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Article abstract

Depuis 1956, la Direction de la géographie du Ministère des mines et des relevés techniques a entrepris l'étude systématique de la formation de la glace dans le golfe Saint-Laurent. Cette étude a pour but notamment d'éclairer les conditions de la navigation dans cette région pendant l'hiver. L'auteur décrit les techniques utilisées pour cette étude, en particulier les relevés aériens, et les principaux résultats obtenus jusqu'ici. Il en profite pour signaler les publications déjà nombreuses auxquelles ont donné lieu ces recherches. L'article se termine par la définition d'une série de termes couramment utilisés maintenant dans l'étude de la glace.

GEOGRAPHICAL BRANCH PROGRAM OF ICE SURVEYS OF THE GULF OF ST. LAWRENCE, 1956 TO 1962*

par

W. A. BLACK

RÉSUMÉ

Depuis 1956, la Direction de la géographie du Ministère des mines et des relevés techniques a entrepris l'étude systématique de la formation de la glace dans le golfe Saint-Laurent. Cette étude a pour but notamment d'éclairer les conditions de la navigation dans cette région pendant l'hiver. L'auteur décrit les techniques utilisées pour cette étude, en particulier les relevés aériens, et les principaux résultats obtenus jusqu'ici. Il en profite pour signaler les publications déjà nombreuses auxquelles ont donné lieu ces recherches. L'article se termine par la définition d'une série de termes couramment utilisés maintenant dans l'étude de la glace.

The Canadian Ice Distribution Survey was established in the Geographical Branch in 1951. The purpose of the survey is « to extend the knowledge of the formation, extent and movement of the different kinds of floating ice and the accompanying navigational difficulties. » At first, the Branch was concerned primarily with the establishment of a file of information on ice conditions gleaned from reports of arctic scientists and explorers. This information is maintained as a card catalogue. Based on material in this file, a « Selected Bibliography on Sea Ice Distribution in the Coastal Waters of Canada, » Bibliographical Series No. IV, was prepared.

As stress was laid on ice distribution, the mapping of the Gulf of St. Lawrence ice fields was undertaken and completed in 1954. The material used in this study was based on aerial ice surveys conducted by the Department of Transport each year from 1940 to 1951 for the months of March, April and May. The results of this work, conducted by C. N. Forward, are presented in Geographical Bulletin No. 6, *Ice Distribution in the Gulf of St. Lawrence During the Breakup Season.* Governmental and maritime interest in the behaviour of ice in the Gulf of St. Lawrence increased rapidly after this date. There followed a series of specialized studies involving ice in gulf waters. These were Geographical Paper No. 10, *A Preliminary Report on Ice Conditions at Cacouna Island,* by B. Robitaille ; Geographical Paper No. 16, *Ice Conditions in the Gulf of St. Lawrence during the Spring Seasons 1953-1957,* and Geographical Paper No. 21, *Sea Ice Conditions in the Norththumberland Strait,* both by C. N. Forward. Beginning in 1957 a series of studies was prepared from data provided by observers at shore-based stations. The first of these, Geographical Paper 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,* was prepared by Michel Brochu.

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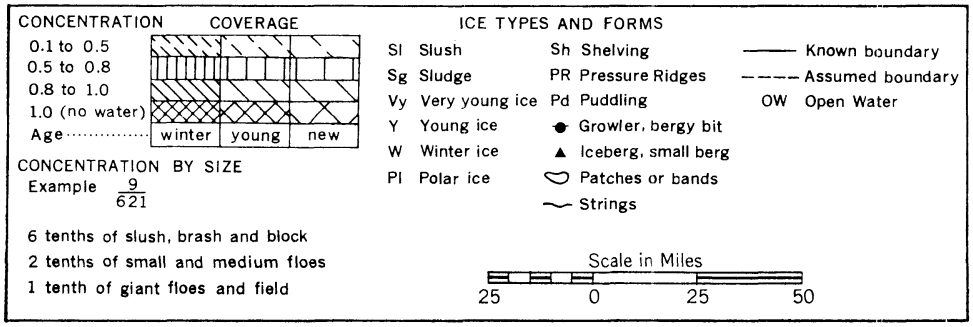
* Published by permission of the Director, Geographical Branch, Department of Mines and Technical Surveys, Ottawa.

Meanwhile, in 1955 the Defence Research Board became interested in the behaviour of ice in gulf waters during the winter months of January and February, about which little was known. As a result of the survey work of C. N. Forward, the Geographical Branch began to participate in the aerial surveys in order to obtain first-hand experience in ice-observing techniques and also to secure information about ice conditions in gulf waters. The Defence Research Board initiated a 5-year program of ice observation in gulf waters, and the Branch provided two geographers to act as aerial ice observers and to conduct the survey. One of these observers participated in a special ice observation course that was given in Washington during 1955. The first survey was undertaken during February and March 1956, in cooperation with Maritime Air Command, Royal Canadian Air Force. The observers were based at the R.C.A.F. stations Greenwood, N.S., and Summerside, P.E.I.

On this first aerial flight of observation, the main function of the ice observers was to map the ice distribution using the American fractional method of ice notation and to prepare word messages for the Ice Central, operated by

FIGURE I

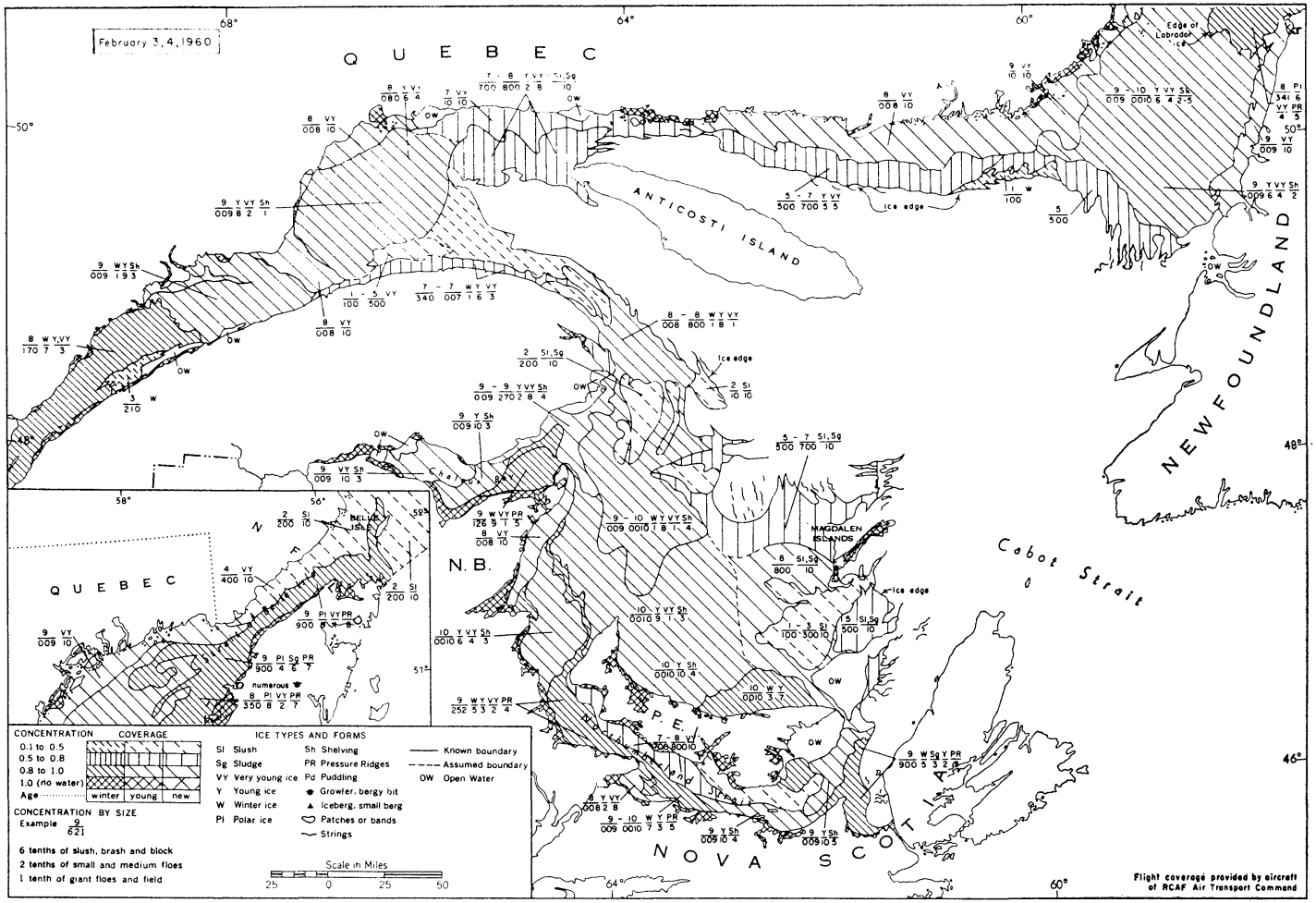


Graphic and descriptive reference.

the Royal Canadian Navy, at Halifax. Except for these duties the ice observers had no other functions. The actual preparation of the maps and delineation of ice types was undertaken by Ice Central.

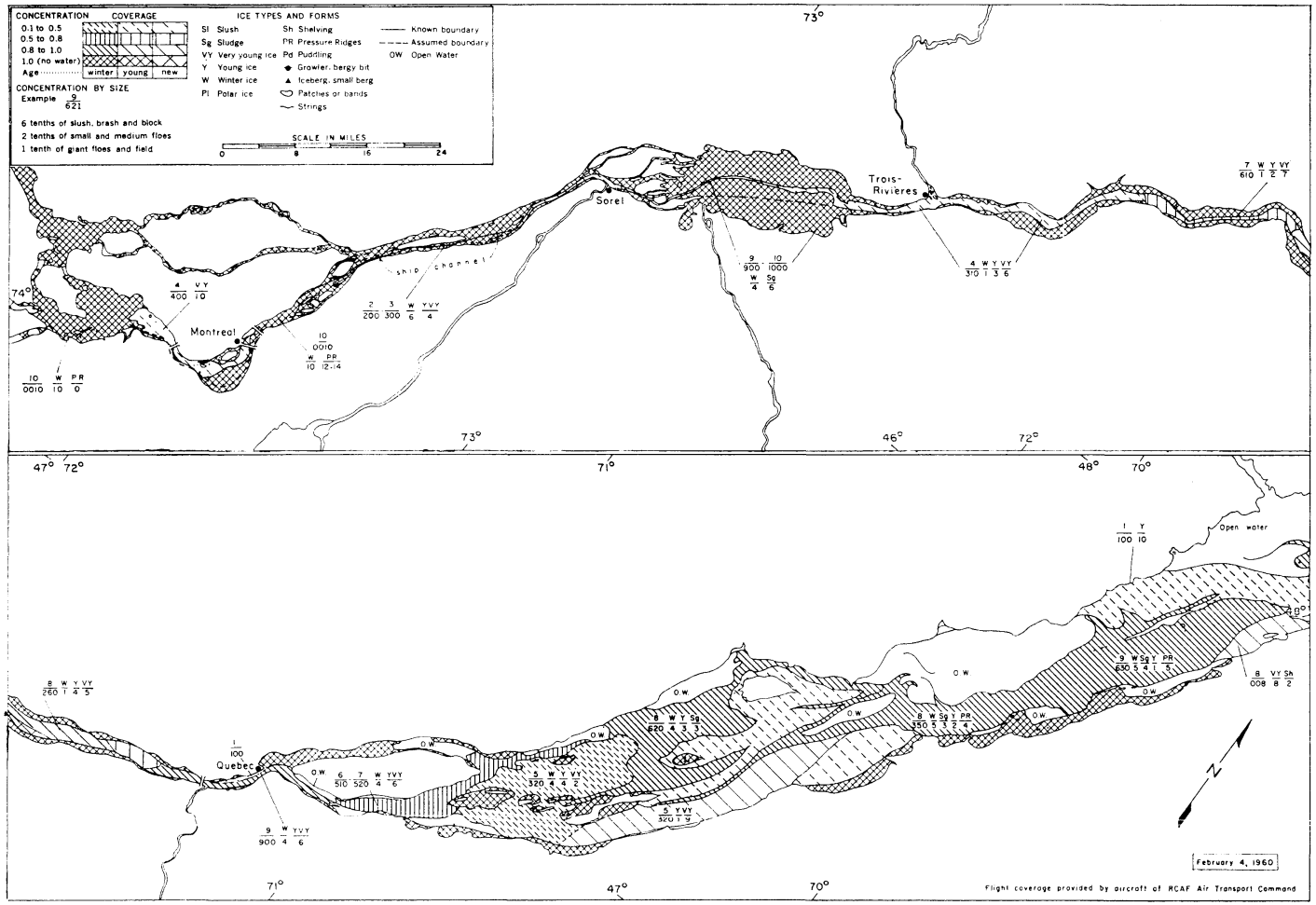
In 1957, the second gulf survey was carried out by one geographer, who was stationed at Summerside ; essentially his main function was to provide information on ice conditions for Ice Central at Halifax. With the completion of the second season's operations, the Branch decided to publish the results of the two surveys even though ice observing techniques were not fully developed. These reports appeared as Geographical Paper Nos. 12 and 14. A successful photographic reconnaissance of ice types, conducted in 1957, also appeared as Geographical Paper No. 11. These reports, covering the first two surveys, were similar in that ice conditions observed on the flights were related to daily weather conditions. They differed, however, in that ' age,' an ice-type cate-

FIGURE II



Ice distribution, Gulf of St. Lawrence, February 3, 4, 1960 (*Figure 8, Geographical Paper No. 25*).

FIGURE III



Ice distribution, St. Lawrence River, February 4, 1960 (*Figure 19, Geographical Paper No. 25*).

FIGURE IV

The accumulation of ice, drifting downstream from above Québec, becomes congested and consolidated as it passes through the constriction in the river at Lévis. The area adjacent to the Port of Québec normally has either open water or has a light ice cover (March 8, 1959, No. 3, RR 1673 S).

gory, was introduced in the second report and this information was shown graphically. It also became apparent that systematic observation of the gulf ice involved observing the distribution of ice types adjacent to the coasts.

In the survey of 1958, flights were planned to observe as much of the gulf ice as possible within a single flying operation. The U.S.N.H.O. fractional and graphic system, which was developed to report ice conditions in arctic waters, was considerably modified to meet the local conditions in the gulf and to present a more accurate picture of ice cover and distribution. New, young, and winter ice forms were shown graphically. As ice is a serious problem to

FIGURE V

A sea-going freighter lies hove-to in young ice off Rimouski in the St. Lawrence estuary ; shelving is a characteristic of new and young forms of ice. The pressure ridges indicate that the ice has become sufficiently thick and ridged, because of shelving, to be classed as winter ice (January 14, 1960, No. 040 RR 1992 V).

winter navigation, the amount of winter ice in the cover was considered to be the critical element in selecting the patterns to show the distribution. Thus, wherever winter ice occurs in amounts of 3/10 or more in association with new or young ice forms, a close graphic pattern representing winter ice is used. An open, graphic 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 is used to show new ice forms. The latter includes such ice as grease, slush, frazil, very young ice and the early stages of sludge or slob ice. A systematic program of ice photography was undertaken with the cooperation of the R.C.A.F. in connection with the ice mapping program.

FIGURE VI

Low water temperatures maintain an environment that causes the winter ice to disintegrate slowly ; the ice, lying off Borden, P.E.I., is sufficiently massive for the icebreaking ferries to avoid going through the icefield (April 22, 1960, No. 008 RR 2068 S [30]).

It was evident from the 1957 operation that the regional effect of climatic conditions throughout the winter months should be considered as an integral part in explaining the expansion and degeneration of the gulf ice fields, and, therefore, a part of the analysis associated with ice distribution.

In 1959 the gulf survey was transferred to 408 Squadron, Air Transport Command based at R.C.A.F. station Rockcliffe. This was the first season when a systematic ice survey was made of the St. Lawrence River ; Cornwall, Ontario, became the western and Belle Isle the eastern limits of the survey, and R.C.A.F. station Summerside, the forward base of operations. As aerial

reconnaissance permitted regular observation of the river from Lake St. Louis to the Saguenay, it was decided to present ice conditions of the St. Lawrence River on a separate map. The duration of the survey was extended from mid-January to the end of April. The results of the 1958 and 1959 aerial surveys appear in Geographical Papers Nos. 19 and 23 respectively.

For the 1960 season (Geographical Paper No. 25), new river and gulf base maps were prepared to provide greater accuracy in showing the relation of ice types adjacent to the shore. Ice data was shown by coloured overlays. The 1961 season saw a more intensive use made of statistical data, of the fractional-graphic presentation and of ice terminology (Geographical Paper No. 32).

Beginning with the gulf survey of 1959 (Geographical Paper No. 23), a more selective and wider use of air photos was introduced to show the ice types and to suggest the problems encountered by ships in the ice-fields.

The 1961-62 winter survey season saw further advances ; the duration of the survey was further extended from mid-December to mid-April. The survey as now conducted requires 12 flights scheduled at regular intervals and averaging 16 to 17 hours' duration. New information provided by the ice-breakers operating in gulf waters during the winter months introduces data on surface water and ice. Thus the two main bodies of information, surface climatic and surface oceanographic conditions, are for the first time being integrated to explain the observed ice distribution.

The immediate objective of the surveys is to relate the ice distribution to surface climatic and surface oceanographic conditions. Techniques for reporting ice types have been substantially refined and the flight route determined so that a complete survey of the gulf can be made on each flight. The long-term objective is to provide a continuity of unbroken records over a considerable period of time so that the reports will serve as a basic reference and in addition provide the essential material for assessing future probability of various types of ice conditions. At the present stage of development it is relatively difficult to determine in advance whether there is going to be a heavy ice season or a light ice season. The scientific forecasting of ice conditions, that is, to forecast the type, form and distribution for any given date appears to be impossible on the basis of data available at present. In the gulf the wind is a major factor in moving the ice and determining surface currents ; nevertheless, there is great variability in the ice distribution from month to month and from year to year. Thus, oceanographic as well as climatic factors must have a bearing on the nature of the distribution. In order to understand the motion of the ice in the St. Lawrence River, which is a tidal stream, the physical forces acting on the « carrier » such as tide, river flow, density exchange motion, Coriolis force and wind must be understood. Scientific ice forecasting is, therefore, a complex and difficult problem.

Listed below are ice terms, together with the definitions that are most frequently used to describe the ice features of the gulf of St. Lawrence region. A graphic and descriptive reference is included and its use in association with the river and gulf ice maps is shown (Figures I to III). Three photographs

of the river and the gulf show the types of ice as seen by the observer (Figures IV to VI).

The following ice terminology has been developed to 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 used on the maps, is to provide a fuller understanding of the ice cover (see also Geographical Paper No. 32).

BLOCK
A fragment of sea ice ranging in size from 6 to 30 ft. across.

BRASH
Fragments of floating ice, less than 6 ft. 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 ft. across ; a medium floe is 600 to 3,000 ft. ; a large floe is 3,000 ft. 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 small piece of ice, up to 100 feet across, frequently appearing greenish in colour 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 schoal 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 also 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. Slab 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 froms a thick, white, soupy mass in the water. The coverage of slush may be expressed in tenths : thus $\frac{Sl}{5}$ - 4/10 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 3 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.

(N.D.L.R.) Nous signalons la *Classification générale des glaces flottantes*, par Louis-Edmond HAMELIN, dans le *Naturaliste Canadien* (vol. 87 (1960), n° 10, pp. 209-227).