ON THE ICEBERG SEVERITY OFF NEWFOUNDLAND AND ITS PREDICTION*

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Abstract. An analysis of the iceberg count off Newfoundland for the period 1880–1925 shows that stronger than usual north-westerly winds off the Labrador and Newfoundland coasts and relatively low temperatures over Newfoundland during the months from December to March lead to greater than average berg counts off Newfoundland in the following months, mainly April to June. Conversely, lighter than usual north-westerly winds and relatively high temperatures lead to lower than average berg counts in the following months. The relative strength of winds can be measured by the pressure difference between Belle Isle and Ivigtut. The relationship investigated provides a basis for predicting the berg count each year at the end of March. A comparison of the computed values of the berg count with the actual values on scale 0 to 10 for the following period 1927–61 shows marked agreement.

It is further indicated that a more detailed representation of the winds, temperatures and other elements during the winter and early spring in that general area would lead to a closer relationship with the berg count and a broader basis for its prediction.

Résumé. Une analyse de la statistique des icebergs au large de Terre-Neuve, de 1880–1925, montre que les vents du nord-ouest soufflant sur les côtes du Labrador et de Terre-Neuve de façon plus forte que normalement et que les températures relativement basses au-dessus de Terre-Neuve pendant les mois de décembre à mars, entraînent, au cours des mois qui suivent et notamment d'avril à juin, une augmentation du nombre des icebergs au large de Terre-Neuve dépassant la moyenne. Inversement, des vents du nord-ouest plus faibles et des températures plus élevées, entraînent une diminution du nombre des icebergs au cours des mois qui suivent. La force relative des vents peut se calculer à l'aide de la différence de pression entre Belle Ile et Ivigtut. La relation établie fournit une base pour la prévision du nombre d'icebergs pour la fin du mois de mars de chaque année. En comparant, à l'échelle 0 à 10, le nombre d'icebergs calculé aux valeurs réelles de la période de 1927 à 1961 on trouve une concordance notable.

Par ailleurs l'on signale qu'une représentation plus détaillée des vents, températures et autres facteurs, règnant pendant l'hiver et au début du printemps dans toute cette région, permettrait d'établir une relation plus étroite avec la statistique des icebergs ainsi qu'une base de prévision plus vaste.

Zusammenfassung. Eine Analyse der Eisberg-Zählungen um Neufundland von 1880 bis 1925 zeigt, dass ungewöhnlich kräftige Nord-West-Winde an den Küsten von Labrador und Neufundland und relativ niedrige Temperaturen über Neufundland während der Monate Dezember bis März zu einer überdurchschnittlichen Eisberghäufung um Neufundland während der Folgemonate, vor allem von April bis Juni. führen. Umgekehrt lassen schwächere Nord-West-Winde und relativ hohe Temperaturen in den folgenden Monaten das Auftreten von Eisbergen unter den Durchschnitt sinken. Die relative Windstärke kann aus Druckunterschieden zwischen Belle Isle und Ivigtut hergeleitet werden. Die festgestellte Beziehung bietet eine Grundlage für die Vorhersage der Eisberg-Häufigkeit zu Ende März jeden Jahres. Der Vergleich gerechneter Werte für die Eisberghäufigkeit mit den tatsächlichen Werten nach de Skala 0–10 für die Folgeperiode 1927–61 zeigt deutliche Übereinstimmung.

Weiter ist anzunehmen, dass eine genauere Statistik der Winde, Temperaturen und anderer meteorologischer Elemente während des Winters und ersten Frühjahrs in diesem Raum zu einer noch engeren Beziehung mit der Eisberg-Häufigkeit und einer breiteren Grundlage für ihre Vorhersage führen würde.

Introduction

The basic scientific problem of iceberg severity off Newfoundland is of special interest because of the hazard icebergs present to North Atlantic shipping. Because of this hazard, a forecast of iceberg severity is desirable. This forecast should include: (1) prediction of the number of bergs that annually cross south of lat. 48° N., the signpost selected by the International Ice Patrol, and (2) prediction of drift and disintegration of bergs which have crossed that latitude and have reached more southerly waters where they are most hazardous.

Frequency of Bergs and Berg Regime

Number of bergs. On the average, 400 icebergs annually cross lat. 48° N. (off Newfoundland). The figure is based on data for the period 1900–61, for which detailed statistics

* Prepared with support from the National Science Foundation.

are available. During this 62 year period, there were 13 seasons, one of which occurred during World War II and is held doubtful, when more than 700 bergs were reported crossing lat. 48° N., and 13 others when less than 50 bergs drifted past the same latitude. The heaviest ice years were 1909, 1912, 1929 and 1945 (doubtful) when over 1,000 bergs were counted. (During the war years, 1942–45, the method used for observing was by air reconnaissance and there was a tendency to overcount the icebergs (Challender, 1947).) The lightest ice years were 1924, 1940, 1941, 1951 and 1958, when less than a dozen were observed during each year. In the two successive years 1940 and 1941, only two bergs were counted per year, and in 1958 only one was counted.

During the 62 year period, the number of bergs has tended to decline: the average for 1900–30 was 432 compared with 351 for 1931–61, a decrease of 19 per cent. This decrease in the iceberg count reflects the recent climatic change in that more of the bergs drifting southward could make their way into the bays and shallows of the Labrador and Newfoundland coasts as the winters have become more open, leaving fewer bergs to reach lower latitudes. The extent of the amelioration may be seen from the fact that the mean December-March temperature at St. John's has risen from $-3\cdot4°$ C. ($25\cdot8°$ F.) (1899/1900–1929/30) to $-2\cdot6°$ C. ($27\cdot4°$ F.) (1930/1–1959/60) while the mean monthly July sea surface temperature in the quadrilateral lat. 45°–50° N., long. 45°–50° W. rose from $9\cdot7°$ C. ($49\cdot4°$ F.) (1904–30, $n = 24$) to $11\cdot2°$ C. ($52\cdot1°$ F.) (1931–55, $n = 22$). It should be noted that bergs are always in abundance to the north, although their actual number depends mainly on how many drift over from the west coast of Greenland. Because of recent amelioration, their numbers may have actually increased as more of them could be freed from the ice-packed fjords and bays of Greenland's west coast, where most of the bergs originate.

The principal iceberg season is three months, April to June, when on the average 80 per cent of all the bergs drifting south cross lat. 48° N. Another 16 per cent cross lat. 48° N. in March and July. In some years the season may be advanced as in 1903, 1909 and 1930, when over 200 bergs drifted past lat. 48° N. before 1 April; in other years the season may be prolonged, as in 1914, 1918, 1919 and 1929 when over 100 were counted after 30 June.

Winds and current. The bergs appear to drift with the Labrador Current and wind at varying distances from the coast. The effect of wind on an iceberg varies with the shape of the berg; the portion that is submerged is influenced by the current and that which is above the surface is exposed directly to the wind. Since the current itself is influenced by the wind in a complex fashion, the total effect of the wind on the drift of a berg must be considerable. Although the winds act on only a small portion of the berg, they exert a pronounced thrust on it due to the great speed of the wind as compared with the speed of the current. In the winter the prevailing wind direction over the general area is from the north-west; therefore it normally coincides with that of the Labrador Current, and the wind and current act on the berg in unison. However, as the direction of the current is relatively steady, especially as it is contained on one side by land, and as the direction of the wind is not steady, the wind can cause important changes in the drift of bergs causing bergs to drift close to shore or away from shore, depending on the direction of the wind in a particular year. Under the impact of steady winds from the north-west, bergs off the Labrador and Newfoundland coasts will continue at a faster rate on their south-eastward course, resulting in high counts at lat. 48° N. Winds from the east or north-east, however, cause the bergs to drift more into shallows and inlets of the Labrador and Newfoundland coasts where they are grounded and eventually disintegrate, resulting in low counts at lat. 48° N. (see also below).

It seems that the effect of the winds on the movement of bergs is more marked when winds continue from a given direction over a long period of time (Mecking, 1906; Quinan, 1915; Levis, 1916; Graves, 1938; Soule and Challender, 1949; Cheney, 1951). Furthermore, a wind from a given direction over a long period causes a pattern of movement that is maintained

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after the wind has ceased and hence permits insight into future berg distribution (Mecking, 1907; Smith, 1931; Schell, 1952).

The rôle of the Labrador Current in the berg count off Newfoundland is at present unknown: there have not been enough observations.

Pack ice, waves, sea and air temperature, and rain. Pack ice along the Labrador and Newfoundland coasts is another factor in determining direction of bergs as they drift southward. Large amounts of pack ice keep bergs from the coasts and lack of pack ice permits bergs to drift into the bays and shallows.

Still other factors in iceberg severity are the eroding action of waves, sea and air temperatures, and rain, especially after the icebergs have reached warmer latitudes.

These factors: current, wind, pack ice off-shore, wave action, together with sea and air temperatures and rain are inter-related: strong north-westerly winds are on the whole associated with lower temperatures, more pack ice, less wave action and less rain and, hence, with more bergs drifting southward and melting more slowly. Weak north-westerly winds or winds with a marked easterly component are associated with higher temperatures, less pack ice, more rain and hence with more bergs drifting westward to be grounded on the coasts, while the fewer bergs passing southward melt more quickly.

Predicting the Iceberg Count off Newfoundland

Fluctuations in iceberg severity off Newfoundland have been the subject of early studies (Meinardus, 1904, 1905; Mecking, 1906, 1907), but not until later, when sufficient data for a statistical study became available (Smith, 1931), could a careful examination of the causes of fluctuations be made. It had appeared that the fluctuations in the berg count were caused by the north-westerly winds in winter and early spring off the Labrador and Newfoundland coasts, and that these winds were presumably related to the Arctic inflow by way of the north-eastern North Atlantic in the preceding summer, fall and early winter (Meinardus, 1904, 1905). It was subsequently shown (Schell, 1952) that the strength of the inflow into the Arctic measured by the pressure gradient between north-west Europe to Iceland does not necessarily lead to an increased outflow of air over Baffin Island and Labrador or to stronger north-westerly winds. This made it desirable to consider the berg count only in terms of variations in the north-westerly winds over Labrador and adjacent waters. Thus the correlation of the mean December–March pressure difference between Belle Isle off the northernmost tip of Newfoundland and Ivigtut on the south-west coast of Greenland as a measure of the strength of the north-westerly winds off Labrador with the berg count off Newfoundland during the iceberg season is $r = 0{\cdot}47$ (1879/80–1925/6, $n = 47$) (Schell, 1952), using the same cut-off date in the data as employed by Smith (1931).

As might have been expected from the fact that low temperatures would favor the development of pack ice off-shore which would tend to keep the bergs away from the coast, and thus allow them to drift southward, a relationship between berg count and air temperature is also involved (Groissmayr, 1939). The correlation of the mean December–March temperature at St. John's with the iceberg count using the same period as above gave $r = -0{\cdot}45$ (1879/80–1925/6, $n = 47$) (Schell, 1952). But since the winter temperature at St. John's is correlated with the strength of the north-westerly winds, the combined correlation of the pressure difference and temperature with berg count is $R = 0{\cdot}57$ (1879/80–1925/6, $n = 47$). The value of the total correlation coefficient R thus obtained accounts for approximately one-third of the variance in berg count ($R^2 = 0{\cdot}32$) and could be predicted from the preceding December–March pressure gradient and temperature. The corresponding regression equation is

$$\Delta N = 0{\cdot}31\Delta P - 0{\cdot}36\Delta T$$

where N is the number of icebergs, P is the pressure difference between Belle Isle and Ivigtut

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in millibars and T is the temperature at St. John's in ° F. The performance of the formula in the ensuing 35 years (1927–61) is shown by the computed and actual deviations in iceberg

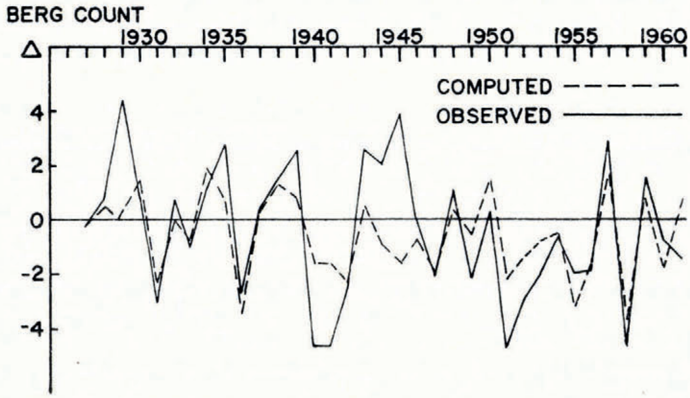

*Fig. 1. Computed and observed deviations from the average iceberg count (1880–1926) on scale 0 to 10 (Smith, 1931) during 1927–61**

count (Table I and Fig. 1), given on scale 0 to 10 as devised by Smith (1931), on which a deviation of 2·0 units, for example, corresponds to a total count of over 700 icebergs and a departure of −2·0 units to less than 100 icebergs, the scale being somewhat asymmetrical.

Table I. Computed and Observed Deviations (Δ) from the Average (1880–1926) in the Iceberg Count off Newfoundland (Lat. 48° N.) on a Scale 0 to 10, During 1927–61

Year	*Computed deviation* Δ	*Observed deviation* Δ	*Year*	*Computed deviation* Δ	*Observed deviation* Δ
1927	−0·2	−0·2	1945	−1·6	3·9*
1928	0·5	0·8	1946	−0·7	0·1
1929	0·0	4·2	1947	−1·9	−2·0
1930	1·5	0·4	1948	0·3	1·1
1931	−2·3	−3·0	1949	−0·6	−2·2
1932	0·0	0·7	1950	1·5	0·3
1933	−0·8	−1·0	1951	−2·2	−4·7
1934	1·9	0·9	1952	−1·4	−3·0
1935	0·7	2·8	1953	−0·8	−2·0
1936	−3·5	−2·6	1954	−0·5	−0·6
1937	0·2	0·4	1955	−3·2	−2·0
1938	1·3	1·5	1956	−1·6	−1·8
1939	0·8	2·6	1957	1·7	2·9
1940	−1·6	−4·7	1958	−3·7	−4·7
1941	−1·6	−4·7	1959	0·8	1·6
1942	−2·3	−2·4	1960	−1·8	−0·8
1943	0·5	2·6*	1961	0·8	−1·5
1944	−0·9	2·0*			

* The agreement between the computed and actual deviations in 1943, 1944 and 1945 would be closer if we had allowed for the apparent over-counting in the war years by less experienced personnel. The results obtained in 1942 would not be appreciably affected inasmuch as the number of bergs that year was low (a total of 40 bergs).

Of the 35 cases available for consideration, 30 agree as to sign of deviation (those equal to zero, either computed or actual, are counted as one-half) as compared with 17·5 cases or 50 per cent by chance. The correlation coefficient between the computed and actual deviations for the series is: $R = 0{\cdot}61$ (1927–61) which is approximately the same as that obtained for the earlier period ($R = 0{\cdot}57$) (see footnote to Table I).

If another basis for comparison were to be chosen, for example by adopting a tolerance of 1·0 units on the same scale (0–10), there would have been agreement in 16 out of a possible 35 cases (Table I), a score that again is appreciably better than chance. It is worth pointing out that a negative deviation in the iceberg count like that computed for 1940, 1941 and 1951,

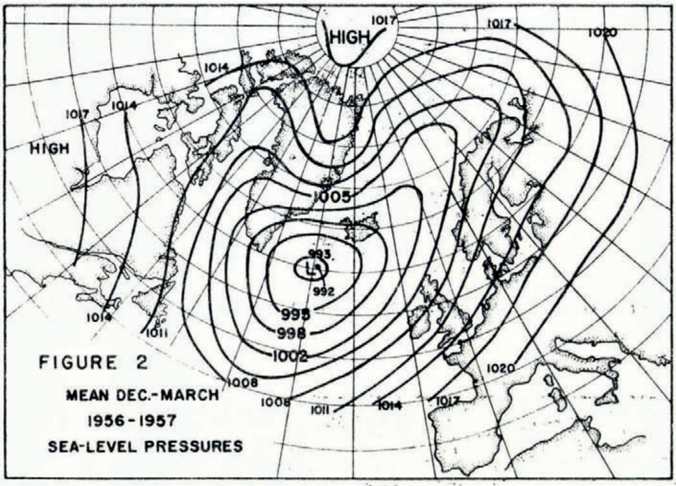

Fig. 2. Mean December 1956–March 1957 pressure distribution favoring a severe iceberg season

which differed from the actual by 2·0 or more units, would in each case have called for quite a light ice season (see Table I).

The use of the simple yet rather effective formula based on the mean December–March Belle Isle to Ivigtut pressure difference and St. John's temperature for predicting the iceberg count may, as we look ahead, be thought of special interest only. Closer measures of the circulation, temperature and other factors controlling the iceberg count can now be considered.

The mean December–March pressure distribution over the northern North Atlantic and adjacent areas for the last five winter seasons (1956/7–1960/1), each representing an essentially different pattern of circulation that is later reflected in widely different berg counts off Newfoundland (Figs. 2, 4, 6, 8, and 10), are indicative of how this may be achieved.

Figure 2, representing the mean pressure distribution during the four winter months December 1956–March 1957, shows a very intense low south-west of Iceland with a narrow spacing of the isobars westward to Labrador and Newfoundland, denoting strong north-westerly winds and, hence, low temperatures and considerable ice off-shore. The ice off-shore would keep the bergs on the south-eastward course and from drifting into the bays and shallows along the coasts, thus giving a large count off Newfoundland. (The mean December 1956–March 1957 temperature departures from their respective averages in that area were −1·0° F. (0·6° C.) at St. John's and −3·4° F. (1·9° C.) at Goose Bay.) The berg count in

1957 was 931, corresponding to a departure of 2·9 units from the average on scale 0 to 10 and was one of the heaviest on record (Fig. 3).*

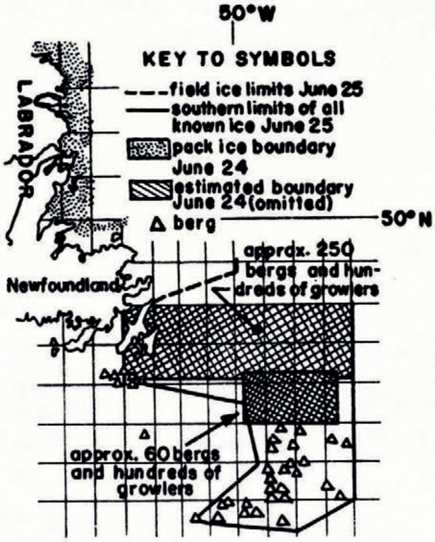

Fig. 3. Iceberg distribution as of 25 June 1957, showing heavy concentration of icebergs south-east of Newfoundland

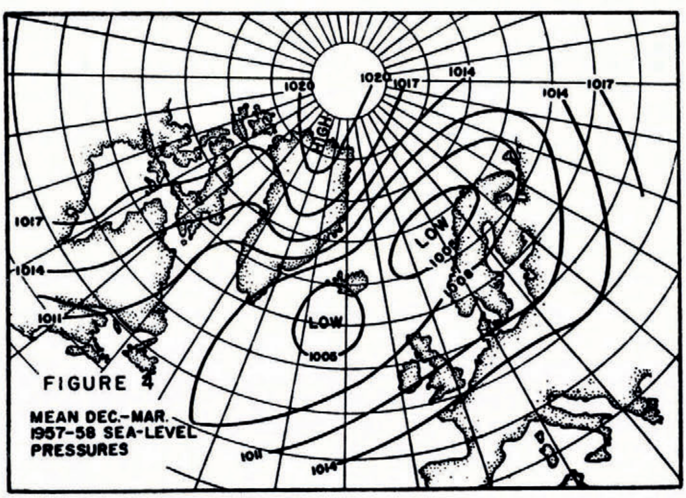

Fig. 4. Mean December 1957–March 1958 pressure distribution favoring a very light iceberg season

Similarly, Figure 4, representing the mean pressure distribution in the four winter months December 1957–March 1958, shows a weakly developed low south-south-west of Iceland with an extremely wide spacing of the isobars westward to Labrador and Newfoundland and a

* Data shown on Figures 3, 5, 7, 9, and 11 were taken from *Weekly Ice Chartlets* published by the U.S. Navy Hydrographic Office, Washington, D.C.

pattern of pressure that is associated with light winds from the north-east, relatively high temperatures, and a little ice off-shore. In these circumstances the bergs would tend to drift

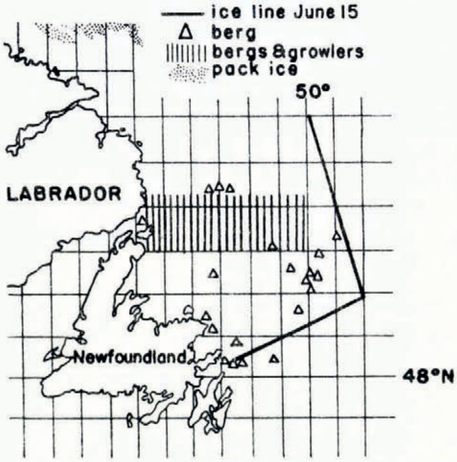

Fig. 5. Iceberg distribution as of 17 June 1958, showing no bergs south-east of Newfoundland

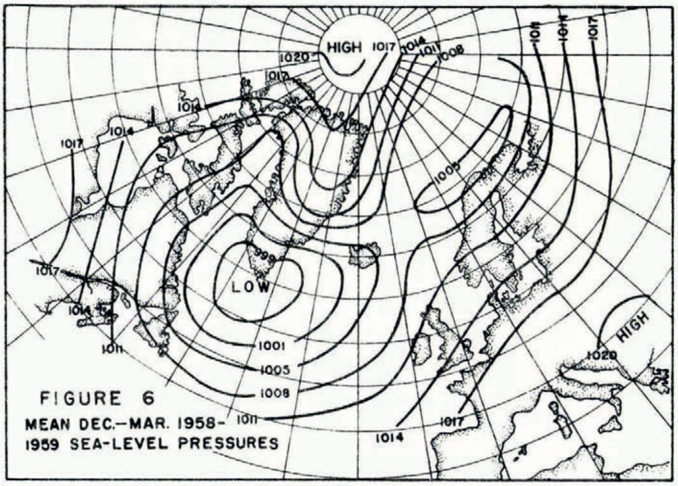

Fig. 6. Mean December 1958–March 1959 pressure distribution favoring an above average season

into the bays and shallows along the coasts leading to a very light iceberg season. (The mean December 1957–March 1958 temperature departures from their respective averages were 7·1° F. (3·9° C.) at St. John's and 11·9° F. (6·6° C.) at Goose Bay.) Only one iceberg crossed lat. 48° N. in 1958 (Fig. 5).

Figure 6, representing the mean December 1958–March 1959 pressure distribution, shows a well-developed low just south of Greenland with a strong flow of air from the north-west over Labrador and Newfoundland, indicating low temperatures and much ice off-shore and in consequence a larger than usual transport of bergs south-eastward to Newfoundland waters. (The mean December 1958–March 1959 temperature departures from their respective averages were −2·2° F. (1·2° C.) at St. John's and −1·9° F. (1·1° C.) at Goose Bay.) The number of bergs in 1959 was 685 as compared with 400 approximately on the average (Fig. 7). In comparing the pressure distribution for the winter 1956/7 when 931 bergs were counted with that for the winter 1958/9 when only 685 were observed, it should be noted

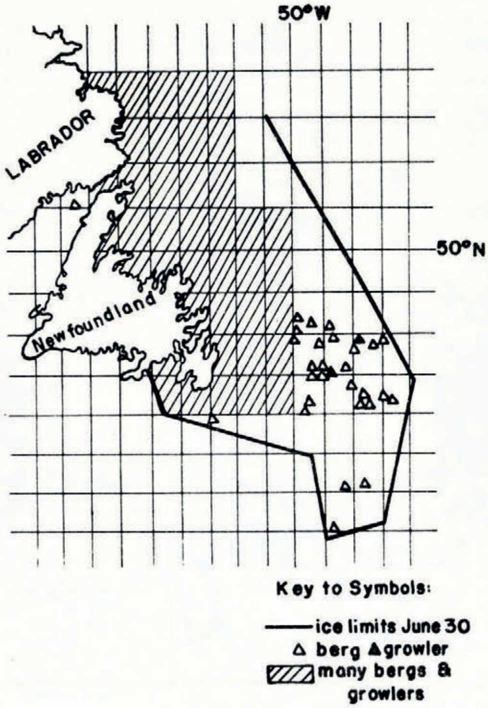

Fig. 7. Iceberg distribution as of 30 June 1959, showing moderate concentration of icebergs south-east of Newfoundland

that the south-eastward orientation of the isobars off Newfoundland was more pronounced in the winter 1956/7 than in the winter 1958/9.

Figure 8, representing the mean December 1959–March 1960 pressure distribution, shows a pattern of pressure that denotes brisk winds from the north-east in marked contrast to the normally prevailing north-westerly flow over that region, indicating a south-westward drift of the bergs onto the coasts of Labrador and Newfoundland, and, hence, fewer bergs south of lat. 48° N. (The mean December 1959–March 1960 temperature departures from their respective averages were 3·6° F. (2·0° C.) at St. John's and 7·7° F. (4·3° C.) at Goose Bay.) The berg count in 1960 was approximately 230, well below the average. As a consequence of the backing of the winds from the north-east, the Strait of Belle Isle was beset with heavy ice and growlers, many of the latter drifting through into the Gulf of the St. Lawrence and subsequently appearing on the west and south coasts of Newfoundland (Fig. 9).

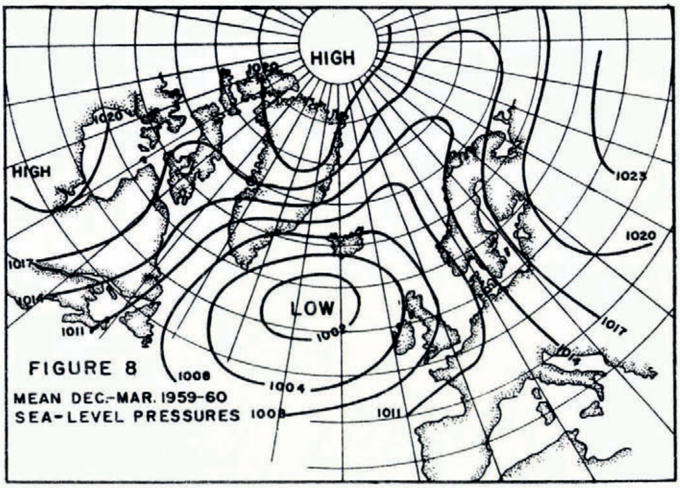

Fig. 8. Mean December 1959–March 1960 pressure distribution favoring a light iceberg season

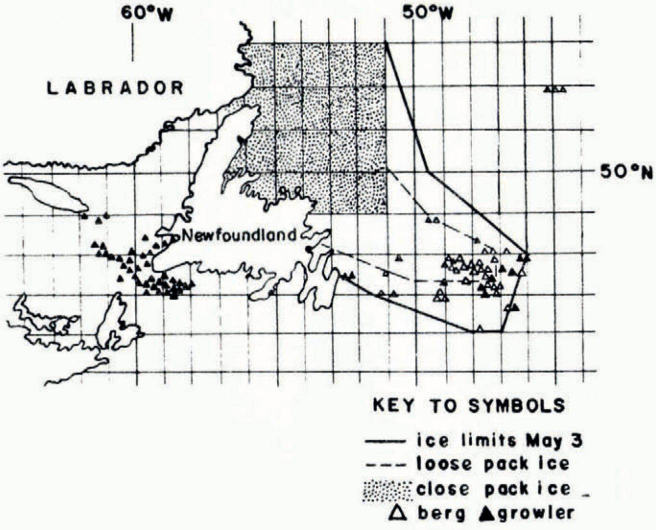

Fig. 9. Iceberg distribution as of 21 June 1960, showing a relatively light iceberg concentration south-east of Newfoundland

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Finally, Figure 10, giving the mean December 1960–March 1961 pressure distribution, shows a well-developed low south-west of Iceland with a closer than average spacing and a

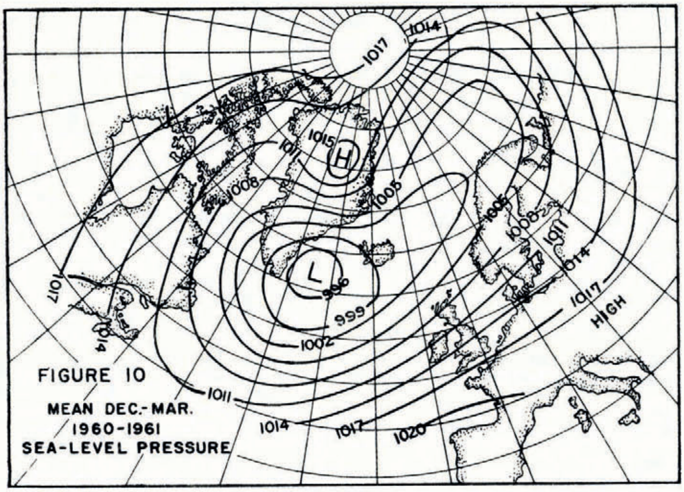

Fig. 10. Mean December 1960–March 1961 pressure distribution favoring an above average iceberg season

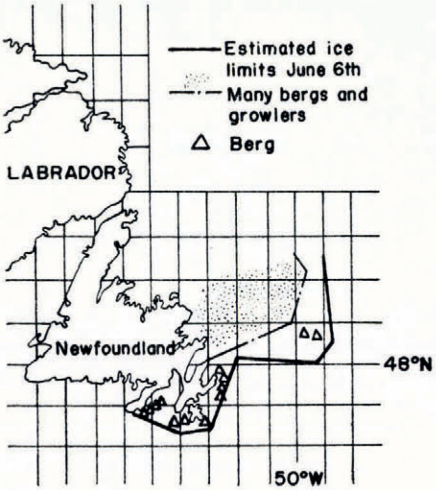

Fig. 11. Iceberg distribution as of 6 June 1961, showing few bergs south-east of Newfoundland but many bergs and growlers north of lat. 49° N.

north-west to south-east orientation of isobars off Labrador and Newfoundland, which favors an above average berg count. (The mean December 1960–March 1961 temperature departures from their respective averages were −0·6° F. (0·3° C.) at St. John's and −1·2° F.

(0·7° C.) at Goose Bay.) The actual count that year was only approximately 115, or well below the average, and marks the first time since 1946 when the computed and observed deviations differed in sign and were in substantial disagreement. The iceberg season that year was unique in that a total of 600 bergs were actually observed at one time just north of lat. 49° N. (Fig. 11). However, most of them were trapped in Notre Dame Bay on the north coast of Newfoundland, emphasizing the importance of winds, currents, and other controlling factors during the iceberg season, which, once every dozen years or so, can reverse the winter controls.

Conclusion

The foregoing suggests that a more detailed circulation index based on the pressure distribution over the larger area of Baffin Land, Labrador, Newfoundland and adjacent waters, a closer evaluation of the temperatures of that general area, and actual observations of the extent of the ice off-shore, would lead to more accurate predictions of icebergs crossing lat. 48° N. each year. Similarly, a prediction of the winds, currents, etc., during the iceberg season would yield a still closer agreement between the actual and observed deviations. The more complete analysis may also provide information about the eastward spread of the bergs in some years as well as the count each month separately, thus indicating also the onset and termination of each ice season. Also, an examination of the sea and air temperatures, winds and currents south of this latitude could give us a measure of the disintegration of the icebergs in the waters where the iceberg hazard is greatest.

Acknowledgements

I am indebted to personnel of the International Ice Patrol, U.S. Coast Guard for supplying data on the iceberg counts and to officials of the Canadian Meteorological Service and the U.S. Weather Bureau for the meteorological data that went into the computation of the iceberg count each year.

MS. received 25 August 1961

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