Article

"Ice Conditions in the Gulf of St.Lawrence and Cabot Strait (with particular reference to the Sydney Bight Area)"

D. K. MacKay

Cahiers de géographie du Québec, vol. 7, n° 14, 1963, p. 211-228.

ICE CONDITIONS IN THE GULF OF ST. LAWRENCE AND CABOT STRAIT (WITH PARTICULAR REFERENCE TO THE SYDNEY BIGHT AREA) *

by

D. K. MacKAY

Research Division, Geographical Branch, Ottawa.

RÉSUMÉ

Les glaces qui, au printemps, se trouvent dans le détroit de Cabot et tout particulièrement dans la région de la baie Sydney, gênent souvent les traversées des bateaux passeurs entre Port-aux-Basques, Terre-Neuve et North Sydney, Nouvelle-Écosse. Des données sur les principaux relevés des glaces dans le golfe Saint-Laurent et le détroit de Cabot ont été recueillies et étudiées en tenant compte de ce problème.

Les relations qui existent entre les nuances de température, les vents et l'étendue des glaces ont été étudiées à la lumière de la statistique. La somme des températures de décembre et janvier correspond assez bien aux principales étendues des glaces qui se trouvaient dans le golfe et le détroit durant ces deux mois. L'étude des vents indique un véritable mouvement de la glace à partir du golfe en direction du détroit durant les années où des observations ont été faites. Si l'on additionne les températures et les vents et les exprime en termes de glace de dérive, on découvre que ces deux éléments sont très étroitement liés l'un à l'autre.

At various times, ice conditions have had a serious effect on the ferry service from Port aux Basques, Newfoundland, to North Sydney, Nova Scotia and in recent years considerable difficulty has been experienced in maintaining the service during the winter period. In 1962, a request was made to the Canadian Committee on Oceanography through its Working Group on Ice in Navigable Waters, for a report on a number of factors that affect ice conditions in the Sydney Bight area. A preliminary report based on the data accumulated as a result of the ice distribution surveys carried out by the Geographical Branch was sent to the Canadian Committee on Oceanography in May, 1962. This unpublished report, prepared by W. A. Black of the Geographical Branch, has served as the framework for this paper. In addition, the advice given by W. A. Black based on his personal knowledge of ice conditions in the areas of concern has been most useful in its development.

Ice, passing out of the Gulf of St. Lawrence into Cabot Strait, does not spread out or open up after moving through the narrows as would be expected, but instead follows a southward drift to the east of Cape Breton Island. As the icefields pass close to the Cape Breton coast, the direction of their drift is greatly affected by prevailing winds. Onshore winds drive the ice against

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

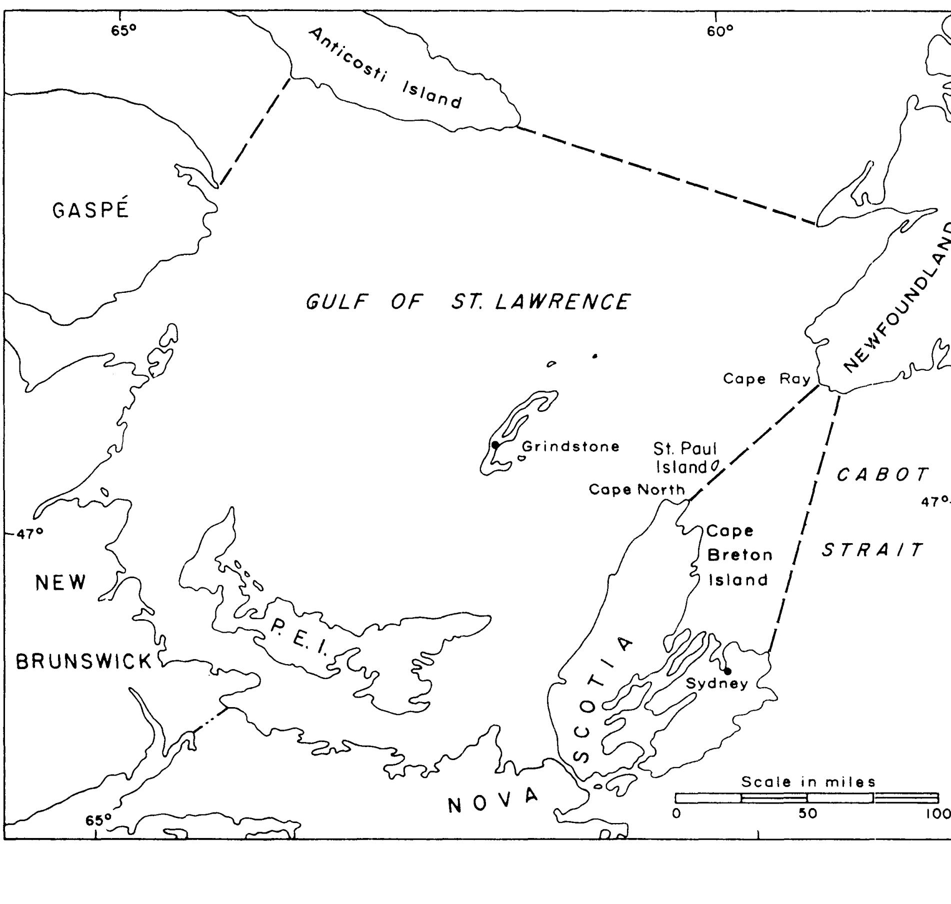
Cape Breton's coast, creating massive pressure ridges and heavy ice concentrations which restrict shipping activities. Offshore winds carry the icefields well to seaward where they spread out and provide no serious obstacle to shipping. At the same time, such winds may remove ice blockades from the coastal areas which impede ferry operations in the Strait.

This paper is based on observed ice conditions in defined areas of the Gulf of St. Lawrence and Cabot Strait (Figure 1) during the break-up season for the period 1940 to 1962 inclusive. It is mainly concerned with the relations among air temperatures, winds, and major ice cover areas. It is hoped that this paper will assist in providing a clearer understanding of the environmental factors affecting the extent and distribution of ice in Cabot Strait during the break-up season.

Ice Cover in the Gulf of St. Lawrence and Cabot Strait

Observations of ice conditions in the Gulf of St. Lawrence and Cabot Strait have been made each year from 1940 to 1962 inclusive. However, the

FIGURE I

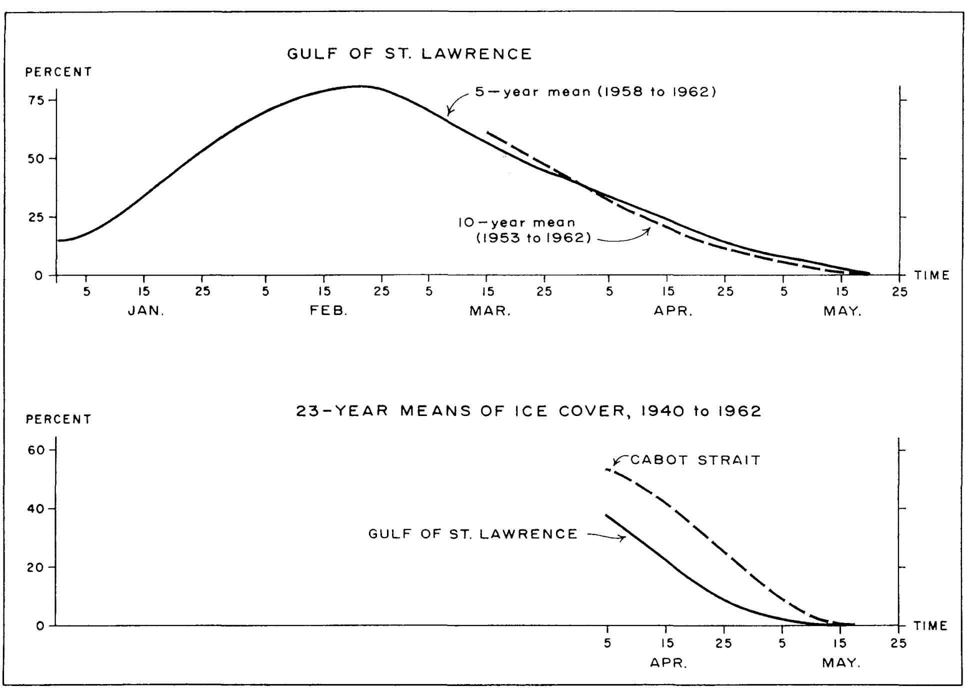


areas under observation have differed from year to year and, therefore, it is necessary to designate standard areas (Figure 1) for purposes of comparing yearly changes in the extent of ice cover. In Cabot Strait, the observed area is delimited to include only the section of interest to Sydney – Port aux Basques ferry operations.

The length of the period in which ice observations have been made has also changed over the years of record. From 1940 to 1952, ice observations began in early April and continued through to the end of the break-up season (Forward, 1952). The period was extended to March 15th for the years 1953 to 1957 (Forward, 1958), and from 1958 on (Black, 1958, 59, 60, 61 and 62) it was further extended to include the months of January and February. Thus, maps of main ice cover areas in parts of the Gulf and Cabot Strait are available for various stages of ice formation and disintegration. Areas of main ice cover in defined sections of the Gulf of St. Lawrence and Cabot Strait were measured with a polar planimeter.

Mean ice cover in the Gulf is illustrated in Figure 2 for 5-year and 10-year periods. Twenty-three-year means for the Gulf and Cabot Strait are also graphed in Figure 2. Ice conditions in Cabot Strait prior to April 5th are extremely variable and, therefore, no illustrations of 5-year and 10-year means are included. Based on the 5-year mean, ice cover in the Gulf reaches a maximum near the end of February when approximately 80 per cent of the water

FIGURE II



area is covered by ice. The formation of the ice cover proceeds more rapidly than its disintegration. The average increase to mid-February is at the rate of 1.3 per cent per day ; the ice cover decreases from this date at an average rate of 1 per cent per day.

In April, the designated area of Cabot Strait has a higher percentage of ice cover than that of the Gulf (Figure 2). Such a relationship is expected for two reasons :

1– air temperatures in April are generally above the minimum required for the formation of ice in the Gulf ; and,

2– the flow of ice out of the Gulf into Cabot Strait is sustained by winds and currents.

The flow of ice is maintained until the supply in the Gulf is exhausted. The supply, of course, is limited to those areas from which wind and current action can drive the ice into the Strait. Except under unusual circumstances, this eliminates a considerable portion of the southern Gulf region as a supply area, as well as those areas of landfast ice in the bays and inlets of the mainland and island coasts which melt or disintegrate *in situ*.

Environmental conditions in Cabot Strait are less conducive to the formation of an ice cover than are conditions in the Gulf. For example, winter temperatures are lower in the Gulf than in the Strait (Table 1). Moreover, depths in the Gulf south of a line joining Cape North, Nova Scotia, to Gaspé, Quebec, are less than 50 fathoms while the Laurentian Channel that passes through Cabot Strait is more than 100 fathoms deep. This factor, together with the probable lower salinities due to the discharge of rivers and streams into the semi-enclosed basin, suggests that the loss of heat to the atmosphere (after mixing) that is required to produce an ice cover need not be as great per unit area in the Gulf as in the Strait. Thus, it may be expected that the percentage of ice cover in the Gulf will remain higher than the percentage in the Strait as long as environmental conditions are favourable to sea ice formation. From the date of maximum ice cover in the Gulf, the action of winds and currents should tend to produce a higher ice-to-water ratio in the Strait.

TABLE I

WINTER TEMPERATURES
BASED ON THE PERIOD OF THE CLIMATIC NORMAL
1921 to 1950

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Grindstone	35.9	26.3	19.3	16.3	23.5	32.4
St. Paul Is.	37.6	28.2	22.3	19.0	24.5	31.9
Sydney	39.0	28.7	22.7	19.8	27.6	36.5

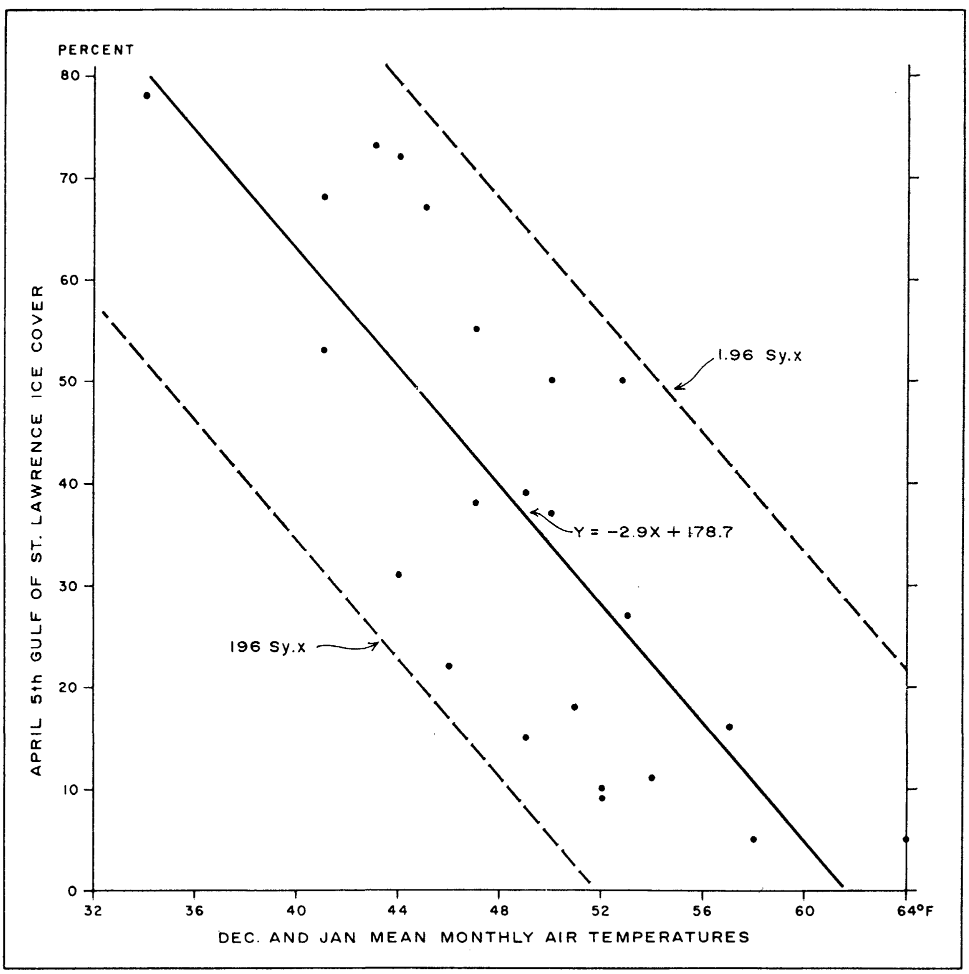
Air Temperatures and Ice Cover

Winter air temperatures summed over different periods are compared to percentages of ice cover in designated areas in the Gulf of St. Lawrence and Cabot Strait. Grindstone (Figure 1) was selected as the station most representative of temperature conditions affecting ice formation in the Gulf. Air temperatures from Grindstone are also compared to ice cover in Cabot Strait for the following reasons :

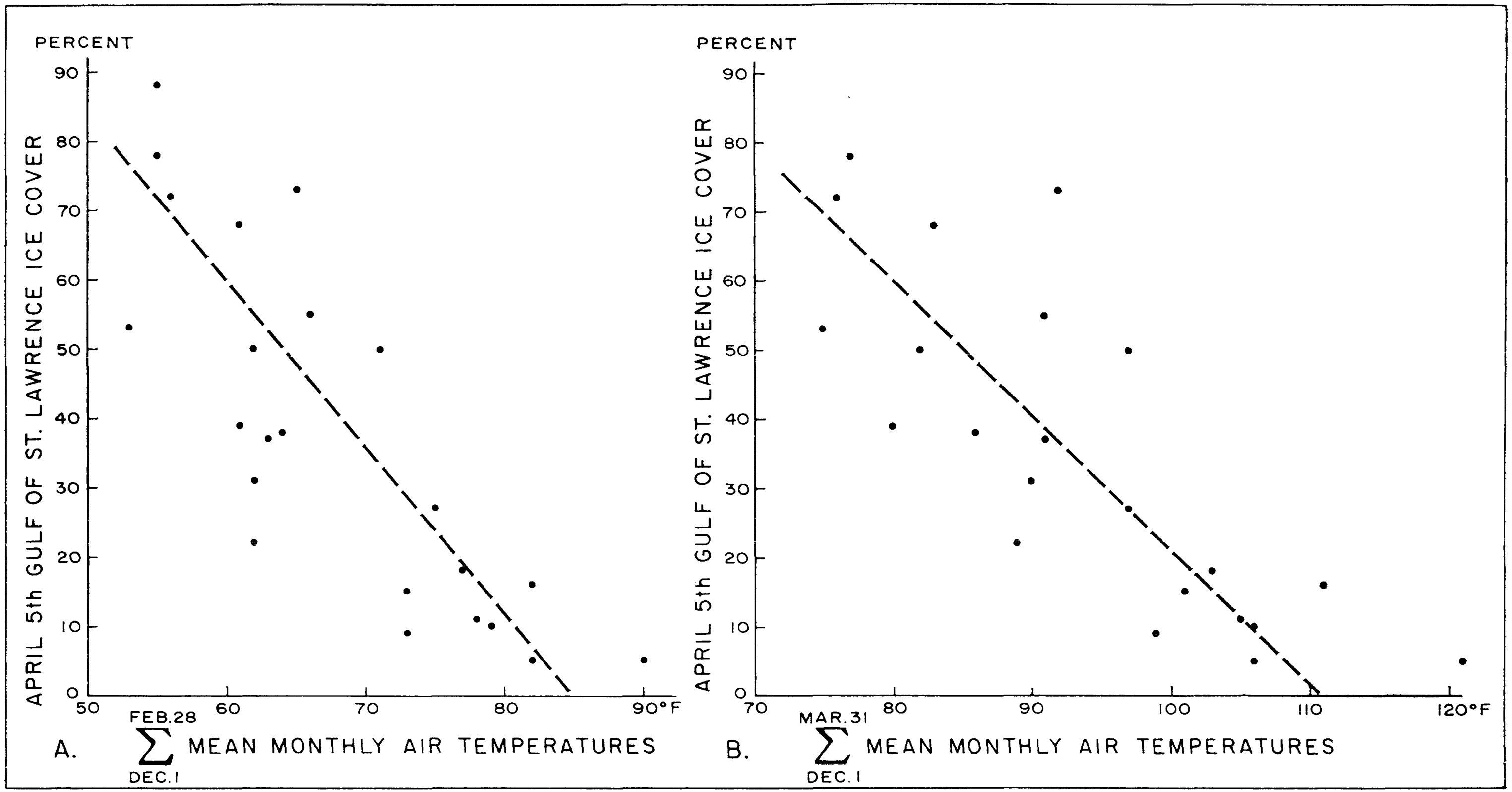
1– a large proportion of the ice cover in the Strait is supplied from the Gulf ;

2– the meteorological station on St. Paul Island in Cabot Strait discontinued operations in 1956 ; and,

FIGURE III



Figures IV and V



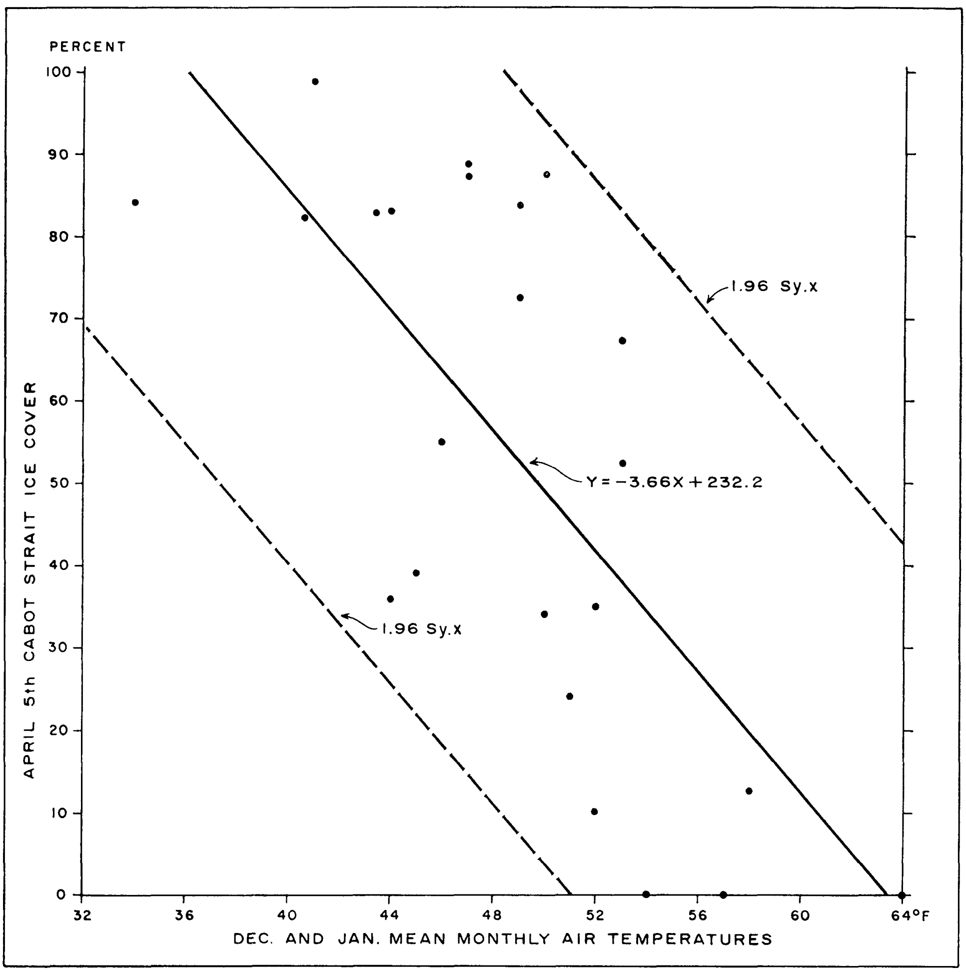
3– Grindstone is more representative of marine conditions than the only other meteorological station with long-term records in the vicinity (i.e. Sydney).

The dependency of ice cover areas on winter temperatures is indicated by the values of the correlation coefficients listed in Table II ; these relations are illustrated by scattergrams (Figures 3, 4, 5, 6, 7 and 8). Percentages of ice cover on April 5th were used in comparisons for two reasons :

1– ice cover in prior months was recorded for an insufficient number of years ; and,

2– later dates are relatively less important insofar as ferry operations between Sydney and Port aux Basques are concerned.

FIGURE VI



FIGURES VII AND VIII

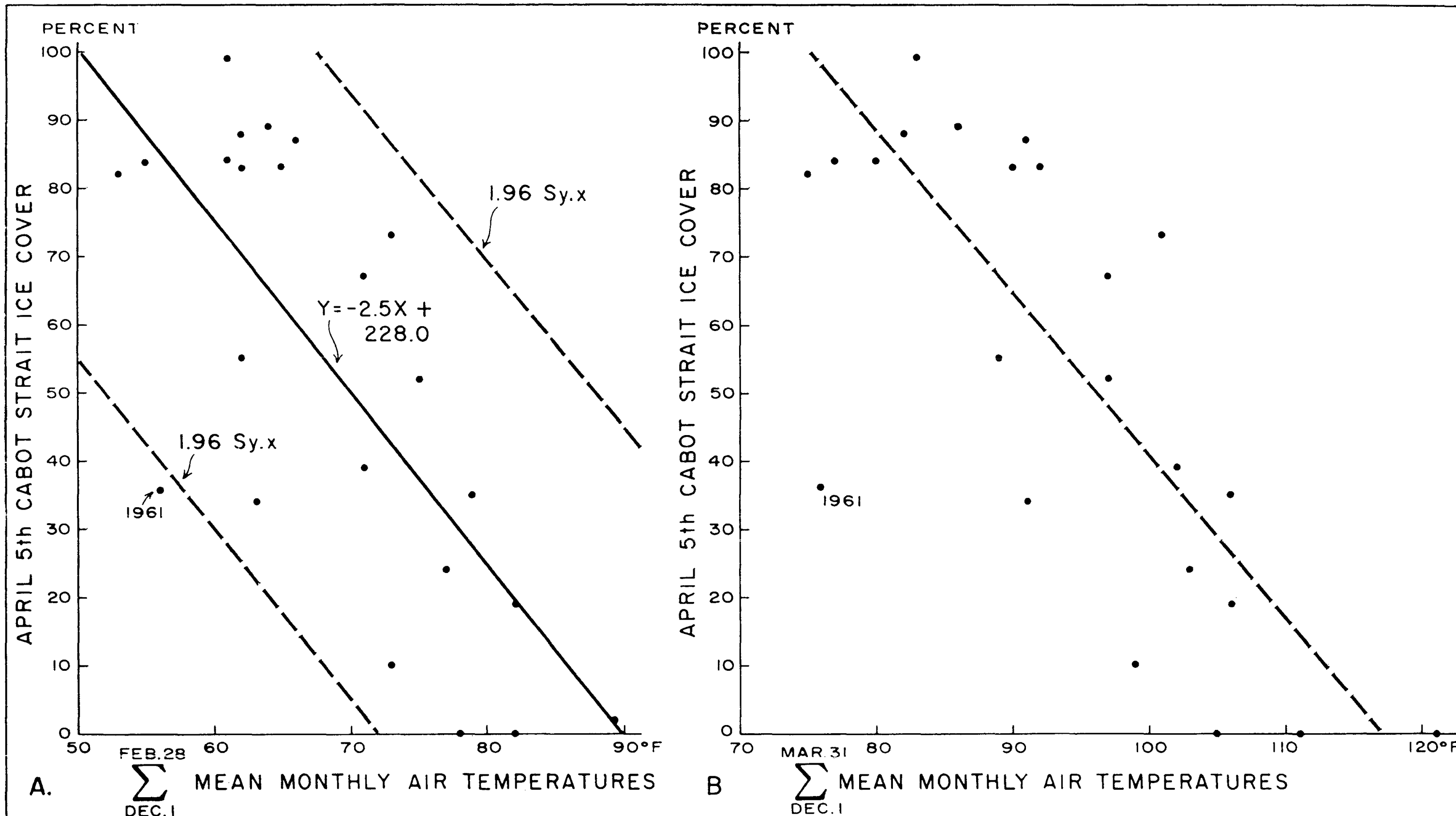


TABLE II

CORRELATIONS BETWEEN SUMMED WINTER AIR TEMPERATURES AT GRINDSTONE AND ICE COVER AREAS IN CABOT STRAIT AND THE GULF OF ST. LAWRENCE ON APRIL 5th, 1940 TO 1962

« r » VALUES *

ICE COVER AREAS	MEAN MONTHLY AIR TEMPERATURES SUMMED FROM DEC. 1		
	To Jan. 31st	To Feb. 28th	To Mar. 31st
Gulf of St. Lawrence......	—.786	—.661	—.795
Cabot Strait.............	—.708	—.741	—.754

* All « r » values are significant at the one per cent level (i.e. r .01 (20) = — .537)

If mean monthly temperatures are summed from December on, the resulting values show a high negative correlation with ice cover areas. All correlations are significant at the one per cent level and, thus, it may be stated with reasonable assurance that approximately 50 per cent of the variability in ice cover areas on April 5th may be explained by variations in winter air temperatures.

The regression of ice cover percentages on summed winter temperatures is indicated in Figures 3, 6 and 7. Although the regression line is our best estimate of ice cover, the residual variation (illustrated by 1.96 times the standard error of estimate of y on x) suggests there is a high degree of uncertainty in the estimation of this phenomenon from winter temperatures. Nevertheless, the fact that mean monthly temperatures summed for December and January may be correlated with ice cover two months hence is highly significant. It may be the case that the introduction of other variables may reduce the residual variation to the point that fairly accurate prediction of ice cover areas in the Strait is possible.

It should be noted that the maps from which ice cover data are determined depict main ice areas that have been generalized from a limited number of observations. Moreover, the measurement of these areas by means of a polar planimeter will inevitably result in certain inaccuracies. Whether increased accuracy of observation and measurement would improve the correlation between ice areas and winter temperatures is not known.

Relationship of Winds to Ice Conditions

The velocity, direction, and persistence of winds are primary factors affecting the distribution and movement of sea ice. The influence of winds on ice movement at any given time depends on the shape, size, immersion-depth, and separation of floes, as well as the geographic conditions of the ice locale and the area surrounding it. For example, the movement of ice from the Gulf of St. Lawrence into Cabot Strait is affected by the shoreline characteristics of the Gulf perimeter, the islands in the Gulf, and the bottom topography ; in addition such variable factors as river discharge, precipitation, and distribution of temperature and salinity tend to induce currents or influence the system of currents affecting ice movement in the Gulf and the Strait.

Wind records from Grindstone Island, St. Paul Island, and Sydney meteorological stations are examined in this study. Sydney records are assumed to be representative of the Sydney Bight area while Grindstone and St. Paul records are taken to be representative of the eastern section of the Gulf and the entrance to Cabot Strait, respectively (see Figure 1). A fifteen-year base period, 1940 to 1954, is used for comparison purposes for the following reasons :

1– the meteorological station on St. Paul Island was closed in 1956 ;

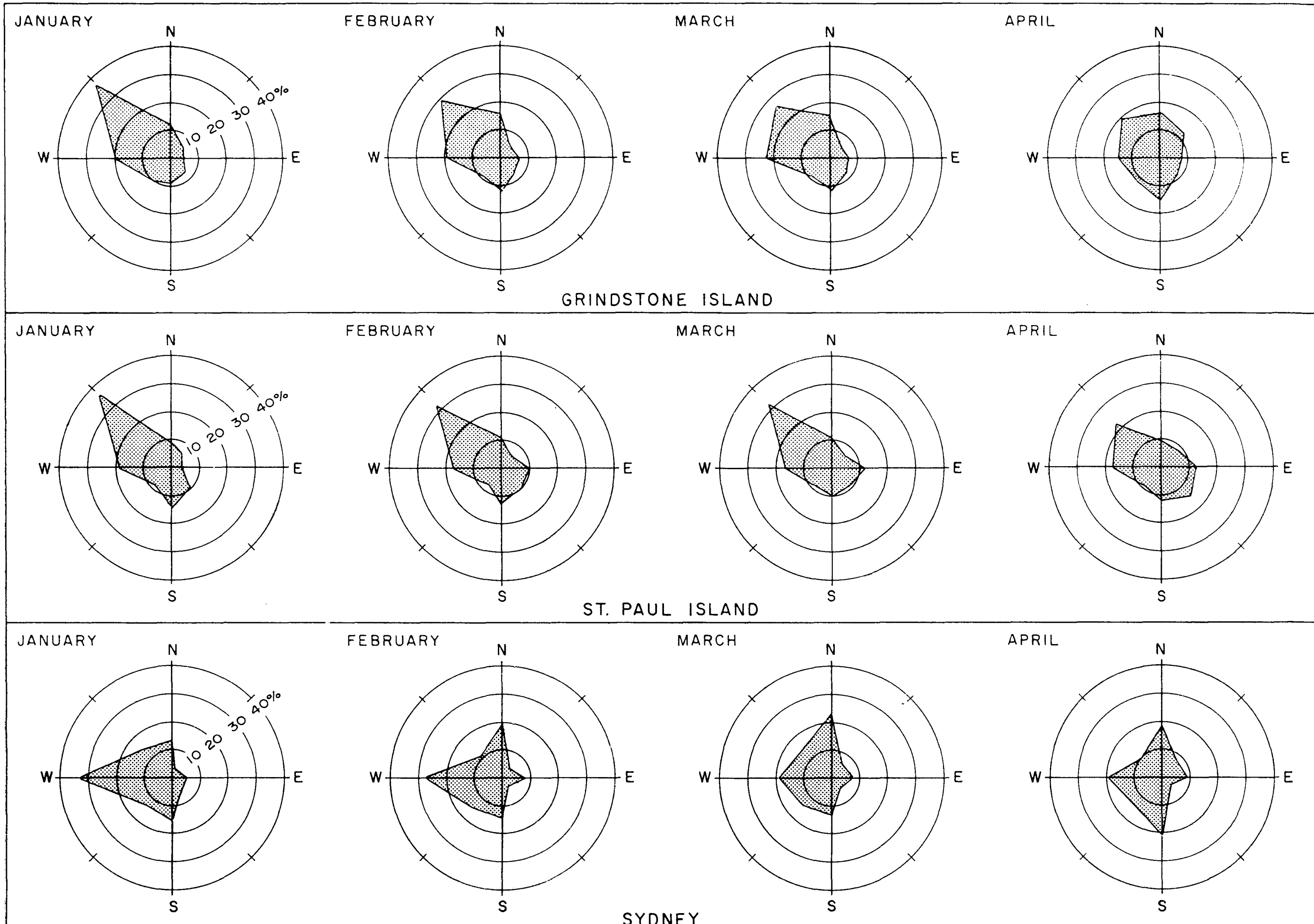
2– wind mileage summaries were discontinued in the Monthly Record, Meteorological Branch, Department of Transport, January, 1955 ; and,

3– the use of frequencies to determine the relative run of the wind (assuming frequencies are proportional to velocities) was not considered justified because the stations with longer records, i.e. Grindstone and Sydney, are not as representative of wind conditions affecting ice drift into the Strait as is St. Paul. The relative run of the wind (wind velocity × frequency in hours) for these locations during the months of January, February, March, and April is shown in Figure 9.

The relative run measured at Grindstone Island indicates that westerly components are dominant in the spring months. Westerly dominance decreases markedly in the month of April. The principal component of the run is from the northwest. Wind measurements taken at St. Paul Island are basically in agreement with those taken at Grindstone Island. At Sydney, however, there are some differences. Although westerly winds are still dominant at this station, the principal component of the run is from the west in January, shifts clockwise to north by March, and splits into three principal components (north, west, and south) in April.

Table III of mean monthly wind characteristics, 1940 to 1954, shows the resultant heading, run, velocity, and persistence of the winds at the various stations. The headings indicate a dominant west-to-east movement in all months examined, with less than a twenty degree variation between consecutive monthly headings at any one station. The resultant run decreases from the beginning of January through to the end of April at each of the three stations. The westerly winds exhibit considerable regularity in January but their steadiness decreases in the following months. The persistence tendencies indicate that April winds are quite irregular in character.

Figure IX



JANUARY
FEBRUARY
MARCH
APRIL
N
E
S
W
10 20 30 40%
GRINDSTONE ISLAND
JANUARY
FEBRUARY
MARCH
APRIL
10 20 30 40%
ST. PAUL ISLAND
JANUARY
FEBRUARY
MARCH
APRIL
10 20 30 40%
SYDNEY

Ice Drift

The empirical relations between surface winds and the drift of Arctic ice islands and ice fields have been discussed in Russian papers (e.g. Drogaicev, 1956 ; Zubov, 1947). Their observations and conclusions are related to the movement of ice over deep water and far from the influences of land. Drogaicev indicates that movement of Arctic ice islands is 35 degrees to the right of the sea surface wind direction ; Zubov's observations suggest that the mean deviation for close ice (6/10 to 9/10 ?) is of the order of 29 degrees. The drift velocity of close ice is roughly approximate to one-fiftieth of the surface wind velocity.

TABLE III

MEAN MONTHLY WIND CHARACTERISTICS, 1940 TO 1954

STATION	JAN.	FEB.	MAR.	APR.
A. Resultant Headings in Degrees (T)				
Grindstone	118°12′	125°17′	112°37′	124°24′
St. Paul Island	106°38′	118°33′	123°02′	106°21′
Sydney	084°41′	092°23′	111°38′	080°44′
B. Resultant Run in Statute Miles				
Grindstone	7918	5804	5061	2216
St. Paul Island	4385	2721	2466	918
Sydney	4318	3283	2464	1803
C. Resultant Velocities in Miles per Hour				
Grindstone	10.6	8.6	6.8	3.1
St. Paul Island	5.9	4.0	3.3	1.3
Sydney	5.8	4.9	3.3	2.5
D. Persistence Tendencies in per cent				
Grindstone	45	37	30	16
St. Paul Island	35	26	25	11
Sydney	41	35	25	20

The relations between the surface winds and the movement of ice into Cabot Strait and the Sydney Bight area are complicated by a number of factors. For example drift velocities are dependent upon concentration and form of the ice. Drift of ice in a 1/10 concentration is nearly four times as great as drift in a 9/10 concentration ; hummocky ice drifts faster than ice lacking this characteristic (Zubov, 1947). Again, the confining aspects of the Gulf perimeter and the shoreline orientation in the Cabot Strait area will influence the velocity and direction of ice drift. Further, the movement of ice under the influence of easterly component winds may be hindered by ice masses in the Gulf.

The expected ice drift past St. Paul Island is calculated on the following bases :

1– the coefficient of ice drift averages 0.02 of the resultant monthly run of the wind ;

2– the estimated angle of ice drift deflection is approximately 22 degrees to the right of the resultant wind direction in any given month. This value is derived by adjusting the mean deflection of close ice in Arctic seas for the latitudinal differences (i.e. from 75 degrees N. to 47 degrees N.) ; and,

3– numerous other factors such as permanent currents, the effect of differing ice drift velocities on the deflection angle, variations in size and shape of ice floes, and so on are not considered here. The accuracy of ice drift calculations based on 1 and 2 would seem consistent with the accuracy inherent in ice cover data.

The calculated ice drift past St. Paul Island, 1940 to 1954, is listed in Table IV.

TABLE IV

CALCULATED ICE DRIFT PAST ST. PAUL ISLAND

YEAR	JAN.		FEB.		MAR.		APR.	
	HDG(T)	Miles	HDG(T)	Miles	HDG(T)	Miles	HDG(T)	Miles
1940......	145	117	158	125	202	20	141	25
1941......	187	145	150	60	138	36	124	65
1942......	108	89	139	80	144	32	223	30
1943......	125	176	077	56	130	65	099	47
1944......	157	107	136	71	144	120	199	54
1945......	092	57	168	74	154	71	158	41
1946......	130	126	126	81	132	79	294	34
1947......	142	122	240	27	209	44	117	70
1948......	121	56	139	131	134	86	104	18
1949......	124	67	155	77	124	44	123	33
1950......	117	123	141	68	118	102	184	23
1951......	110	88	008	7	227	47	317	49
1952......	094	54	266	39	197	32	099	36
1953......	078	83	096	81	279	16	067	14
1954......	149	61	355	4	138	96	—	—

In order to compare the yearly differences in ice drift past St. Paul Island, the vector components of the wind were cumulated and resultant headings and drift determined. The resultant vectors were then adjusted to a heading of 141°(T). This heading is at right angles to a line joining Cape North, on Cape Breton Island, to Cape Ray, Newfoundland. It is an arbitrary optimum for ice entering Cabot Strait that is used solely for standardization purposes. The results are listed in Table V.

TABLE V

RESULTANT VECTORS OF ICE DRIFT
ADJUSTED TO A HEADING OF 141°(T), ST. PAUL ISLAND

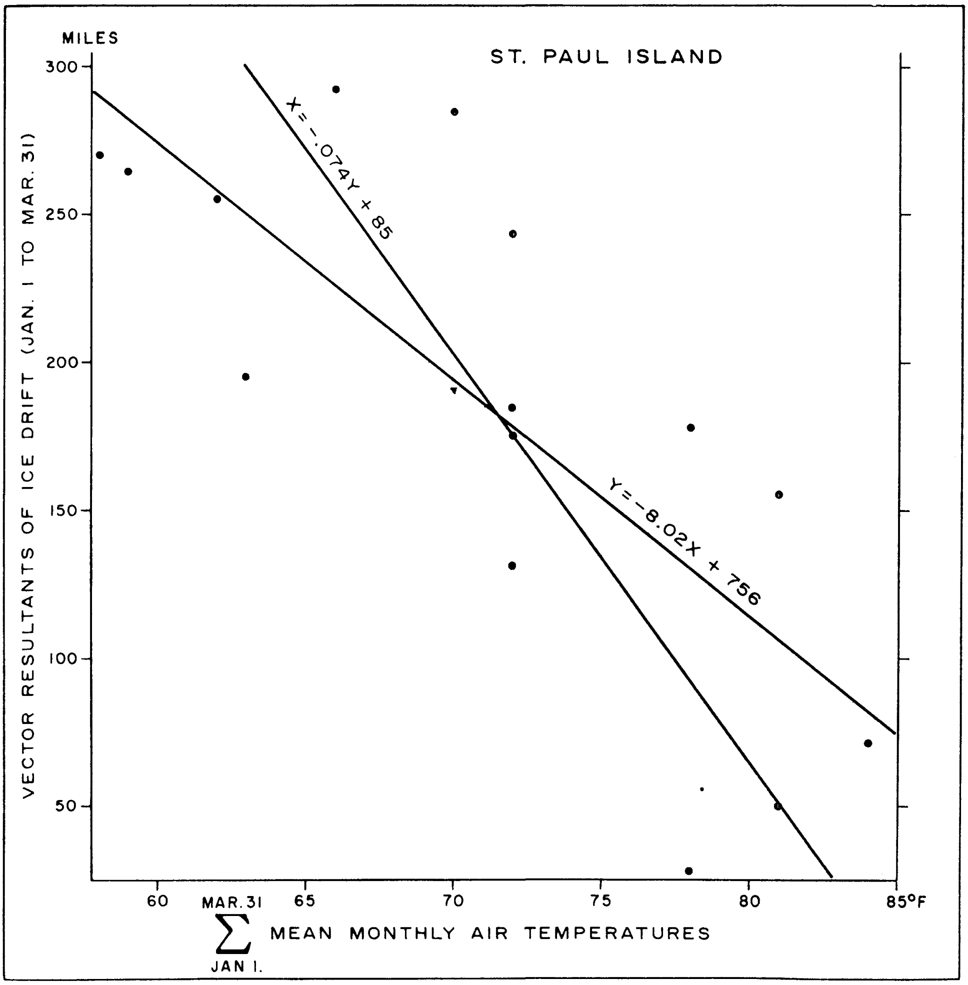
YEARS	ICE DRIFT IN MILES FROM JAN. 1st TO :		
	End of Feb.	End of Mar.	End of Apr.
1940	236	243	270
1941	168	195	260
1942	150	185	198
1943	190	255	300
1944	174	292	318
1945	104	175	212
1946	200	285	260
1947	115	132	198
1948	185	265	280
1949	138	178	212
1950	175	270	290
1951	70	72	22
1952	15	28	55
1953	95	50	85
1954	56	155	—
Mean	138	185	211
Standard Deviation	59	83	109

Drift calculated on the basis of resultant winds suggests there is a positive movement of ice from the Gulf into the Strait in each of the years examined. This movement is generally sustained through the spring months to the end of the break-up period. Three months in which drift calculations indicate a movement from the Strait into the Gulf are April 1946, April 1951, and March 1953.

The resultant vectors of ice drift (in miles) were compared with the residuals from the regression of ice cover areas on summed winter temperatures. Results showed no significant correlation between them. This may be due to the interdependency of winds and air temperatures.

As ice drift mileages are essentially wind mileages transformed, they may be compared to summed winter temperatures to show the degree of interdependency between air temperatures and winds. The relationship between air temperatures and winds (expressed as ice drift) is shown in Figure 10. The strong negative correlation ($r = -.772$) is indicated by the limited divergence of the two regression lines.

FIGURE X



The correlation between air temperatures and winds may be explained in the following way. There is a positive west to east ice drift vector over the period from January 1st to March 31st in each of the years examined, but the vector length (measured in miles) differs from year to year. When the vector is short, easterly component winds are stronger than usual and when the vector is long, westerly component winds are the more dominant. The westerlies generally bring cold air from the interior of the continent which results in severe temperature conditions in the Gulf and the Strait. The easterlies bring relatively warm air from the open reaches of the Atlantic which tends to ameliorate temperature conditions in the areas of concern.

Ice Conditions in the Sydney Bight Area

A number of significant factors contribute to the serious ice conditions that often develop in this area. As stated earlier, a high proportion of the ice that congests the Sydney bight originates in the Gulf of St. Lawrence, outside the area. These ice fields normally drift southeastward from St. Paul Island into the bight ; however, with an extensive cover the outer edge usually swings south past Scatari Island. The ice surface becomes intensely worked over and results in ice wreckage and pressure ridges forming a substantial part of the ice surface. One of the main effects of low freezing temperatures, when the ice fields under pressure are subject to compaction, is the consolidation of wreckage and pressure ridged surfaces into massive ice concentrations. It is usual in areas of high concentration for the pressure ridged ice to occupy from 5/10 to 7/10 of the ice surface. Pressure ridged ice may be from 20 to 30 feet thick. It is often observed that a ship passing through level floes leaves an open water wake, and passing through areas of ice wreckage and pressure ridges, leaves an ice-congested wake, indicating that the later is considerably thicker. Stress and strain on the ice barrier induced by tides, winds, and currents prevent a single rigid surface developing over an extensive area of the sea. During mild winter weather and in the spring when freezing is no longer a factor in ice consolidation, ice wreckage areas prevent passage of a ship because of the thickness and heavy concentration of the ice floes.

The area of greatest ice congestion tends to be that part of the Cape Breton coast that has a WNW-ESE trend, that is, from St. Ann's Bay to Cape Percé. North winds are most effective in piling up the ice against this stretch of coast. With sustained ice supplies, as during the winter of 1962, the barrier extends northward and eastward. Ice fields in this area were extensive during the winter of 1959, but westerly component winds were prevalent and these winds held the ice fields well off the coast. If westerly winds have a high persistence tendency throughout the period of ice disintegration, the ice fields are driven out to sea. On the other hand, when large sections of the Strait are covered by ice and the persistence tendency of the westerlies drops markedly, ice wreckage and pressure ridges may congest the Sydney Bight area.

The ice fields that form off the SW-NE trending part of the Cape Breton coast, between St. Ann's Bay and Cape North, produce quite a different picture of ice conditions. Prevailing westerly winds and the trend of the coast produce conditions that give rise to a bordering strip of open water or an open ice cover ; it generally does not experience the heavy ice barrier that develops farther south. Also, ice drifting through the passage between St. Paul Island and Cape North tends to go through in intermittent masses rather than as a steady, sustained flow, although the duration of each mass varies. As a result, local areas of open water or light ice cover occur in the ice fields adjacent to the coast. Only strong easterly component winds could be effective in establishing a blockade, with the main ice fields for this purpose existing to the southeast of the area.

Summary and Conclusions

The Gulf of St. Lawrence is the main source of ice affecting shipping in Cabot Strait and the Sydney Bight area. An examination of the relations among air temperatures at Grindstone Island, calculated ice drift past St. Paul Island, and ice cover areas in the Gulf and the Strait leads to the following conclusions :

1– There is a high negative correlation between summed winter temperatures and ice cover areas both in the Strait as well as in the Gulf. Summed December and January mean monthly temperatures are significantly correlated with ice cover two months hence.

2– Calculation of ice drift shows there is a positive west to east movement past St. Paul Island in each of the years examined.

3– The correlation ($r = -.772$) between summed winter temperatures and winds (expressed as vector resultants of ice drift) suggests that it is usual for low freezing temperatures and strong westerly winds to occur concurrently. Such conditions are optimum for ice formation in the Gulf and for sustaining the flow of ice into the Strait.

4– If the persistence tendency of westerly winds remains high during the break-up period, the ice fields are driven out to sea. If, however, there is a marked drop in the regularity of the westerlies during March and April, ice masses may become consolidated in the Sydney Bight area and stagnate there. This appears to be a recurring phenomenon.

In summary, the prediction of ice conditions that hinder ferry operations in the Sydney Bight area of Cabot Strait is an extremely difficult task. The extent of April ice cover in the Strait may be estimated from summed December and January temperatures (although the standard error of estimate is quite large). Assuming that large sections of the Strait become ice covered during the break-up season, the action of tides, winds, and currents, which combine to produce massive concentrations of ice wreckage in the Sydney Bight area, must be ascertained. Until a more detailed knowledge of the interrelationships among the factors causing ice consolidation in Sydney Bight is gained, reasonably accurate prediction of ice conditions hindering ferry operations does not seem possible.

References

Black, W. A., 1958. Gulf of St. Lawrence Ice Survey, Winter, 1958. Department of Mines and Technical Surveys, Geographical Branch, *Geographical Paper*, No. 19, 56 pp.

Black, W. A., 1959. Gulf of St. Lawrence Ice Survey, Winter, 1959. Department of Mines and Technical Surveys, Geographical Branch, *Geographical Paper*, No. 23, 56 pp.

Black, W. A., 1960. Gulf of St. Lawrence Ice Survey, Winter, 1960. Department of Mines and Technical Surveys, Geographical Branch, *Geographical Paper*, No. 25, 64 pp.

Black, W. A., 1961. Gulf of St. Lawrence Ice Survey, Winter, 1961. Department of Mines and Technical Surveys, Geographical Branch, *Geographical Paper*, No. 32, 52 pp.

Black, W. A., 1962. Gulf of St. Lawrence Ice Survey, Winter, 1962. Department of Mines and Technical Surveys, Geographical Branch, *Geographical Paper* (in press).

Drogaicev, D. A., Zones of compression and rarefaction of ice in the atmospheric pressure field. *Izv. Akad. Nauk*, Geophysical Series, 1956, II, 1331-1332. (Transl. by E. R. Hope, Defence Research Board T264R, Ottawa, 1957.)

Forward, C. N., 1954. Ice distribution in the Gulf of St. Lawrence during break-up season. *Geographical Bulletin*, No. 6, pp. 45-84.

Forward, C. N., 1957. Ice conditions in the Gulf of St. Lawrence during the spring seasons, 1953-1957. Department of Mines and Technical Surveys, Geographical Branch, *Geographical Paper*, No. 16, 13 pp.

Zubov, N. N., 1947. Dynamic oceanology ; Chapter VIII titled « Wind and the movement of ice » pp. 336-353. (Transl. by L. G. Robbins, Tech. Services Br., Division of Oceanography, U. S. Navy Hydrographic Office, 1947, 18 pp.)