Belle Isle and Northumberland Strait, were covered with radically different major types of ice, and gave rise to severe pressure ridging. The Labrador ice that entered the gulf region through the Strait of Belle Isle is described in this report as polar ice as it originated in arctic or sub-arctic areas outside the confines of the Gulf of St. Lawrence. This ice was intensely worked over with pressure ridging usually amounting from 7/10 to 9/10 of the ice surface. These icefields, containing small bergs and numerous growlers, were also whiter than the winter ice of the gulf. Although reddish in color, the ice in Northumberland Strait was as intensely worked over as that in the Strait of Belle Isle. The progress of the ice through Northumberland Strait is revealed in the area of pressure-ridged ice which increased from west to east.

Also remarkable were the heavy icefields that developed off the east coast of Cape Breton Island. Sustained southerly drift of the ice formed a massive barrier with a large amount of pressure ridging off the Cape Breton coast. Northerly gales in February and March rafted this ice to a thickness of 30 feet, and drove the icefields to the vacinity of Sable Island.

The invasion of Labrador ice was marked by an influx of small bergs and growlers that followed the general southwestward drift of the ice. A number of these reached Anticosti Island after mid-April; a small berg reached the position of 62°15'W 48°48'N on the ship route southwest of Heath Point. Small bergs and growlers continued to drift into the northeast arm of the gulf after the disappearance of the sea ice but these generally lay off the North Shore.

By mid-January, landfast ice had covered the sheltered bays and harbors on the western and northerly parts of the gulf (Figure 5); it was closely related to the movement of the ice cover across the gulf. In the spring, break-up of the landfast ice began after mid-April in the western and northern parts of the gulf, a considerable time after the offshore waters had become ice-free. In the southern and northeastern parts of the gulf the harbors did not become ice-free until the ice barrier had moved off the coasts in May.

## GULF ICE DISTRIBUTION MAPS

The principal features of ice distribution that have been discussed and which were observed in the course of the 1961 ice reconnaissance survey are shown graphically in Figures 5 to 15. These maps cover a period of changing ice conditions from January 12 to April 28. For the months of May and June, when the icefields were restricted to the southern and the northeast arm of the gulf. Figures 16 to 19, produced by the Meteorological Branch, Department of Transport, are included to show the final deterioration of the icefields.

### Ice Terminology

The terms, together with their definitions, are those most frequently used to describe ice features of the gulf of St. Lawrence region. The number of terms are kept to a minimum, to help facilitate the classification and mapping of the ice distribution that is observed in the course of the winter survey. The main purpose of this terminology, together with the quantitative symbols employed, is to provide a fuller understanding of the ice cover that is presented graphically in Figures 5 to 26.

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

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

Consolidated ice: Ice floes of different sizes that are compacted into extensive fields; consolidation usually advances 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 is 600 to 3,000 feet; a large floe is 3,000 feet to 5 miles. Qualifying terms such as light and heavy are often used but these terms 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 ft.) frequently appearing greenish in color 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 which, through consolidation by freezing and compression, binds together the shorefast ice on either shore.

Ice concentration: The ratio of the areal extent of ice present to the total combined extent of the ice and water surface. 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 giant floes. The total ice surface is 9/10.

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

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

Ice forms: Ice forms consist of 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 area of ice, usually composed of ice wreckage or small fragments and detached from larger areas of ice.

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

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: New ice includes such forms as grease, slush, frazil, very young ice and the early stage of sludge.

Pack ice: Any substantial area of floating ice, 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 sub-arctic areas outside of the confines of the Gulf of St. Lawrence region.

Polynya: An area of open water of varying size and located in the same area every year. In the gulf, polynyas occur on the leeside of coasts during the winter months.

Pressure ridge: A ridge of ice. Wherever a substantial area of the ice is in the form of pressure ridges, coverage may be expressed in tenths; for example $\frac{PR}{3}$ denotes 3/10 of the area of the ice surface is in the form of pressure ridges, and is a measure of surface roughness as well as of the normal ice area that has been reduced through pressure ridging.

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

Shelving: Shelving refers to the interlocking rectangular pattern of new and young ice types; 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 $\frac{Sg}{4}$ - 4/10 of sludge.

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

Very young ice: Ice that is recently formed in calm water and is dark in appearance. Coverage is expressed in tenths; thus $\frac{VY}{6}$ - 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 becoming grey from water seepage through the ice. Coverage is expressed in tenths; thus $\frac{W}{5}$ - 5/10 of winter ice.

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

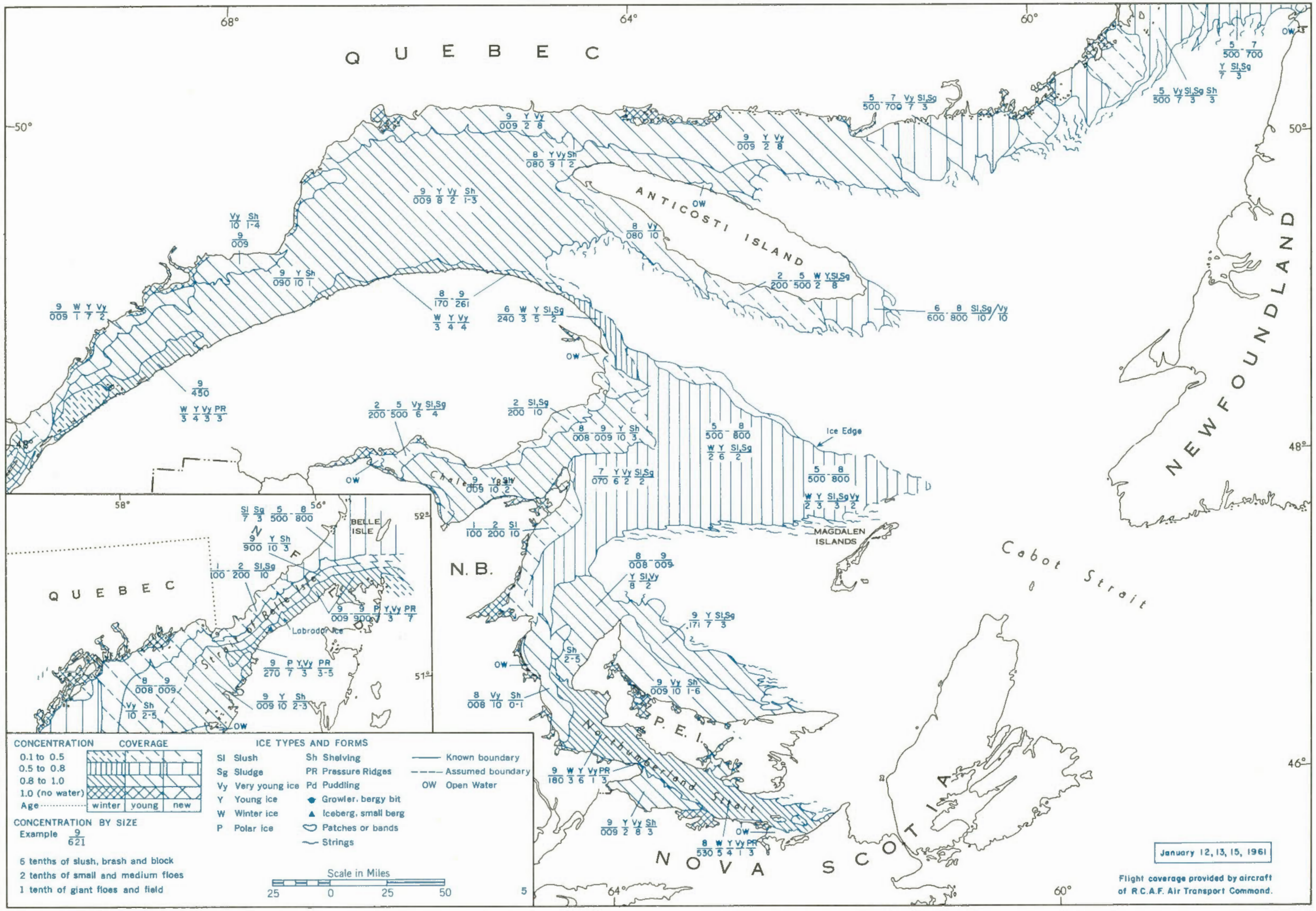


**Figure 5.** Ice distribution, Gulf of St. Lawrence, January 12, 13, 15, 1961.

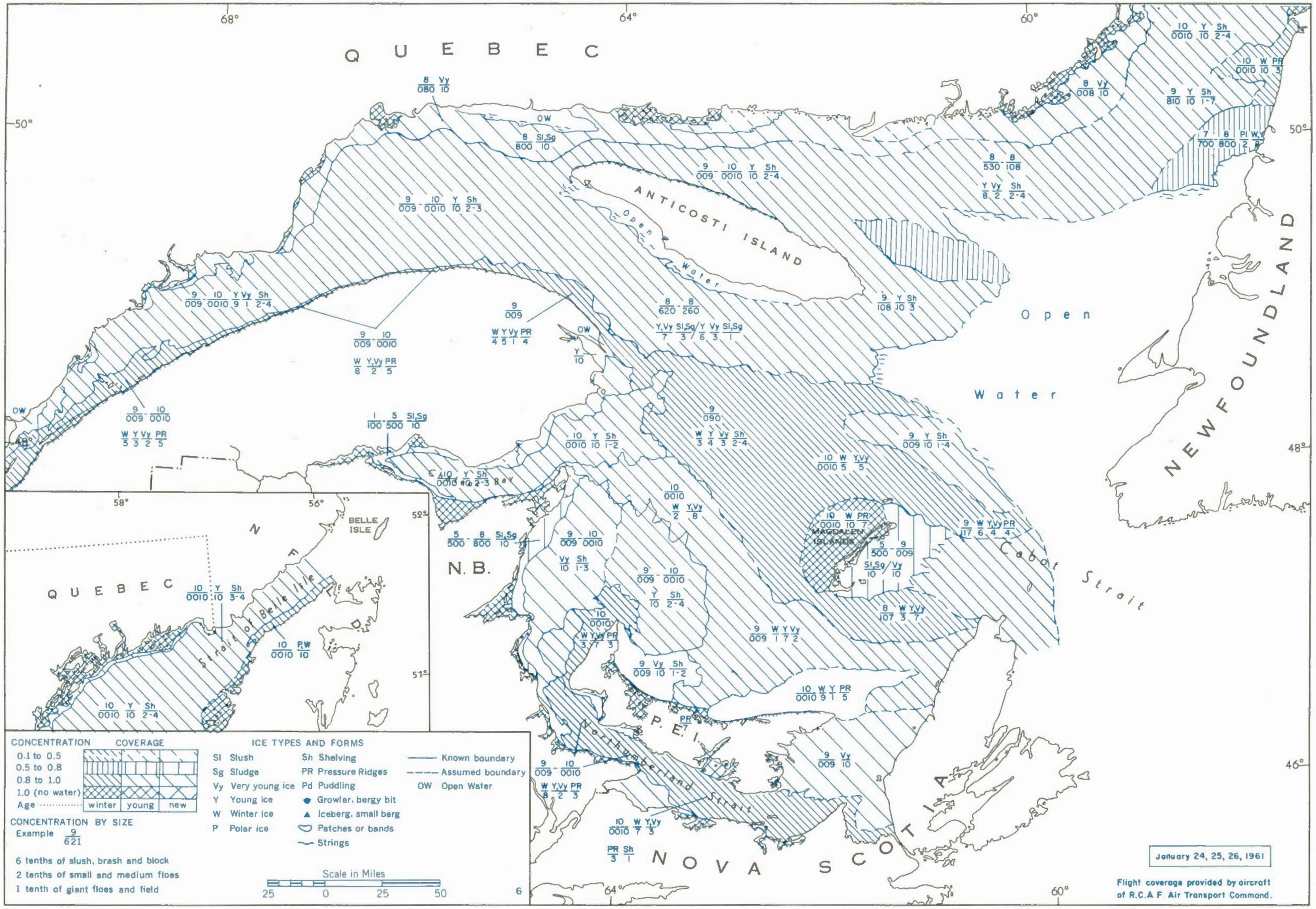


**Figure 6.** Ice distribution, Gulf of St. Lawrence, January 24, 25, 26, 1961.

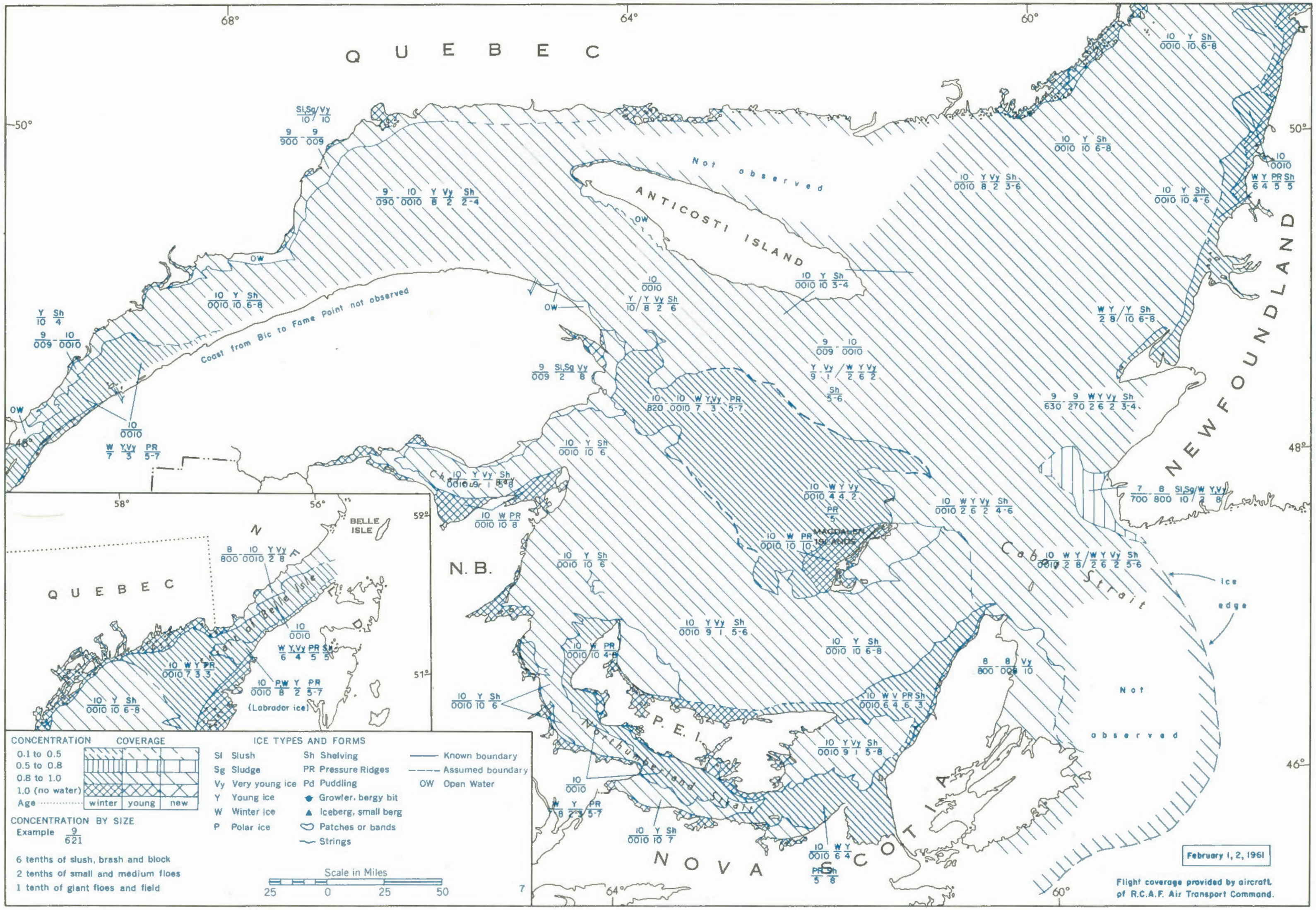


Figure 7. Ice distribution, Gulf of St. Lawrence, February 1, 2, 1961.

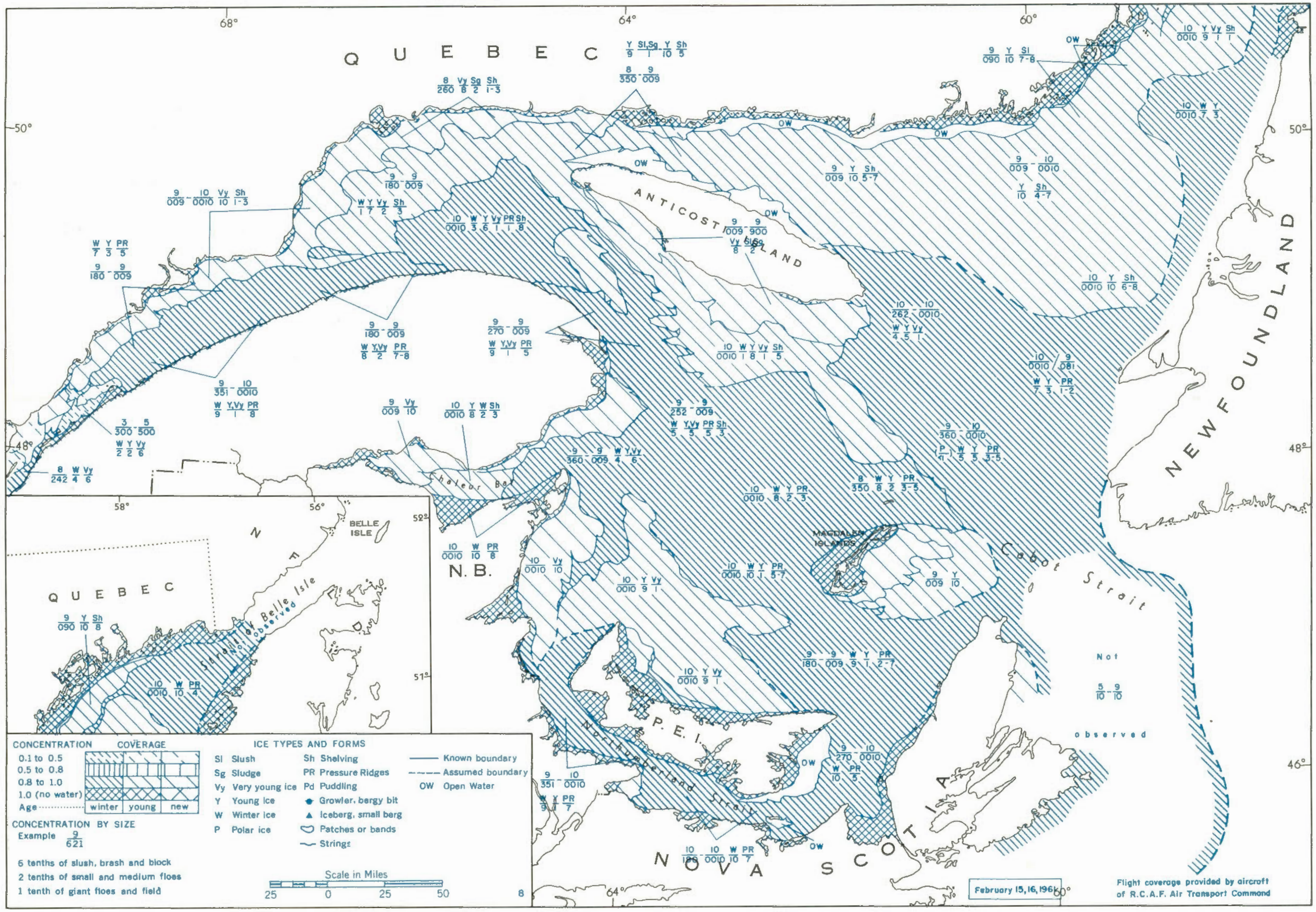


**Figure 8.** Ice distribution, Gulf of St. Lawrence, February 15, 16, 1961.

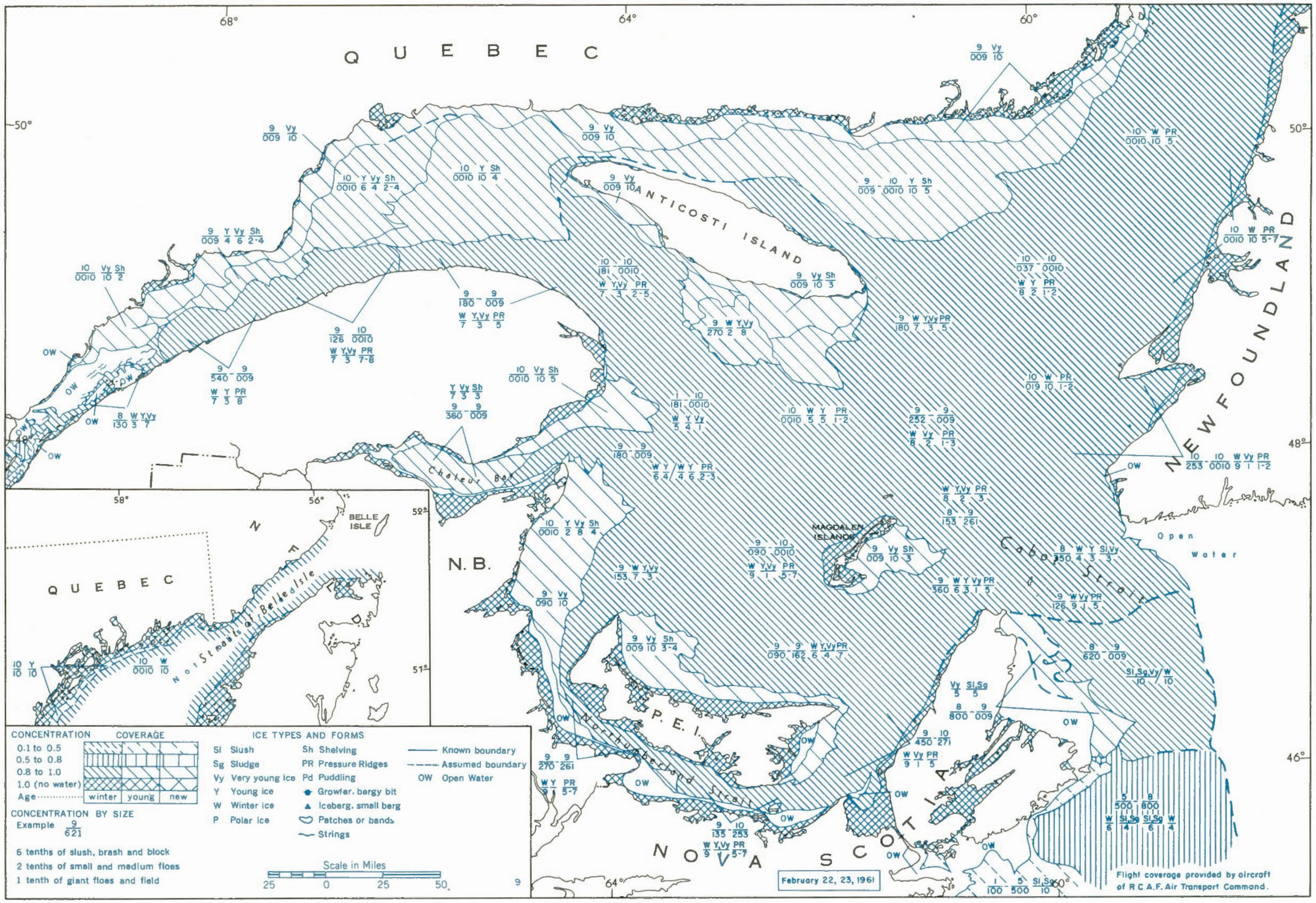


**Figure 9.** Ice distribution, Gulf of St. Lawrence, February 22, 23, 1961.

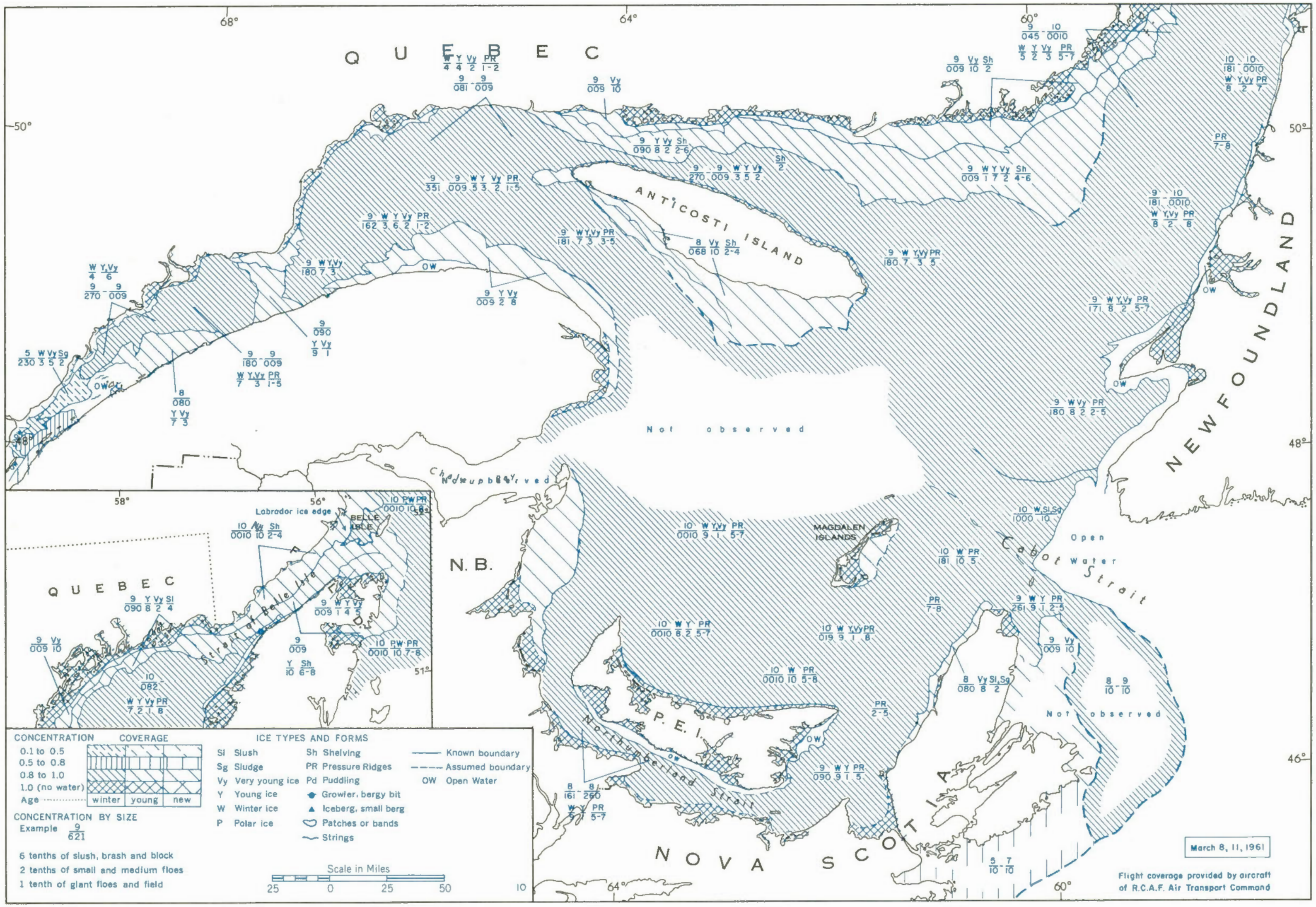


Figure 10. Ice distribution, Gulf of St. Lawrence, March 8, 11, 1961.

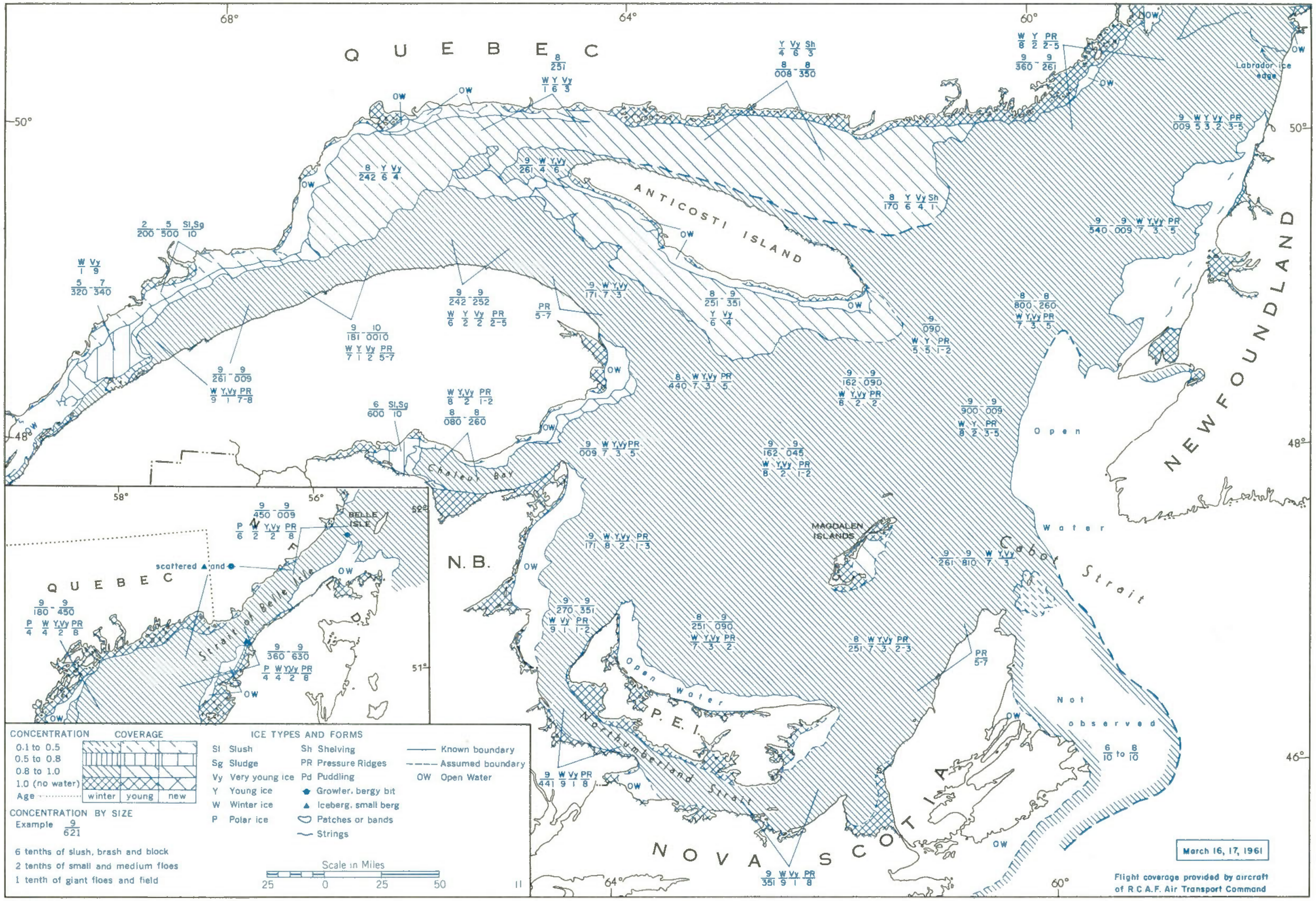


**Figure 11.** Ice distribution, Gulf of St. Lawrence, March 16, 17, 1961.

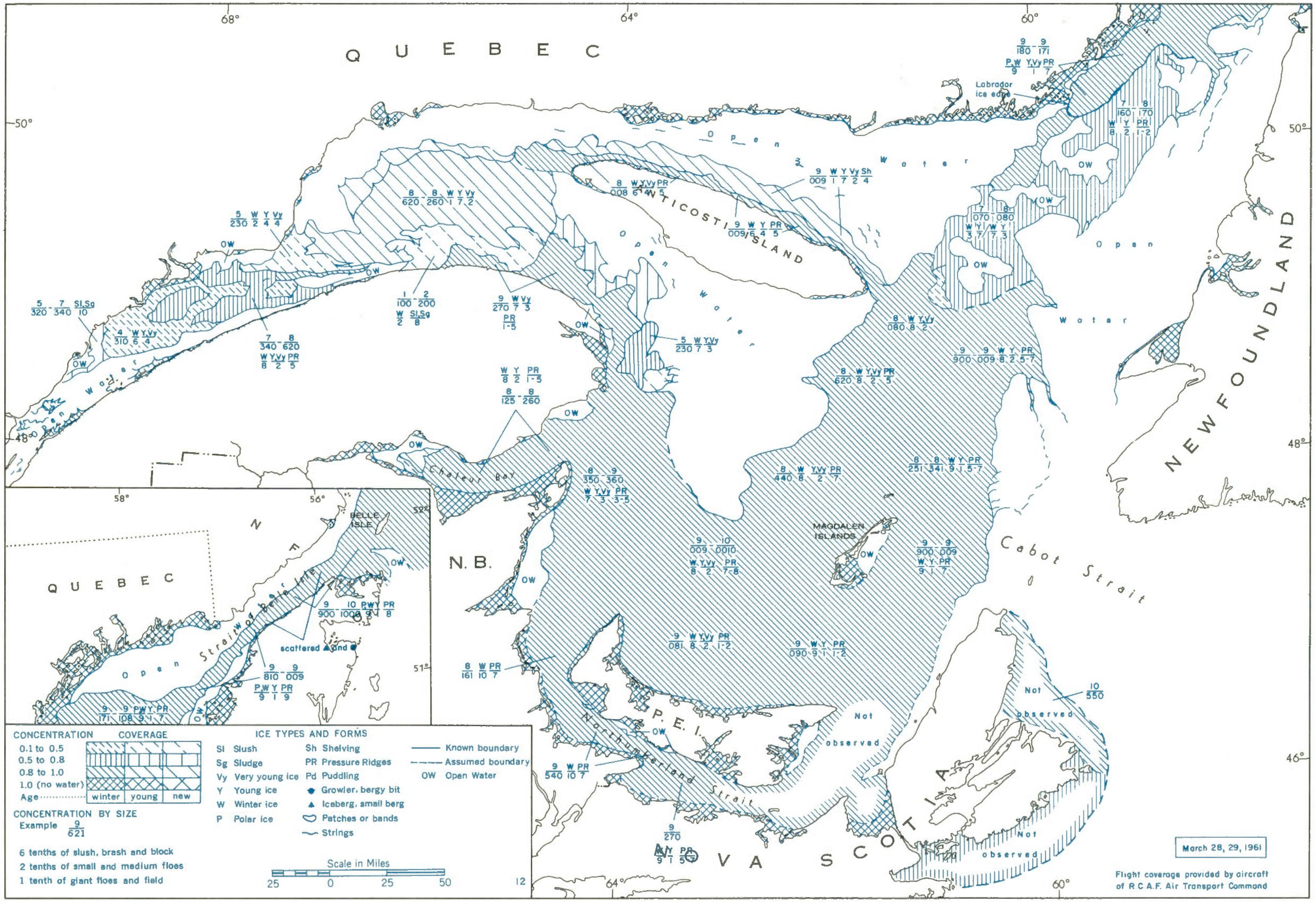


**Figure 12.** Ice distribution, Gulf of St. Lawrence, March 28, 29, 1961.

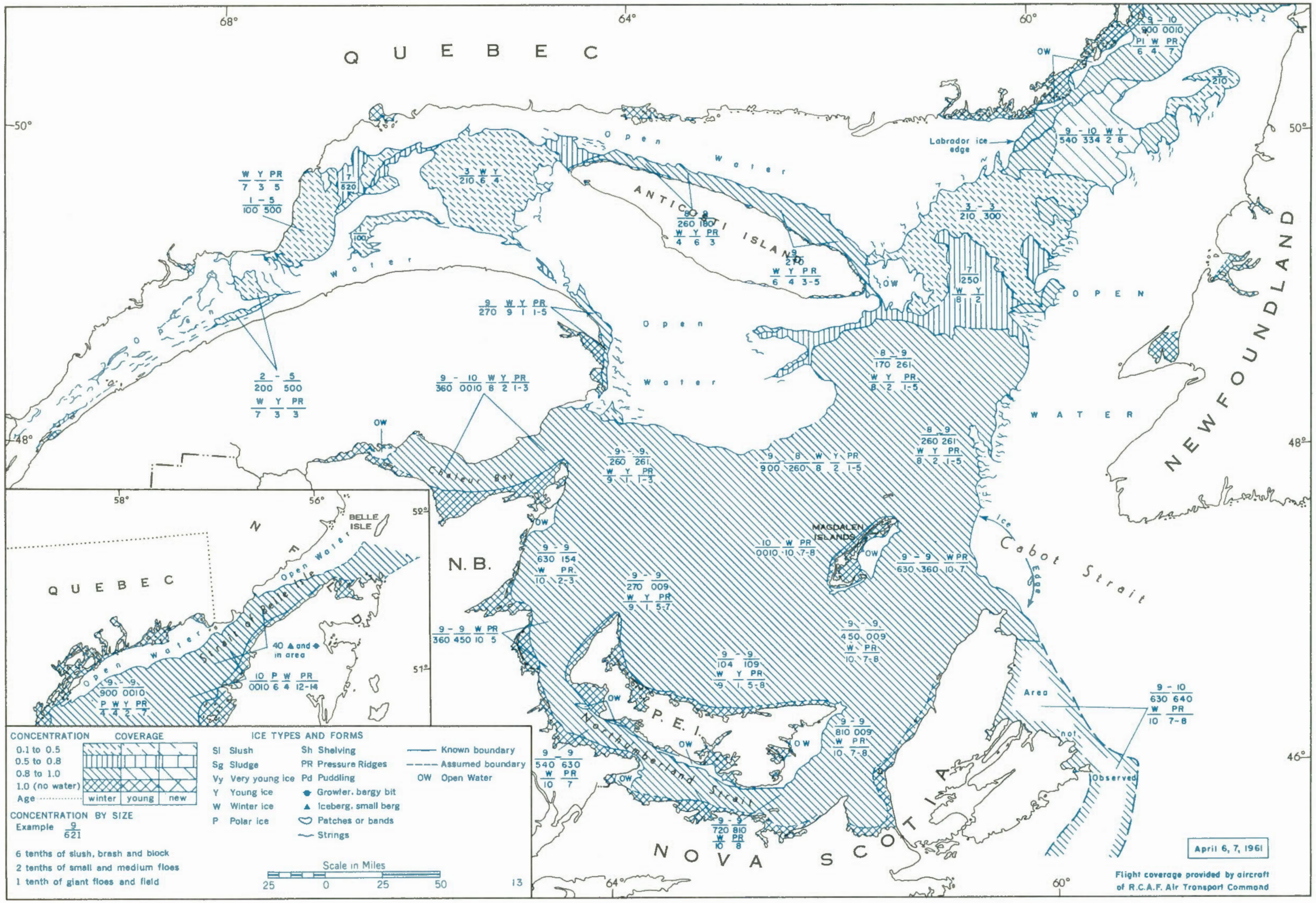


**Figure 13.** Ice distribution, Gulf of St. Lawrence, April 6, 7, 1961.

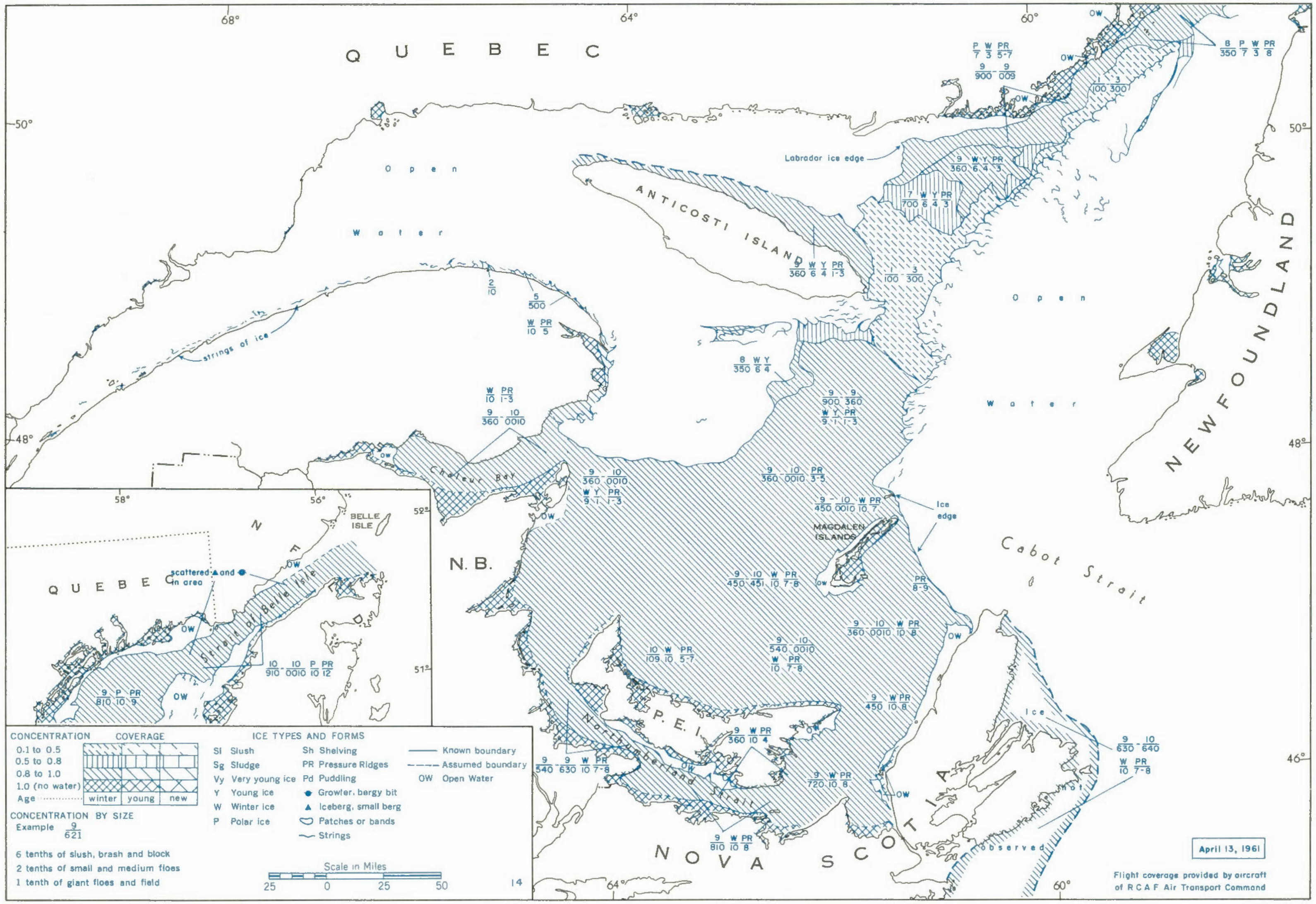


**Figure 14.** Ice distribution, Gulf of St. Lawrence, April 13, 1961.

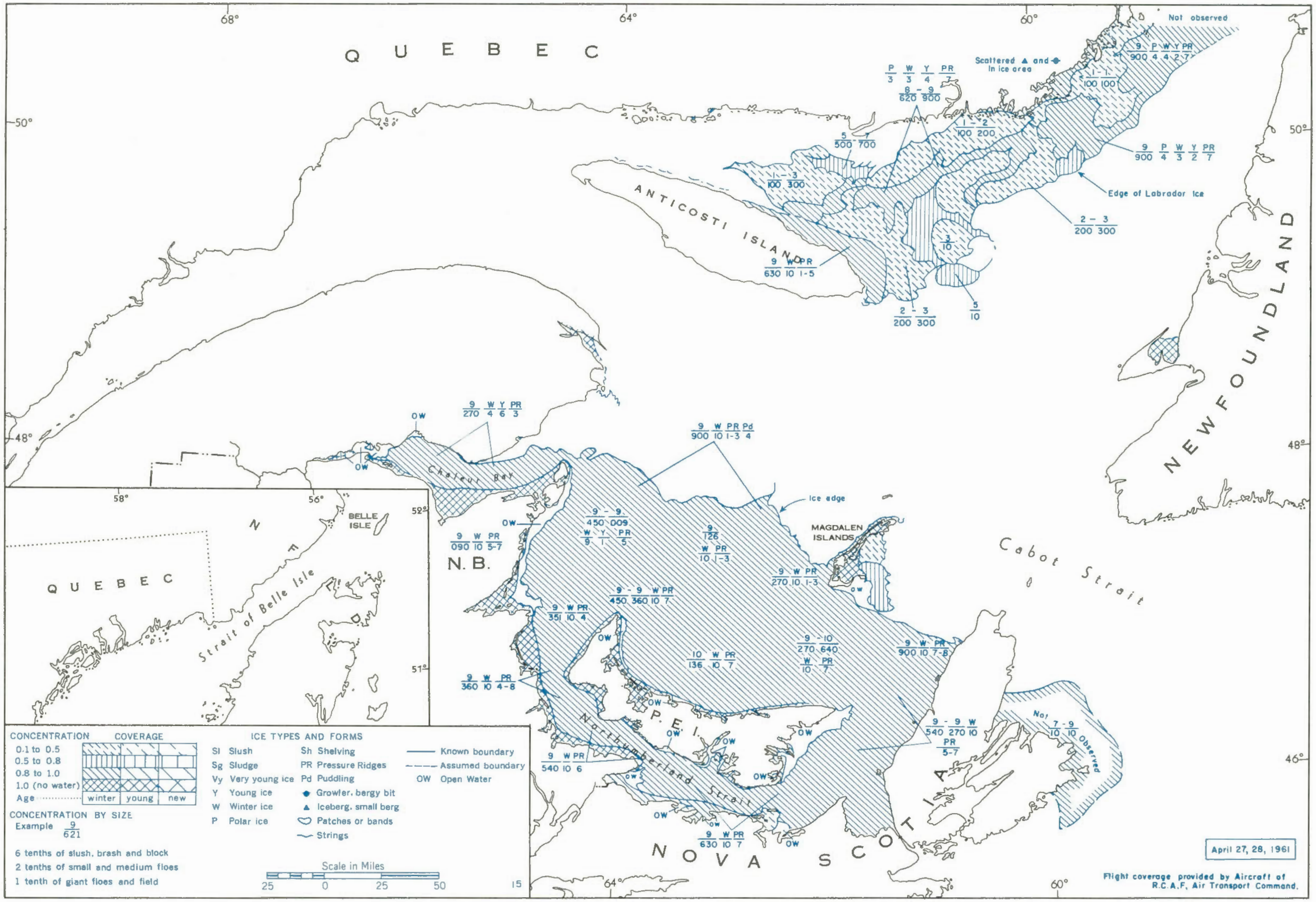


**Figure 15.** Ice distribution, Gulf of St. Lawrence, April 27, 28, 1961.

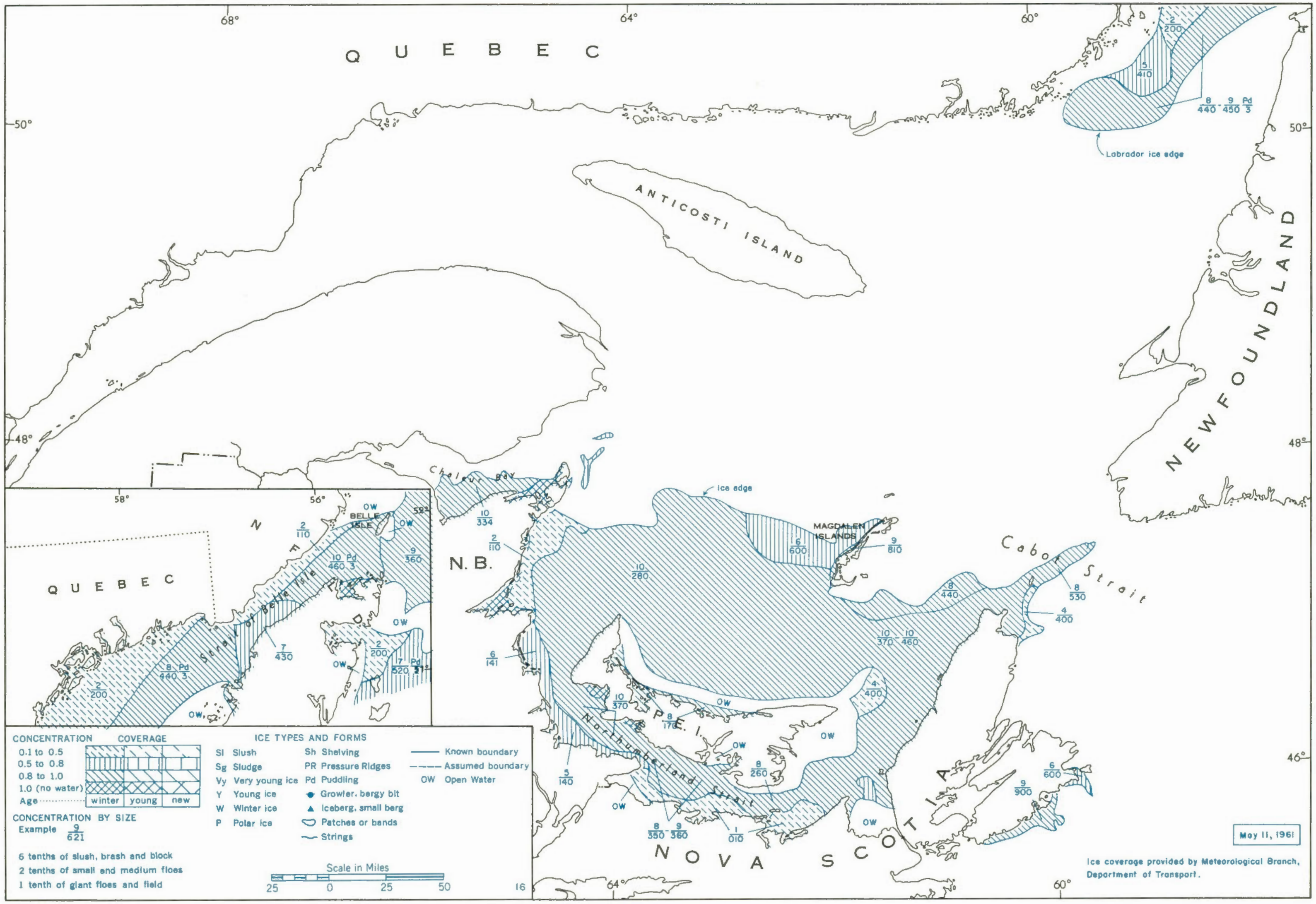


**Figure 16.** Ice distribution, Gulf of St. Lawrence, May 11, 1961.


Figure 17. Ice distribution, Gulf of St. Lawrence, May 19, 22, 1961.

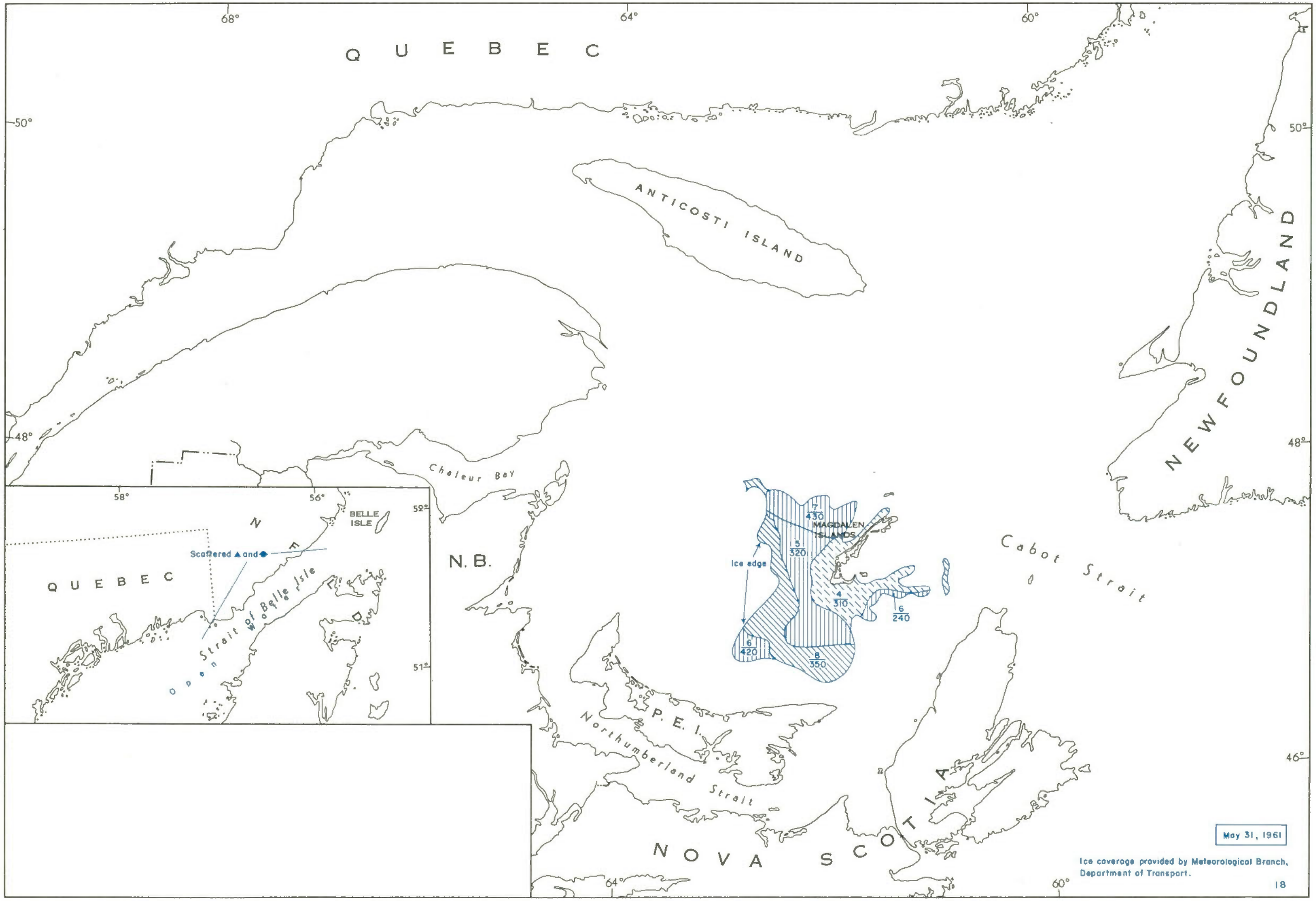


Figure 18. Ice distribution, Gulf of St. Lawrence, May 31, 1961.


**Figure 19.** Ice distribution, Gulf of St. Lawrence, June 8, 1961.

## PART II

## THE ST. LAWRENCE RIVER

The middle St. Lawrence River extends from Lake St. Louis to the Island of Orleans; the lower St. Lawrence River is the broad, shallow estuary that extends from the Island of Orleans to the Saguenay River. The ice charts (Figures20 - 26) include these two parts of the St. Lawrence River; Part II of the report deals with the middle St. Lawrence.

### WEATHER CONDITIONS

November was mild in the St. Lawrence River valley, and mean temperatures ranging from 35 to 41°F. or 5 degrees above normal, at first appeared to herald a mild winter (Table IV). December was a cold month with the mean temperature falling to 16°F., 2 degrees below normal. Conditions favorable for ice formation and growth existed, and shorefast ice became established along either shore of the river. January was cold throughout the month, and in the latter half the area was in the grip of a severe cold wave; mean temperature dropped to 5°F., or 6 to 8 degrees below normal. During February temperatures began to climb, the mean being 17°F., or 4 degrees above normal. Temperatures continued to rise, and in March were back to normal with a range of 22 to 27°F. for the valley. April, with high mean temperatures of 38 to 42°F., saw the rapid removal of the shorefast ice. The difference in temperature between the southwestern and northeastern parts of the river varied from 5 to 7 degrees, throughout the winter. The lowest temperatures in the valley tending to centre about Lake St. Peter. Intervals of mild weather associated with passing storms heralded a premature break-up of the river ice in March; however, with the onset of arctic air the river ice was again re-consolidated.

TABLE IV

Mean Temperature values (F.°) 1960-1961
(Middle St. Lawrence River area)

| Category | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. |
|---|---|---|---|---|---|---|
| Mean temperature | 38 | 16 | 5 | 17 | 25 | 40 |
| Temperature range | 35 to 41 | 14 to 19 | 4 to 9 | 13 to 30 | 22 to 27 | 38 to 42 |
| Departure from normal | 5 | -2 | -6 to -8 | 4 | 0 | 1 |
| Mean monthly degree-day* | -6 | 16 | 27 | 15 | 7 | -11 |
| Excess of temperatures at Montreal over Quebec | 6 | 3 | 1 | 4 | 3 | 3 |

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

In the middle St. Lawrence River valley ice formation and growth was a rapid process during the winter of 1960-61. By the end of February the mean monthly degree-days had reached 58, a value about one-third higher than in the previous year and exceeded in the same period only in the North Shore region of the gulf. The value for March was equivalent to that recorded in the southern parts of the gulf; whereas, the rate of melting in April as expressed by the number of mean monthly degree-days was substantially higher than in the previous year.

RIVER ICE DISTRIBUTION

The main outline of shorefast ice was established in December and bordered both shores of the river downstream to the east end of the Island of Orleans. In the lower St. Lawrence intermittent stretches of shorefast ice occured on the North Shore; on the south side of the river, except for a few gaps, it continued almost an an unbroken strip beyond Matane. Above the Lachine Rapids and upstream past Cornwall shorefast ice covered the river; below the rapids the current carried the drifting ice downstream. Because of shoals and extensive tidal flats that lie off-shore, heavy masses of pressure-ridged ice bordered the channel, particularly between the Island of Orleans and Montreal.

Drifting ice which began with the onset of freezing temperatures had advanced downstream to a point on the river below La Malbaie by December 18.

In the lower St. Lawrence, between the Island of Orleans and the mouth of the Saguenay, new and young ice cover was gradually replaced by winter ice towards the end of January. The period of heavy ice in the estuary seems to have lasted no more than 7 or 10 days; thereafter, areas of open water, new and young ice, and light winter icefields predominated. Heavy local concentrations of winter ice occurred, and the general distribution of the ice varied from day to day. In the upper estuary below the Island of Orleans, there appeared to be a general shift of the ice from the north to the south shore and back again. The retreat of the ice began about March 16 and continued upstream from the mouth of the Saguenay, so that, by the end of March, the estuary was open to within 15 miles of the Island of Orleans. For approximately three weeks the river ice continued to discharge through Orleans Channel east of Quebec city before disappearing about April 20.

The ice that formed in the river generally consisted of a stream of heavy winter ice bordered on one side by new ice and on the other by open water swinging at the bends from one side of the river to the other. This general pattern continued until the ice discharged into the estuary past the Island of Orleans. Usually the amount of drifting winter ice was quite negligible in the upper part of the river but at

Quebec it constituted a large part of the ice cover. The winter ice consisted mainly of ice snapped from the leading edge of the shorefast ice. A perennial feature of the Montreal harbour area is the extensive area of massed parallel ridges that develops and which largely results from the 15-mile stretch of open water that feeds ice into the harbour. However, a line of piers that supports the new Champlain bridge which crosses the basin from Nuns Island caused the shorefast ice to extend across the basin and to back up to the foot of the Lachine Rapids. The immediate effect was to reduce the area of open water that previously contributed supplies of ice. The presence of this bridge may well reduce the amount of ice that forms in the harbour area.

Although ice continued to break off from the leading edge of the landfast ice, changes in the outline of shorefast ice in the middle St. Lawrence River were of a minor nature. It was not until mid-March, when the general retreat of the shorefast ice began, that there was a reduction in the amount of winter ice moving downstream; masses of winter ice continued to jam in the bends of the channel from time to time. Shorefast ice had all but disappeared from the river above Sorel by April 13, and by April 21 the river was virtually ice-free.

The river may be considered in two parts; namely, the riverine section from Montreal to Quebec and the estuarine section below Quebec. In the former section from Quebec to Lake St. Peter the ship or deep river channel tends to be more clearly defined than that above Lake St. Peter. Lines of islands, bars, shoals and other obstructions which border the deep river channel form a nucleus around which shorefast ice develops. Strong easterly winds and excessive low temperatures associated with an in-coming tide can reduce substantially the rate of flow of the river and produce conditions at various places on the river, particularly at bends and constrictions, conducive to the growth of ice bridges. With the formation of an ice bridge, the blocking of the channel progresses upstream, the rate of which depends on the amount of ice being carried by the river. The ice is often compressed into tight windrows of pressure ridges that have a damming effect on the river. Below the ice bridge the open water area gradually becomes more extensive. Often, ice bridges are relatively short; however they may, for example, extend under favourable conditions from Sorel to Montreal. Often the bridges burst under the pressure of the backed-up river. The first ice bridge of the winter season develops at Lake St. Peter, the area of highest heat loss, and lowest current velocity.

In a tidal river such as the St. Lawrence, tidal action has an important influence on the distribution of the ice. It is stated (Neu and Clarke, 1961) that below Lake St. Peter tide is a major factor in keeping the channel open and also in producing the tongue-shaped stretch of open water that is a perennial feature at the eastern end of the lake. One of the major effects of a consolidated ice cover is to choke the upstream range of the tide thereby reducing the tide as an agent for maintaining an open channel. In the St. Lawrence estuary the ratio of the volume of river water to tidal water decreases rapidly below Quebec, being 1:1 at Quebec, 1:12 at Ile aux Coudres and 1:40 at the mouth of the Saguenay. The following quotation (Neu, 1961) explains the nature of the forces that affect the distribution of ice in the St. Lawrence River:

> "In September 1959, the National Research Council surveyed the hydrographic properties of the river at Pt. Origneaux, 60 miles below Quebec. From this survey it was clearly established that salt water intrusion, which extends to Orleans Island, creates a density current. This, superimposed on the tidal current, substantially increases surface current outward and bed current inward. The rotation of the earth which causes water to deviate from its normal course in the northern hemisphere to the right and in the southern hemisphere to the left of the water motion has a pronounced effect on this condition. The strength of the deviation is a function of the velocity of moving water, the surface layer with its greater current outward and the bed layer with its greater current inward are therefore, in their residual motion, directed to the south and north shore respectively. A calculation of the forces acting on the surface layer, 20 ft. deep and normal to the direction of the river channel, shows that those to the south shore are three to four times greater than those to the north shore. This excess of force piles up the ice along the south shore and maintains it there until it is melted or flushed into the Gulf. The wind, which is predominantly from the northwest, contributes to this deviation but cannot upset it."

In the estuary it appears that ice is diverted with the fresh water surface layer to the south shore because of the Corrolis force. However, in the gulf, Jarlan (1961) has shown that wind moves the ice with the upper surface layers of the water. To understand the motion of the ice in a tidal river the physical forces acting on the 'carrier' such as tide, river flow, density exchange motion, Coriolis force, and wind must be considered.

## RIVER ICE DISTRIBUTION MAPS

The various features of the distribution of the St. Lawrence River ice that have been discussed and that were observed in the course of the 1961 ice reconnaissance survey are shown graphically in Figures 20 to 26. These maps cover the period from January 12 to April 26. As the survey covered the area between Cornwall and Montreal, six insets were selected that are representative of ice conditions in this part of the river between freeze-up and the spring break-up. These insets are shown in Figure 26. The graphic and fractional method of showing ice types and ice concentrations is similar to that used in the ice distribution maps for the gulf. The break-up of the Ottawa River between Ottawa and Montreal during March is also shown on Figure 26.

## SUMMARY

The aerial ice reconnaissance survey of 1961 showed that ice conditions in the St. Lawrence River and the Gulf of St. Lawrence were severe. Mean monthly temperatures for January and February were considerably lower than in previous years and also were considerably below the normal for the region (Table V).

TABLE V

A comparison of mean monthly temperatures (F.°) of 1958-1961

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

The mean temperatures from December 1960 to March 1961 ranged from 5 to 25°F. for the middle St. Lawrence River, 7 to 19°F. for the northern gulf region, 16 to 26°F. for the central and southern gulf region, and from 20 to 29°F. for the Cabot Strait area. Because of the abnormally low temperatures and prevailing westerly and northerly sector winds, the gulf region supported an extensive ice cover. The lightest ice formations occurred on the leeside of the coasts bordering the North Shore of the gulf and the St. Lawrence estuary, southern Anticosti Island, northeastern New Brunswick, and other leeward areas.

Icefields were well developed in the middle and lower St. Lawrence River by the end of December. Rapid expansion of the icefields followed in January and continued through February into March. In the main, the deterioration of the icefields took the form of a three-pronged retreat progressing from east, northwest and north. The St. Lawrence estuary was ice-free by April 13, and the river by April 20. By April 20, the shipping lane through the gulf and Cabot Strait became open. At the end of April, the southern gulf and the northeast arm were the two major areas of ice congestion. In the northeast arm, much of the ice consisted of polar or Labrador ice which had entered the gulf mainly after March 8. This ice reached its maximum penetration about the end of April; its retreat after this date was steady, and, except for small bergs and growlers, it disappeared from the Strait of Belle Isle about May 22.

New and young ice constituted the main types in the ice cover until mid-February; thereafter, winter ice was the main cover in the gulf. Topographical forms, such as shelving in new and young ice and pressure ridging in winter ice, constituted a large part of the ice cover.

Winter Navigation

The extensive ice cover was a major threat to winter navigation during the winter of 1961. On December 19, Marine Operations Branch, Department of Transport, established an Operations Office at Point Edward Naval Base, Sydney. Because of the rapid growth of the icefields in early January, Sydney was established as the main operational base for five of the nine Department of Transport icebreakers operating in the gulf. Icebreakers also operated from other bases such as Quebec, Rimouski, Les Escoumins, Seven Islands, Dalhousie and Corner Brook.

As a result of increasing commercial winter shipping, worsening ice conditions and an increasing demand for icebreaker support, ships travelled in convoy through the gulf during the winter 1960 - 1961. Vessels approaching Cabot Strait were advised by the Ice Information officer at Sydney to assemble off Cape Ray, Newfoundland for convoy and to refrain from entering the ice barrier until icebreaker support had been arranged. Each vessel was routed by means of a 'suggested shipping track', and advised of the rendezvous position of the icebreaker; the latter in turn was advised of the approaching vessels. The ice cover off the south coasts of Anticosti and the North Shore of the estuary and gulf provided no obstacle to navigation. However, a number of vessels failed to advise the Ice Information officer of their sailing plans and all of them ran into immediate trouble.

TABLE VI

Ships receiving icebreaker assistance in the gulf region, 1960-61[1]

| Port/Port Area | January | February | March | April | Total |
|---|---|---|---|---|---|
| Corner Brook | 5 | 11 | 12 | - | 28 |
| Chaleur Bay | 18 | 9 | 14 | 7 | 48 |
| Baie Comeau | 18 | 13 | 27 | 40 | 98 |
| Sydney | 6 | 35 | 8 | - | 49 |
| Total[2] | 47 | 68 | 61 | 47 | 223 |

[1]Information provided by Marine Operations Branch, Department of Transport, Ottawa.
[2]No icebreaker support was required in December.

During the period December 15, 1960 to April 15, 1961, 329 ships passed through the gulf; of these, 106 vessels were routed along a suggested track, and 223 were assisted by icebreaker. The freight tonnage moved to and from ice restricted ports during this period totalled 1,464,449 tons. The icebreakers on duty steamed some 107,653 miles in 13,116 hours.

As ice conditions of unseasonable severity continued after April 15, it was not until late May that the gulf became freely navigable.

Considering the severity of ice conditions in the Gulf of St. Lawrence and the large number of vessels that passed through the icefields, the routing and convoying of the traffic by the icebreaker fleet was eminently successful.

## PHOTOGRAPHIC RECORD OF ICE COVERAGE

The photographs selected provide a picture of the nature and distribution of the ice that was observed in the course of the ice survey and illustrate the conditions encountered by ships using the St. Lawrence maritime winter route 1960-61.

Requests for photos should be addressed to the National Air Photo Library, 603 Booth Street, Ottawa. The print and roll number, which follows the figure number, should be given for each print requested.

| Figure | | | | | Figure | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Front. | 1 | T(35) | RR | 2143/1 | 36 | 5 | V | RR | 2151/1 |
| 27 | 68 | S(30) | RR | 2138/3 | 37 | 3 | S(30) | RR | 2151 |
| 28 | 54 | S(30) | RR | 2138/3 | 38 | 4 | S(30) | RR | 2153 |
| 29 | 35 | S(30) | RR | 2138/3 | 39 | 1 | S(30) | RR | 2153 |
| 30 | 4 | V | RR | 2142 | 40 | 10 | S(30) | RR | 2153 |
| 31 | 24 | V | RR | 2142/2 | 41 | 7 | S(30) | RR | 2153 |
| 32 | 13 | V | RR | 2143/2 | 42 | 005 | S(30) | RR | 2155 |
| 33 | 13 | S(30) | RR | 2143/2 | 43 | 012 | S(30) | RR | 2155 |
| 34 | 2 | S(30) | RR | 2147/1 | 44 | 25 | P(30) | RR | 2165/2 |
| 35 | 25 | S(30) | RR | 2147/2 | 45 | 2 | S(30) | RR | 2177-1 |
| | | | | | 46 | 17 | S(30) | RR | 2143/2 |

## Figure 27

The open water area, lying below and above the Lachine Rapids, contributes large quantities of ice that congests the harbor area of Montreal. The St. Lawrence Seaway Canal appears on the left side of the rapids. (Alt. 1,500 feet, Jan. 15, 1961).

## Figure 28

The ship passage lies on the north side of Ile au Coudre, but the greatest amount of ice passes downstream on the south side of the island. (Alt. 4,500 feet, Jan. 15, 1961).

## Figure 29

New ice floes drift past the mouth of the Saguenay River, the polynya at the mouth of the Saguenay is a perennial feature. (Alt. 4,500 feet, Jan. 15, 1961).

Figure 30

The icebreaker *C.M.S. d'Iberville* forcing a passage through a St. Lawrence River winter ice bridge; strong easterly winds, low temperatures, and incoming tide prevent ice wreckage from drifting downstream. (Alt. 1,500 feet, Jan. 24, 1961).

Figure 31

Ice congestion with substantial pressure ridging provides a major obstacle to low-powered vessels and icebreaker support is required. (Alt. 1,800 feet, Jan. 26, 1961).

Figure 32

Massive ice bridges produced by the strong river current and formed in the constrictions of the river are formidable for an icebreaker. (Alt. 1,500 feet, Feb. 2, 1961).

## Figure 33

Winter ice floes in the vicinity of Bird Rocks appear to form a nucleus around which new and young ice develops. (Alt. 1,750 feet, Feb. 2, 1961).

## Figure 34

This ice bridge, formed in the constriction of the river east of Sorel, consists mainly of young ice which like winter ice may also be difficult to dislodge. (Alt. 2,200 feet, Feb. 15, 1961).

## Figure 35

Heavy winter ice, bordering the south coast off Rimouski is bounded on its northern side by new ice. The icebreaker in the centre is struggling to enter the harbor; Rimouski was not re-opened until February 26. (Alt. 4,500 feet, Feb. 16, 1961).

Figure 36

**Although extreme climatic conditions existed over the gulf region and were conducive to rapid ice growth, the passage south of the Canso Causeway was ice-free. (Alt. 2,500 feet, Feb. 22, 1961).**

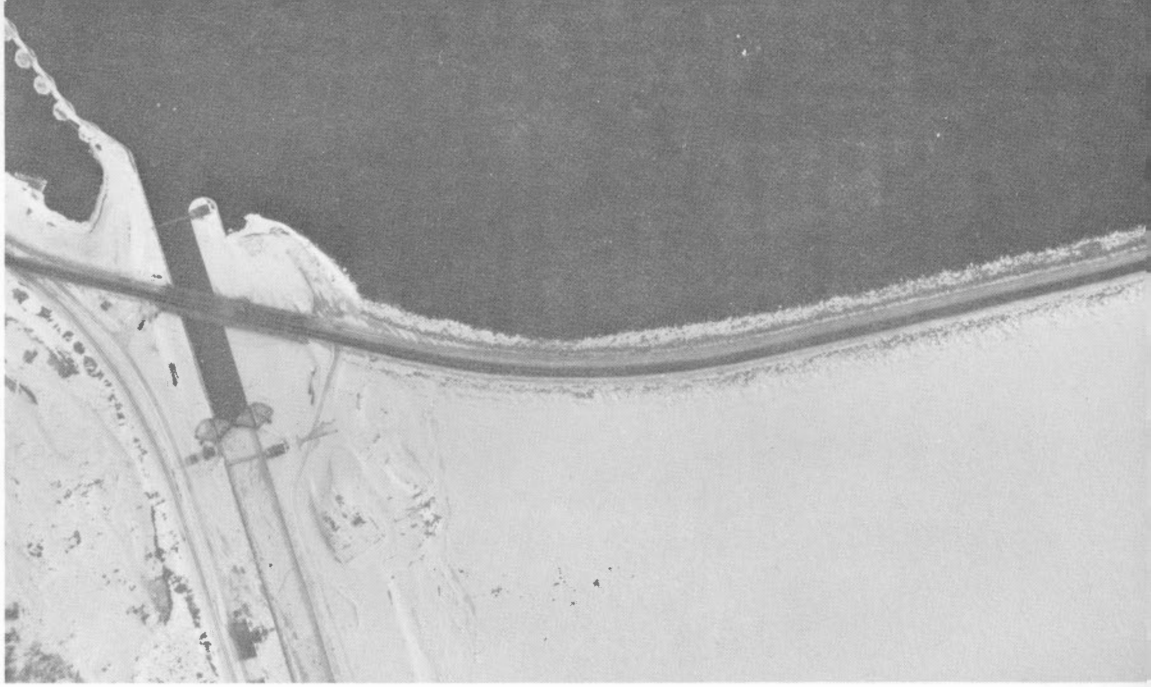

Figure 37

**Extensive icefields at this time lay across the shipping track in the vicinity of Heath Point, Anticosti Island. (Alt. 9,000 feet, Feb. 23, 1961).**

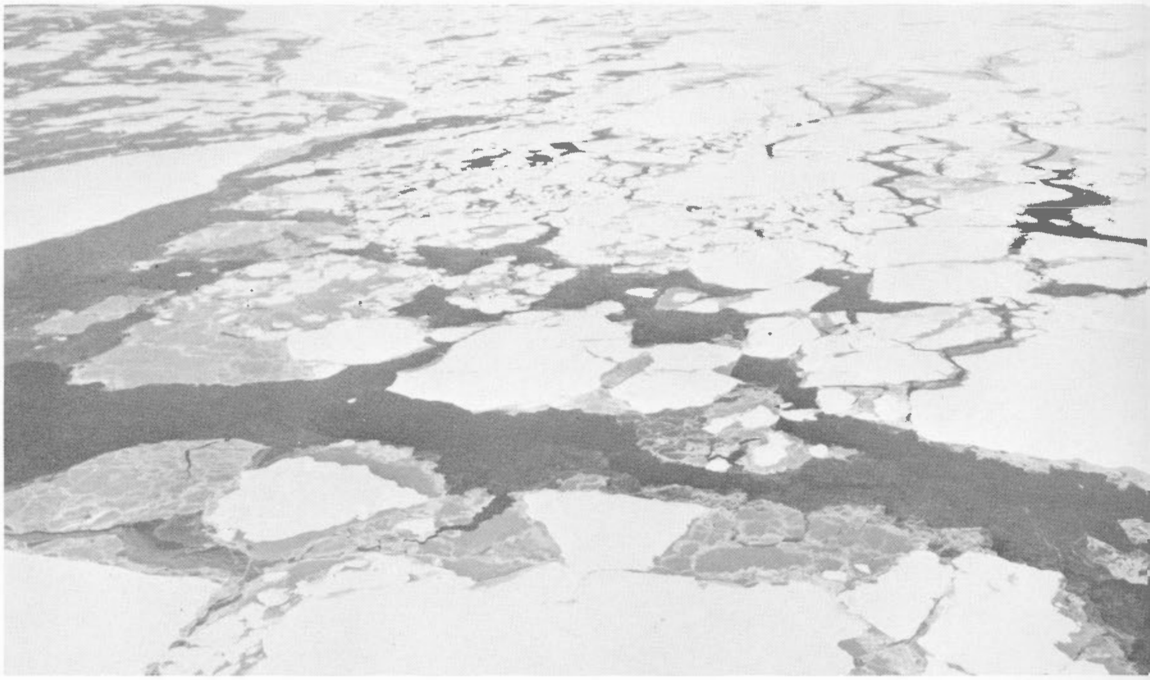

Figure 38

**River ice sweeps past the docks at Quebec to round Point Lévis; a deep-sea freighter is tied up at the dock. (Alt. 1,660 feet, Mar. 8, 1961).**

## Figure 39

The greater part of the St. Lawrence River provides no serious obstacle to winter navigation; the first freighter of the season is shown entering the harbor area of eastern Montreal. (Alt. 1,840 feet, Mar. 8, 1961).

## Figure 40

Looking south from the Bay of Islands, the photo shows the beginning of the open water area that was to free the west coast of Newfoundland; the open water extended north to Bonne Bay. (Alt. 1,900 feet, Mar. 8, 1961).

## Figure 41

A view facing eastward from Ellis Bay to Southwest Point along the south coast of Anticosti Island, shows the parallel zones of landfast ice, open water, new ice and young ice, that form off leeward coasts. (Alt. 7,800 feet, Mar. 8, 1961).

## Figure 42

The zones of open water, new and young ice are shown beyond the landfast ice that extends from Percé Rock to Bonaventure Island. By steaming through such areas with a light ice cover, ships reached their ports of call. (Alt. 1,900 feet, Mar. 17, 1961).

## Figure 43

This ice bridge occurred at the eastern entrance to the St. Lawrence Seaway Canal at Montreal. A narrow neck of ice remains to be broken by the C.M.S. *d'Iberville* before the dock area is ice-free. (Alt. 4,200 feet, Mar. 17, 1961).

## Figure 44

The ice barrier that extended from the Strait of Belle Isle to Magdalen Islands was breached by a gradual thinning of the icefields east of Heath Point, Anticosti Island. (Alt. 4,400 feet, April 6, 1961).

Figure 45. Decayed winter ice, drifting past Dalhousie is no obstacle to the freighter anchored in mid-channel; however, in Chaleur Bay the ice fields were congested for freighters without icebreaker support. (Alt. 5,000 feet, April 27, 1961).

Figure 46. Severe pressure in icefields 4 to 5 feet thick causes the wake of the icebreaker C.M.S. *John A. MacDonald* to close rapidly and restrict progress of the freighter following (Feb. 2, 1961).

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