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DEPARTMENT OF TRANSPORT
METEOROLOGICAL BRANCH

'BLOCKING' CIRCULATIONS OVER THE NORTH
ATLANTIC AND THEIR INFLUENCE ON
GANDER TERMINAL WEATHER
DURING MAY

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ABSTRACT

This investigation was undertaken to illustrate the importance of "Blocking" circulations over the North Atlantic as related to the terminal weather at Gander Airport during the month of May, (the month containing the highest percentage of poor weather during the year).

Periods of prolonged poor weather (ceilings below 300' and/or 3/4 mile visibility) are examined for the months of May from 1950-1960 inclusive. Correlation between the large scale blocking-type circulations over the Atlantic and the poor weather periods at Gander are illustrated and discussed. The life cycle of the most typical Blocking sequence resulting in a prolonged poor weather period at Gander is pictured in chart form and its significant characteristics examined.

The characteristic properties of prolonged poor weather periods in May are investigated. Some useful statistical parameters are derived to aid in the preparation of forecasts at Gander involving extensive low ceilings and visibilities in May.

CANADA - DEPARTMENT OF TRANSPORT - METEOROLOGICAL BRANCH

"BLOCKING" CIRCULATIONS OVER THE NORTH ATLANTIC AND
THEIR INFLUENCE ON GANDER TERMINAL WEATHER DURING MAY

by

R. F. Cake

1. INTRODUCTION

Forecasters in the Canadian Meteorological Service who have spent a portion of their service in Newfoundland, will remember only too well, the unpleasant experience of seemingly endless days of rain, drizzle, and fog during the early spring there.

The current study began as a statistical analysis of this poor weather with the hope of obtaining some significant averages for daily use in forecasting terminal weather at Gander Airport.

Upon examination of Forms 2369 for the period 1950-60 (Figures 1, 2, 3), showing hourly ceiling and visibility ranges of actual weather at Gander Airport, it was noted (Table #1) that May had the largest percentage of hours of weather in the ranges: less than 300' and/or 3/4 mile visibility; February, January and April followed not far behind in that order, for total percentage of bad weather conditions. May 1954 showed a staggering 31.5% of the total hours of the month to have weather below the 300' and/or 3/4 mile range! May 1952 follows closely with 28.5% and May 1960 shows a total of 25.2%. The average for the month of May during the eleven year period selected 1950-1960, was 15.4% with a low of 4.4% recorded in 1956.

Examination of the general synoptic situations associated with the good weather months of May, as compared with the poor weather months, clearly indicated the primary reason for the prolonged bad weather periods. The general circulation pattern for the poor weather months of May was of the low-index type. The presence of large scale "Blocking" patterns in the circulation over Eastern Canada, the Atlantic and Western Europe was very frequent during the bad weather months and played a major role in the local weather at Gander.

2. Purpose of Study

Accordingly, further investigation was then directed toward the examination of prolonged periods of poor weather during the months of May at Gander Airport with a view to illustrating causes, and obtaining characteristic properties, frequencies and duration of such periods.

3. GENERAL CIRCULATION FOR MAY OVER NEWFOUNDLAND

Mean Circulation

The mean monthly maps for the period 1950-1960 for May months show at all levels from 700 mbs to 300 mbs, a mean trough position along the east coast of North America, a weak ridge over Iceland and Eastern Greenland, a marked ridge over western North America and a trough in the Eastern Pacific, [Lahey et al (1) and U.S. Weather Bureau (2)]. As expected with this mean circulation pattern, during this period 1950-1960, the major storm tracks showed that strong anticyclones from Northern Canada tended to migrate deep into South-eastern United States along the west side of the trough position with a secondary track across Hudson Bay and southeastward across Labrador and Newfoundland. Cyclonic activity in May was normally quite strong with the favourite position of cyclogenesis along the east coast of the United States. The most likely location for cyclogenesis was near Hatteras, these cyclones following a northeasterly course toward Newfoundland and curving sharply northward and even northwestward near latitude 55 degrees off Labrador.

The Mean Monthly maps for May for the Newfoundland area (1, 2) show a tendency toward a lower index in the zonal flow accompanied by height rise of 200-300 feet in keeping with the seasonal warming from April to May. The lower index is shown by a noticeable sharpening of the eastern seaboard trough in May from April. (Winston (3) found that there is a sudden southward shift of the westerlies from late April to early May and Namias (4) noted that the least persistence in all three weather elements - temperature, precipitation and upper-level pressure patterns occur from April to May and again from October to November).

Out of the eleven years examined (Monthly Weather Review) 1950-1960, only in one year, May 1956, was there a marked departure from the normal low index circulation to a decidedly high index circulation. This, as we shall see later in this study, resulted in the lowest number of hours of poor weather for a May month in our 11-year period.

4. DEFINITION OF PERIOD OF POOR WEATHER FOR THIS STUDY

First an arbitrary minimum period of duration of consecutive days of poor weather was chosen to eliminate the normal transient synoptic systems. A period of three days was selected, so that all periods in May from 1950-1960 were examined that fulfilled the following conditions:- for successive periods of three days or longer the hourly weather reports for Gander Terminal contained not less than 5 hours of weather conditions in the ranges lower than 300' and/or 3/4 mile on each day. This figure of 5 hours was long enough to eliminate the few cases of radiation fog (early morning) at Gander as in such cases the duration is normally only 2 to 4 hours. The choice of a three-day period proved quite reasonable, for in the eleven year period a total of eleven cases were found which fulfilled the above conditions and only a further two cases could be termed close to marginal.

The two marginal cases, 1952, May 29-31st and 1954, May 12-14th, failed to qualify under the above conditions by only one hour on the third day of each period. Each period contained several hours in the next higher range on the third day and radiation fog was not a factor. It was decided that they should be included in the study as they certainly qualify as periods of poor weather, and of course our initial conditions were set up only to delineate as closely as possible our periods of interest. The fact that no other periods came close to qualifying would seem to make the choice of the above limits a reasonable one.

Thus a total of thirteen cases of poor weather periods were found in the eleven-year period including May months from 1950-1960. Typical periods are illustrated on figures 1 and 2 (Cases I, II, VII, VIII) comprising Forms 2369 for May 1950 and 1954. The above years were chosen to show a very poor weather May, 1954; and a moderately poor May, 1950. The best weather month in the study, May 1956 is shown on figure 3.

Although the minimum interval of 5 hours may appear to be rather low for a definition of a poor weather day (24 hour period 0000Z - 2400Z), it was found that the average number of hours in our poor weather periods (56 days in all) below the limits 300' and/or 3/4 mile, turned out to be a very large 11.1 hours per day. The distribution of the number of hours per day below these specified limits is shown in figure 26. The graph shows a rather surprisingly even distribution in frequency of occurrences from 7 hours to 24 hours per day.

5. DISTRIBUTION OF POOR WEATHER PERIODS

An examination of Forms 2369 (e.g. figures 1, 2, 3) for the number of periods meeting the conditions specified above, was conducted for the eleven-year period 1950-1960. Table 1 shows the distribution of such periods by the month and by the year.

May contained the highest number of cases with 13, June next with 10 cases and January, February, March and April all had 8 cases each.

The average duration of such periods (lower limit arbitrarily chosen as 3) came to 5 days.

The longest period found to fulfil the initial conditions above was a 14-day period in July and August in 1954. There was one case of 12 consecutive days in January 1956. Under the column for May month the thirteen cases found for the eleven-year period and their duration are noted. Over half of the cases, 7 to be exact, are found in the three poorest weather months of 1952-54-60. The longest period in May months proved to be eight days duration in 1954 and the two months containing the lowest percentage of poor weather, 1956-58, contained no poor weather periods as per our criterion. (Section 4).

6. CORRELATION OF BLOCKING CIRCULATION WITH POOR WEATHER PERIODS

To illustrate the presence of Blocking action during the May months encompassed in the study, a plot of the motion of blocking high pressure cells throughout the period are shown in figures 27, 28, 29, 30 with the dates of each of our thirteen cases shown on the left hand margin. The blocking patterns were followed at the 500-mb level for this purpose. In all but case XII, the location of the blocking high was between 15 degrees west and 60 degrees west longitude during the duration of the poor weather period and in every case a blocking pattern was present in the circulation over the Atlantic or Western Europe.

Further evidence of the presence of blocking action during the thirteen cases under study may be seen in the series of figures (Nos. 4-16) showing the circulation pattern at 500 mb superimposed upon the surface isobaric pattern. Each chart corresponds to approximately the mid-period of one of the thirteen poor weather periods (cases I-XIII). Further discussion of this series will be given in section 9.

7. LACK OF CORRELATION OF POOR WEATHER PERIODS WITH WINTER SEVERITY AND ICE CONDITIONS ALONG EAST COAST OF NEWFOUNDLAND

Another possible factor that appeared likely to influence the weather at Gander during May, was the presence of large ice-fields and corresponding low water temperatures in the coastal waters along eastern Newfoundland.

Figures on ice conditions were not available at Gander to compare directly with our poor weather months, but Table III shows an alternative approach to this problem. For each winter, the average daily temperature for the winter months, January, February, March and April was calculated and compared with the long-term average. Thus each winter was assessed a bias figure from the normal and labelled relatively, cool, mild or warm. The assumption was made that the amount of ice in the coastal waters east of Gander in May, would vary directly as the severity of the winter months preceding.

As can be readily seen from Table III, if the above reasoning is correct, no correlation appears to hold between the severity of the winter (thus the amount of coastal ice) and number of hours of poor weather at Gander in May. Both the highest and lowest number of hours of poor weather at Gander occurred following mild winters; 1956 and 1954 respectively.

Of course the presence of ice fields off Eastern Newfoundland would be a factor in Gander weather only when easterly circulations (north through southeast) prevailed. Ceilings at Gander would not be affected by coastal water temperatures in the case of westerly circulations. It would appear then that circulation patterns hold the key to the cause of the persistent poor weather periods at Gander in May.

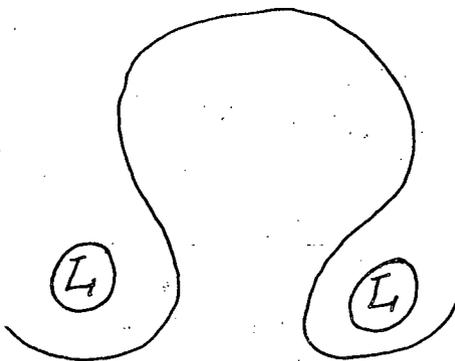
8. DEFINITION OF THE TERM BLOCKING

The definition by Namias and Clapp (5) is the one quoted in the Glossary of Meteorology and is adequate for this study.

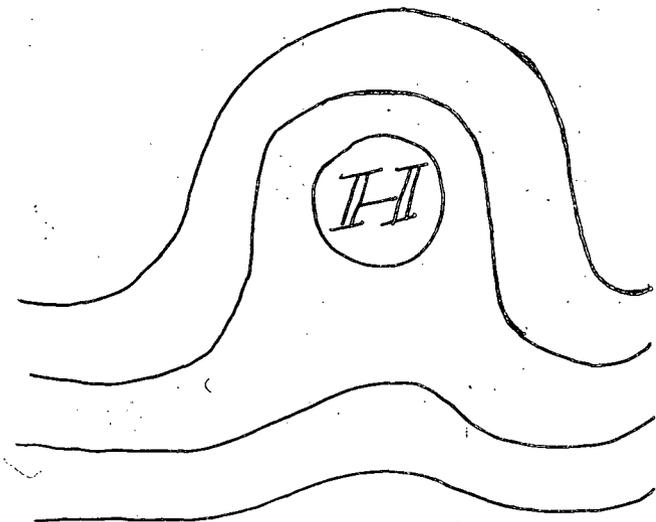
"Blocking" is defined as the obstructing, on a large scale, of the normal west-to-east progress of migratory cyclones and anticyclones. A blocking situation is attended by pronounced meridional flow in the upper levels, often comprising one or more closed anticyclonic circulations at high latitudes and cyclonic circulations at low latitudes (cut-off highs and cut-off lows). This anomalous circulation pattern (the "block") typically remains nearly stationary or moves slowly westward, and persists for a week or more."

Some investigators have emphasized various parameters in their studies and definitions of blocking action. For example Rex (6) defines his blocking model more rigidly, with a clear-cut upper jet (500 mb) which splits abruptly into two definite streams, one taking the northerly route around the north of the warm anticyclone and the other the southerly route around the cold cut-off low. (See as example, figure 14). For the purpose of this study two main blocking patterns were accepted, along similar lines to Sumner (7, 8). The first type being that accepted by Rex (6) as shown by figure 14. This pattern appeared most frequently and proved to be the more persistent blocking sequence. This pattern is hereafter referred to as the "cellular" pattern (see sketch below). The second type shown by figure 8, is essentially a single upper ridge of very large amplitude extending throughout the troposphere and usually assuming the familiar "omega" shape. The resulting circulation is strongly meridional. This type will be referred to as the "omega" pattern (see sketch below). It should be noted that during the period of a continuous blocking sequence, changes from one type of pattern to the other frequently occur. (See figures 27, 28, 29, 30, where type of pattern is shown as block progresses.)

For a summary of significant properties of blocking action in the Atlantic see Appendix I.



Omega Block



Cellular Block

9. ILLUSTRATIONS OF BLOCKING PATTERN RESULTING IN POOR WEATHER PERIODS AT GANDER IN MAY 1950-1960

As seen in Section (4), a total of thirteen periods were found on Form 2369 to meet our initial conditions. A plot of the motion of blocking high pressure cells throughout the months of May 1950-1960 are shown in figures 27, 28, 29, 30 with each of our thirteen cases shown on the left hand margin. The blocking highs were followed at the 500-mb level for this purpose.

From figures 27, 28 perhaps the most striking feature is the duration of blocking for the entire months of May in 1950-1952 and 1954. Two of these months contained the highest number of poor weather hours of the May months in our eleven-year period. Also very evident is the fact that a very large percentage of the blocking action occurs between 15° and 60° longitude, with the main concentration between 20° and 40°.

All thirteen cases of poor weather periods occurred during a period of blocking action, with location of the blocking high ranging from 65° to zero degrees. The most frequent location of the blocking high during the thirteen cases under study occurred between 20° and 45°, with a double "blocking-high" pattern influencing the period in some cases, such as cases II and XII (see figures 5 and 15).

Figures 4 - 16 show the circulation at 500 mb superimposed on the surface isobaric pattern, each taken at approximately the midperiod for every one of the poor weather periods (cases I - XIII).

From figures 4 - 16, cases I, III, V, VII, IX, XI, XIII, illustrate examples of strong cellular blocking patterns which are very common in the Atlantic during May. Slightly weaker blocking patterns are shown in cases II, IV, and X, while cases VI, VIII, XII illustrate the weakest patterns, although in the latter two cases, VIII and XII, the blocking high is actually almost off the map, north of the British Isles.

Cases IX and XI (figures 12 and 14) are good examples of the cellular blocking patterns while cases VI and VIII (figures 9 and 11) illustrate the omega pattern.

From this series of figures (4-16) the most obvious cause of the prolonged poor weather over Gander and Eastern Newfoundland is explained by the long fetch of moisture laden Atlantic air around the southern quadrant of the blocking surface ridge, or around the north quadrant of the cut-off low. When this moist air is lifted some 493 feet from sea level to the airport at Gander in a distance of 15 to 25 miles, the result is extremely low ceilings and visibilities. Just how frequently this occurs in May we have seen from Table I.

10. ILLUSTRATION OF MOST COMMON TYPE OF BLOCKING PATTERN FOUND IN MAY DURING ELEVEN-YEAR PERIOD 1950-1960

From figures 27-30 it was noted that one type of blocking pattern appears to be by far the most common in our thirteen cases. This is where the blocking high is initiated over the eastern north Atlantic or Western Europe and

then retrogrades westward across the Atlantic during at least a portion of its life cycle, normally the initial portion. This is the case in cases I, II, III, IV, V, VII, X, XII, and XIII. This type of block is normally a very persistent feature, frequently, as we have noted in Section 9, maintained for the entire month. One fortunate feature of this pattern is that normally it can be readily observed several days before reaching mid-Atlantic, and thus the possibility of prolonged, extremely poor weather periods anticipated.

To illustrate a typical example of this type of blocking pattern a series of figures (17 - 24) is shown for the circulation on the Atlantic during the period May 15 - 24, 1960.

This example was chosen to show the usual initiation of such a block; the digging low in the southeastern Atlantic being cut-off while the anticyclone extends into high latitudes over Western Europe resulting in a complete breakdown of the zonal pattern into large scale eddies. Then the western retrogression of the blocking high takes place across the Atlantic. This retrogression is often of a rapid and discontinuous nature, as is the case in this instance where the cell of the blocking high moves from near zero degrees to 45 degrees west during the period from May 17th to May 20th, (see figure 30). The decline of the blocking pattern occurs when a rapid-moving short wave trough, moving southeastward from Baffin Island, digs strongly in the Western Atlantic, picking up the cut-off low southeast of Newfoundland and opening it out into an open trough. Meanwhile the blocking ridge shows progressive weakening over the Maritimes with the resulting return to a much more zonal, westerly circulation. This sequence of decay was found to be the case in over 50% of the 115 cases studied by Sumner (7, 8). Unfortunately, in the case of decay, there may occur many instances during the cycle of the block, indicating possible sign of decay, when in reality the only change taking place is a change in intensity or pattern, so that in this study I have found it very difficult to be sure of a positive decaying trend.

11. CHARACTERISTIC PROPERTIES OF POOR WEATHER PERIODS (CASES I TO XIII) FOUND IN STUDY

11.1 Frequency and Duration

As noted in Table I in the eleven-year period only three May months had no bad weather periods as defined by Section 4.

Three May months 1950, 1954, 1960 had two periods each, giving a total number of days of poor weather ranging from seven days to twelve days each.

May, 1952, had three separate poor weather periods giving a total of thirteen days of poor weather (as per Section 4).

The remaining four May months had one period each ranging from three to six days duration.

The average duration of the poor weather periods in the thirteen cases, lower limit arbitrarily set at three days, was 4.3 days.

From the above figures, it can only be concluded that very poor ceilings and visibilities at Gander in May are very common and comprise a very significant feature of the total weather pattern for May.

11.2. Climatology of Poor Weather Periods During Thirteen Cases

11.2.1. Diurnal Variation in Ceilings and Visibilities

One of the most important and difficult duties facing the forecaster on duty at Gander during these poor weather periods in May, is the problem of diurnal variation in ceilings and visibilities.

From Table 2, as one would normally expect, we find that the percentage of hours below 300' and/or $3/4$ of a mile to be higher during the night time than during the day. Columns 4 and 5 show that the total number of hours of poor weather during the 0000Z - 1200Z period to be at least double or more than the 1200Z - 2400Z period in all but 1954 where the ratio is just under double, 145:88.

Also columns 6 and 7 show that it is not at all unusual to have limits below 300' and/or $3/4$ mile during the whole night (0000Z - 1200Z) while only on three days during the thirteen cases (56 days) did the limits remain that low throughout the daylight hours (1300Z - 2400Z).

11.2.2. Time of Diurnal Improvement

The forecaster is frequently faced with the problem of estimating a time of improvement from below 300' and/or $3/4$ mile during the night-time hours to ranges above this figure in the early morning.

Figure 31A shows the results of 60 occurrences of such a problem during the eleven-year study. The obvious peak at 1300Z would appear to be a very useful guide in estimating an answer for such a forecasting problem. A period of improvement in TAFOR language of GRADU 1200Z - 1400Z would have proven correct in half of the above sixty occurrences.

11.2.3. Time of Diurnal Deterioration

Unfortunately the results do not resolve themselves so nicely when estimating the time of diurnal deterioration to below 300' and/or $3/4$ mile at the end of the day.

In figure 31B we find a very flat frequency distribution. An effort to further separate the 45 occurrences was made to differentiate between days when the low overcast never broke up during the day and those days when the ceiling during the day did rise to above range 4 (500-900', one mile or more). The results are shown in figure 31C and 31D.

Again we see no clear cut maximum for C when the low overcast persists during the day. In D, when daytime conditions are better, there is a good

maximum at 0100Z, about where one might expect, approximately two hours after sundown. It is interesting to note the very definite shift in time of diurnal deterioration between C and D from a peak from 2100Z-2300Z in C to 0100Z in D. This again is just what one would expect, a later time of lowering of ceilings after better daytime conditions.

11.2.4. Winds

During the 56 days encompassed by the thirteen cases of poor weather, the winds distribution by hours for various directions is shown in figure 32, Curve 1. The large peak in the occurrences for the NORTH quadrant is very pronounced, with the frequency for north, north northwest and north northeast about equal. A secondary peak is shown to the east southeast. As would be anticipated, if our theory of circulation around blocking highs and cut-off lows in the Atlantic is correct as the prime cause of the poor weather periods, wind frequency from WEST, SOUTHWEST and SOUTH is very low. Figures for this graph were taken from the Gander hourly observation records (form 2323). On the same graph, curve 2 shows frequencies of wind direction plotted for every day in May 1950-1960 for ranges 300' and/or 3/4 mile or less from the tables given in General Summaries of Hourly Weather Observations in Canada, Part II, published each year by the Canadian Meteorological Service.

Data for curve two for the years 1950, 1951, 1952 included ceilings up to 500' and/or 3/4 mile.

Curve three is that found by Johns (12) for May ceilings 0-200' visibilities 0-3/4 mile, using data for year 1942-1950.

The similarity between the three curves is very obvious. Curves one and two indicate little significant difference between the total population of our period May 1950-1960 and our special 56 days. The comparison with curve three for data for the period 1942-1950 as found by Johns (12) shows remarkable persistence between the two periods covering the 1940's and 1950's.

11.2.5. Number of Hours Per Day of Poor Weather Encountered

Included in cases 1 - 13 there was a total of 56 days of poor weather (as per Sections 4), and in this period figure 26 shows the frequency distribution of days with a certain number of hours of weather below 300' and/or 3/4 mile.

The graph shows a flat frequency distribution (arbitrary lower limit 4 hours) almost across to 24 hours, weighted slightly to the lower values 5 and 6 hours. The average day in the 56 days would contain 11.1 hours of weather below 300' and/or 3/4 mile; quite a large percentage, almost half the day! This again points out the extremely high frequency of prolonged poor weather in May. Naturally a feature so significant will demand a large share of the forecaster's attention.

12. CONCLUSIONS

It is very evident from the foregoing examination of May weather at Gander Airport that ceilings and visibilities in the lower ranges (less than 300' and/or 3/4 mile) are normally very frequent and often very persistent.

This means that the forecaster at Gander will have to direct a large portion of his time to studying this type of critical aviation weather in preparing his forecast.

On the basis of this study, I believe the major factor causing such a high percentage of poor weather at Gander in May, is due to intense, persistent large-scale blocking circulation patterns in the North Atlantic, (As illustrated by figures 27, 28, 29, 30). Because of the persistent nature of blocking circulations we find prolonged periods of poor terminal weather associated with these blocking patterns. The circulation set up by the blocking surface ridge, or cut-off low, in the Atlantic, is normally such that a long easterly (north through SE) fetch of moist, Atlantic air covers the east coast of Newfoundland, (as illustrated in figures 4 - 16). This relatively mild and very moist Atlantic air crosses the very cold coastal waters off eastern Newfoundland (often containing ice fields in May) and is lifted some 493 feet in a distance of 15-25 miles from the coast to the airport at Gander. The result is, understandably, extremely low ceilings and visibilities at Gander.

Thus it is most important that the forecasting problem be recognized as being closely related to the blocking action both from the point of view of anticipating such prolonged poor weather periods and estimating their duration.

The general properties of blocking patterns as listed in Appendix I, will aid in this assessment. Also the results of this study shown in Sections 5 and 11.1 will form a basis for anticipating the general behaviour, such as frequency and duration of the poor weather periods. (Average duration of 4.3 days (Table I) over the eleven-year period for May and average number of hours below 300' and/or 3/4 mile, per day, 11.1 hours (figure 26).

With nine out of our total of thirteen cases associated with the general type of blocking pattern illustrated and discussed in Section 10, there is no doubt that such a sequence should be highly suspect for resulting poor weather periods at Gander whenever it shows up in the eastern Atlantic in May. As pointed out in Section 10, this pattern can often be readily observed for several days as it retrogrades to the central Atlantic, at which time, the probability of it creating an on-shore, poor weather, circulation over eastern Newfoundland reaches a maximum. The best guide for long range motions on blocking patterns (36 - 72 Hours) are the barotropic and baroclinic NWP prognostics.

During each period of poor weather, a knowledge of the climatology of the periods studied here (Sections 11.2) will prove beneficial in the short-range forecast problem. The results obtained in Section 11.2.2. appear to be of special significance in forecasting the time of diurnal improvement after a night of low ceilings and visibilities, with 1300Z \pm 1 hour clearly indicated as the most probable range. (Figure 31A).

The time of diurnal deterioration curves as discussed in 11.2.3. although not as neatly peaked as that for diurnal improvement, do indicate a useful range of values. In both cases (11.2.2. and 11.2.3.) the results serve to confirm rule of thumb figures used by forecasters at Gander for years.

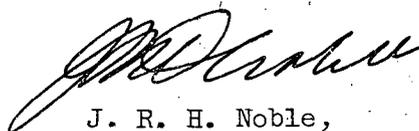
The figure of 31.5% of the total hours for May of 1954 ranging below 300' and/or 3/4 mile as shown in Table II is an extremely high value, but when 1952 and 1960 both show over 25% such a figure is not at all unrealistic.

On the other hand, in the eleven-year period, as shown in the last column of Table II, there were only three occasions when ceilings and visibilities remained continuously below the 300' and/or 3/4 mile range during the daylight hours 1300Z - 2400Z. This was much lower frequency of occurrence than would have been anticipated from experience, and one that the forecaster should take into account when faced with the problem of whether or not to forecast improvement of the terminal weather during the daytime period.

The frequency distribution of days with a certain number of hours of poor weather (figure 26), shows an unexpected distribution of the higher values (days with 13 to 24 hours of poor weather) with very little weighting toward the lower values (4 to 12 hours) as one might expect. Although from Table II it can be expected that approximately twice as many hours of poor weather will occur at night (0000Z - 1200Z) than during the day (1300Z - 2400Z), the mean of 11.1 hours per day for figure 26 has little (statistical) practical significance due to the frequency distribution of the data.

In summary, it has been the intention in this study to provide a background of information for the forecaster at Gander, to illustrate the importance of "Blocking" as related to the terminal weather at Gander, and to derive some useful statistical parameters to aid in the preparation of the forecast involving extensive low ceilings and visibilities in May.

APPROVED,



J. R. H. Noble,
Director.

13.

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APPENDIX I.

SIGNIFICANT CHARACTERISTICS OF BLOCKING ACTION IN THE NORTH ATLANTIC AS FOUND BY VARIOUS INVESTIGATORS

The outstanding characteristics of Blocking have long been recognized and its synoptic and climatological features delineated. Perhaps the most important work in this field was accomplished in the early 1950's by Rex (6), Elliott and Smith (10) and Sumner (7, 8). A summary of the characteristics that most directly relate to this study follows:-

1. Rex (6) found for blocking in the northern hemisphere the most favoured initiation location was between 5° and 15° west longitude in the eastern Atlantic.

2. Sumner (7, 8) and Saunders (9) found a shift in the blocking high locations from January to May occurs with the axis moving from Western Europe to the Eastern Atlantic.

3. Many studies have confirmed, Sumner (7, 8) Rex (6) and Saunders (9), that in the monthly distribution of blocking in Europe and the Atlantic, (using surface data), an annual maximum occurs in May. This (Table I) corresponds to an annual peak in hours of poor weather in May at Gander.

Mook (II) also found a peak in May for the annual variation of zonal index spread (from 75°W to 25°W) at 500 mb on the North Atlantic, showing a correlation with the surface data as found by Sumner and Saunders.

4. Elliott and Smith (10) found blocking patterns having high latitude type of high pressure cell cut-off are considerably more stable than a blocking high cell at lower latitude, even though the former represents the more extreme disturbance. This was observed to be the case in this study.

5. The average duration of blocking sequence was found by Rex (6) to be 16.6 days and Sumner (7, 8) 14.5 days for the year as a whole. Sumner (7, 8) also found the average duration for May to be 16.5 days.

6. The average speed of motion of blocking highs in spring on the Atlantic was computed by Sumner (7, 8) to be approximately 5° longitude per day, either eastward or westward.

7. For May, Sumner (7, 8) found the percentage frequency of motion of blocking highs to be 42% quasi-stationary, 36% retrogressive and 22% progressive. Certainly in this study, retrogression of the blocking high would appear to be the most common motion.

Along similar trends, Rex (6) found that Atlantic blocks, on the average, move toward the west some 10° during the first half of their development. Subsequently during their final half-life, most blocks move eastward some 30° . This would agree in part with evidence by Sumner (7, 8) that blocks seldom dissipate unless moving progressively.

8. The barotropic prognostic charts handle the low index or blocking sequence very well and have frequently forecast the formation or decay of a blocking pattern well in advance (36 to 72 hours) when such a development was not too evident.

The barotropic NWP prognostics should of course theoretically handle the large scale blocking patterns quite well because of the barotropic nature of the blocking ridge - the baroclinic areas being confined to the perimeter of the large blocking ridge or cut-off high pressure cell.

The foregoing statistical characteristics, while giving an excellent guide to the overall picture of what may be expected of blocking patterns in the Atlantic, must be relied upon with caution. As in most meteorological parameters, blocking patterns occur in a wide range of intensities and configurations, often appearing to pass through several cycles of rejuvenation during their life cycle.

TABLE I
PERCENTAGE OF TIME AT GANDER CIGS. AND/OR VISIBILITY BELOW THE LIMITS
300' and/or 3/4 mile

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1950	6	11 3*	7	20 3,4	14 4,3	3	6	2	2	5	12 4	14% 3
1951	9	20.4 6	23 5	30 7,3	12 0	18	6	15 4	1.3	9	8.1	6.5%
1952	12.2	20.4 3	8.4	7.5	28.5 7,3,3	16.7 5	6	3.8	5.5	1.6	26.1 6	12.1% 5
1953	2	5.1	9.2	33.2 6,3	12.2 4	3	4	4.3	5.6	7.2	9.4	7.7%
1954	9.2 3	26.7 5	14.9 3	1.7	31.5 8,3	19.6 4,3	14.1 3,7	17.3 7	6.5 3	5.8 5	8.3	10.6%
1955	32.4 5,9	15.1 7	11.3 8	8.3	16.4 4	20.7 8	5.6	6.2	.3	19.9 4	15.2	10.2%
1956	34.0 3,12	4.9	5.1	17.1 3	4.4 0	7.8 4,3	5.8 4	7.8 4	2.2	7	8.3	6.9%
1957	5.8	7.8	15.1 3	11.4 3	9.1 4	7.9 4	7.4 4	4.1	7.3	9.5	3	9.1%
1958	20.4 5	19.1 3	23.6 9	7.7	6.6 0	11.3 3	7.1	3.9	1.1	4.6	4.3	4.3%
1959	9.0 3	4.5	2.9	8.5	9.9 4	17.7 8	4.6	10.0	4.5	5.3	11.8 4	3.7%
1960	11.0 3	21.2 3,8	12.2 4,3,6	3.1	25.2 4,5	7.3 5	2.3	2.0	2.6	7.5	5.3	3.9%

Total % for
11 year
period

151.0	156.2	132.7	148.5	169.8	133	68.9	76.4	38.9	82.4	111.8	89%
-------	-------	-------	-------	-------	-----	------	------	------	------	-------	-----

Total # cases
for each
month *

8	8	8	8	13	10	4	3	1	2	3	2
---	---	---	---	----	----	---	---	---	---	---	---

Average
duration
(days)

5.4	5	5.1	4	4.3	4.7	4.2	5	3	4.5	4.9	4
-----	---	-----	---	-----	-----	-----	---	---	-----	-----	---

* Lower figures in table I indicate duration, in days, of cases where each day, the records for Gander indicated 5 hours or more of ceilings or visibilities below the limits of 300' and/or 3/4 mile, for three consecutive days or longer.
e.g. for May 1952 - 7,3,3 indicate three periods during that month that fulfill the above conditions, the first case lasting 7 consecutive days, and the 3rd also 3 days.

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TABLE II

MAY	% hours below 200' &/or 1/2mi	% hours below 300' &/or 3/4mi	Total # occur- ences hours below 300' &/or 3/4mi between 00-12Z 13-24Z	# nights continuously below 300' &/or 3/4mi 00-12Z	# days continuously below 300' &/or 3/4mi 13-24Z
1950	9%	14%	96 hrs. 11 hrs.	3	0
1951	9%	12%	63 27	1	0
1952	<u>19.5%</u>	<u>28.5%</u>	<u>157</u> <u>64</u>	9	1
1953	7.2%	12.2%	67 23	2	0
1954	<u>15.6%</u>	<u>31.5%</u>	<u>145</u> <u>88</u>	8	1
1955	7.9%	16.4%	105 17	7	0
1956	1.7%	4.4%	22 11	1	0
1957	2.8%	9.1%	46 22	2	0
1958	2.4%	6.6%	41 10	1	0
1959	5.6%	9.9%	65 9	3	0
1960	14.2%	25.2%	136 50	8	1

TABLE III

Long term average daily temperature Year	Jan	Feb	Mar	April	Total	Bias		May	Number of hours below 300' &/or 3/4 mile
	18.6	17.0	24.5	33.3	93.4			43.6	
1951	24.4	25.2	30.2	40.4	120.3	+ 26.9	warm	43.9	90
1952	22.8	23.2	28.2	34.5	108.7	+ 15.3	mild	43.6	221
1953	24.0	23.8	25.0	39.9	112.7	+ 19.3	warm	41.5	90
1954	17.6	26.2	27.2	32.2	103.2	+ 9.8	mild	42.5	<u>233</u>
1955	28.4	23.0	25.2	30.3	106.9	+ 13.5	mild	42.2	122
1956	29.8	21.2	22.0	35.0	108.0	+ 14.6	mild	41.6	33
1957	11.4	17.7	26.2	31.5	86.5	- 6.9	cool	41.3	68
1958	28.8	27.8	28.8	38.6	124.0	+ 30.6	very warm	49.6	51
1959	21.0	10.7	20.2	33.9	85.8	- 7.6	cool	42.9	74
1960	22.9	27.7	24.9	31.4	106.9	+ 13.5	mild	46.2	186

MONTHLY SUMMARY OF OPERATIONAL WEATHER

Airport GANDER, NEWFOUNDLAND Month MAY 19 50

RANGES SYMBOL	CEILING AND VISIBILITY RANGES		PERCENTAGE OF TIME	
	LIMITS 1. Equal to; or greater than:	LIMITS 2. Less than:	Between limits 1 & 2	Below limits 2
1	ZERO - ZERO	200 ft. &/ or 1/4 mi.	9	
2	200 ft. & 1/2 mi.	300 ft. &/ or 3/4 mi.	5	14
3	300 ft. & 3/4 mi.	500 ft. &/ or 1 mi.	9	23
4	500 ft. & 1 mi.	1000 ft. &/ or 3 mi.	11	34
5	1000 ft. & 3 mi.	2500 ft. & 3 mi.	13	47

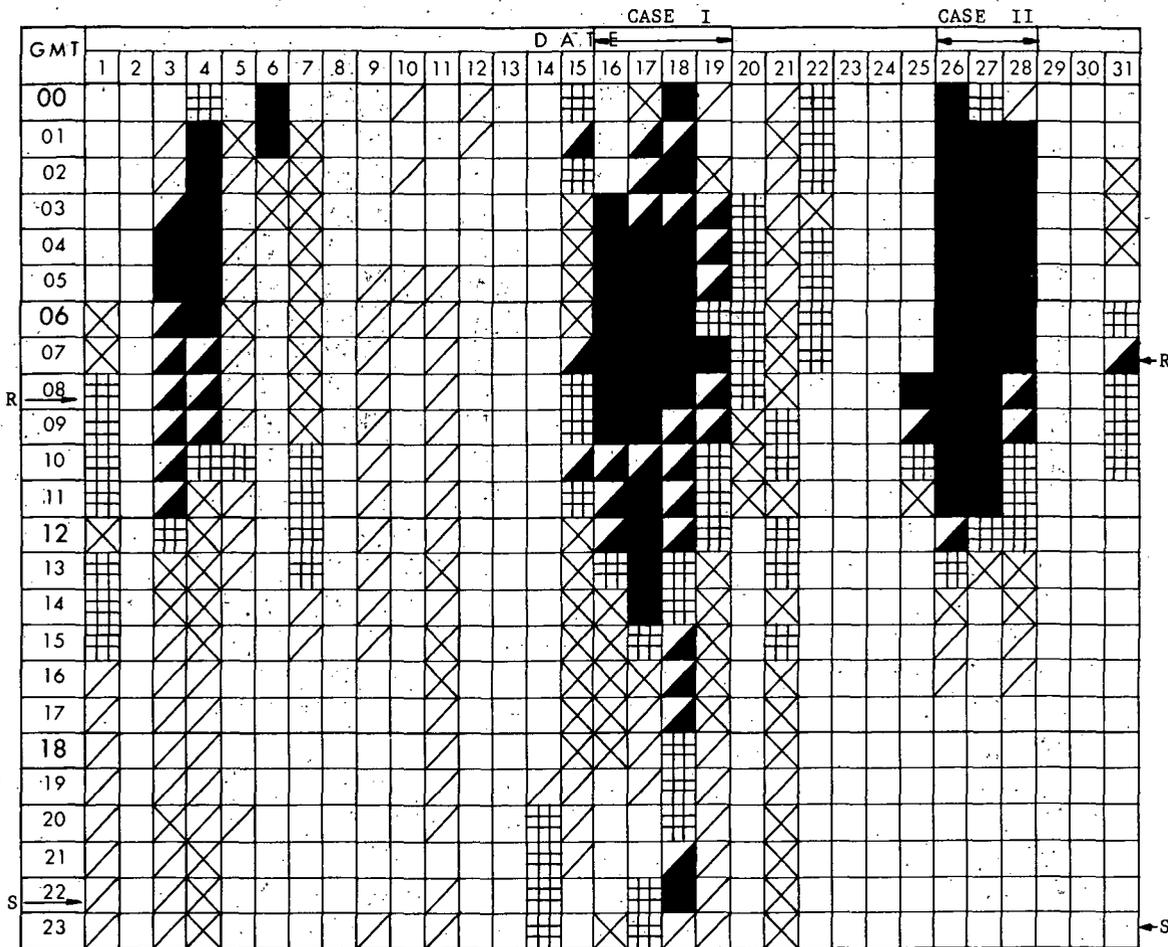


Figure 1

CIR-4074
 TEC-530
 23 July 64.

MONTHLY SUMMARY OF OPERATIONAL WEATHER

Airport GANDER, NEWFOUNDLAND Month MAY 19 54

RANGES	SYMBOL	CEILING AND VISIBILITY COMBINATIONS					PERCENTAGE OF TIME			
		CIGS. (ft.)	with	VSBYS. (mi.)	or	VSBYS. (mi.)	with	CIGS. (ft.)	IN RANGE	IN and BELOW RANGE
1	■	0 - 100	with	0 or more	or	0 - $\frac{1}{2}$	with	0 or more	15.6	15.6
2	▣	200	with	$\frac{1}{2}$ or more	or	$\frac{1}{2}$ - $\frac{3}{4}$	with	200 or more	15.9	31.5
3	▤	300 - 400	with	$\frac{3}{4}$ or more	or	$\frac{3}{4}$	with	300 or more	13.7	45.2
4	▥	500 - 900	with	1 or more	or	1 - 2 $\frac{1}{2}$	with	500 or more	12.5	57.7
5	▦	1000 - 2400	with	3 or more	or	3 or more	with	1000 - 2400	11.2	68.9
6	▧	2500 or more	with	3 or more	or	3 or more	with	2500 or more	31.2	100.0

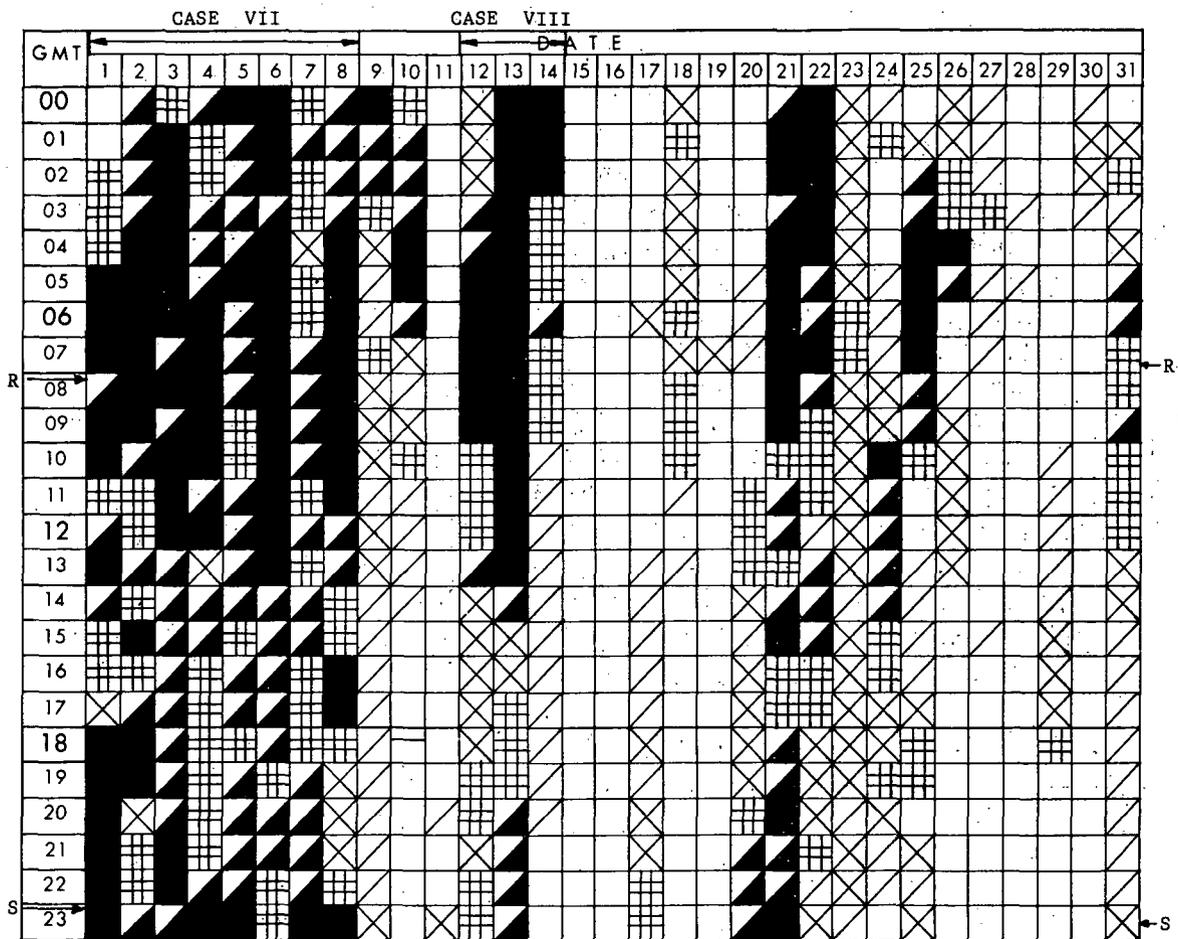


Figure 2

MONTHLY SUMMARY OF OPERATIONAL WEATHER

Airport GANDER AIRPORT, NEWFOUNDLAND Month MAY 19 56

RANGES	SYMBOL	CEILING AND VISIBILITY COMBINATIONS						PERCENTAGE OF TIME		
		CIGS. (ft.)	with	VSBYS. (mi.)	or	VSBYS. (mi.)	with	CIGS. (ft.)	IN RANGE	IN and BELOW RANGE
1	■	0 - 100	with	0 or more	or	0 - 1/8	with	0 or more	1.7	1.7
2	▀	200	with	1/8 or more	or	1/8 - 1/4	with	200 or more	2.7	4.4
3	▄	300 - 400	with	1/4 or more	or	1/4	with	300 or more	5.9	10.3
4	▆	500 - 900	with	1 or more	or	1 - 2 1/2	with	500 or more	12.9	23.2
5	▇	1000 - 2400	with	3 or more	or	3 or more	with	1000 - 2400	14.2	37.4
6	■	2500	with	3 or more	or	3 or more	with	2500 or more	62.5	100.0

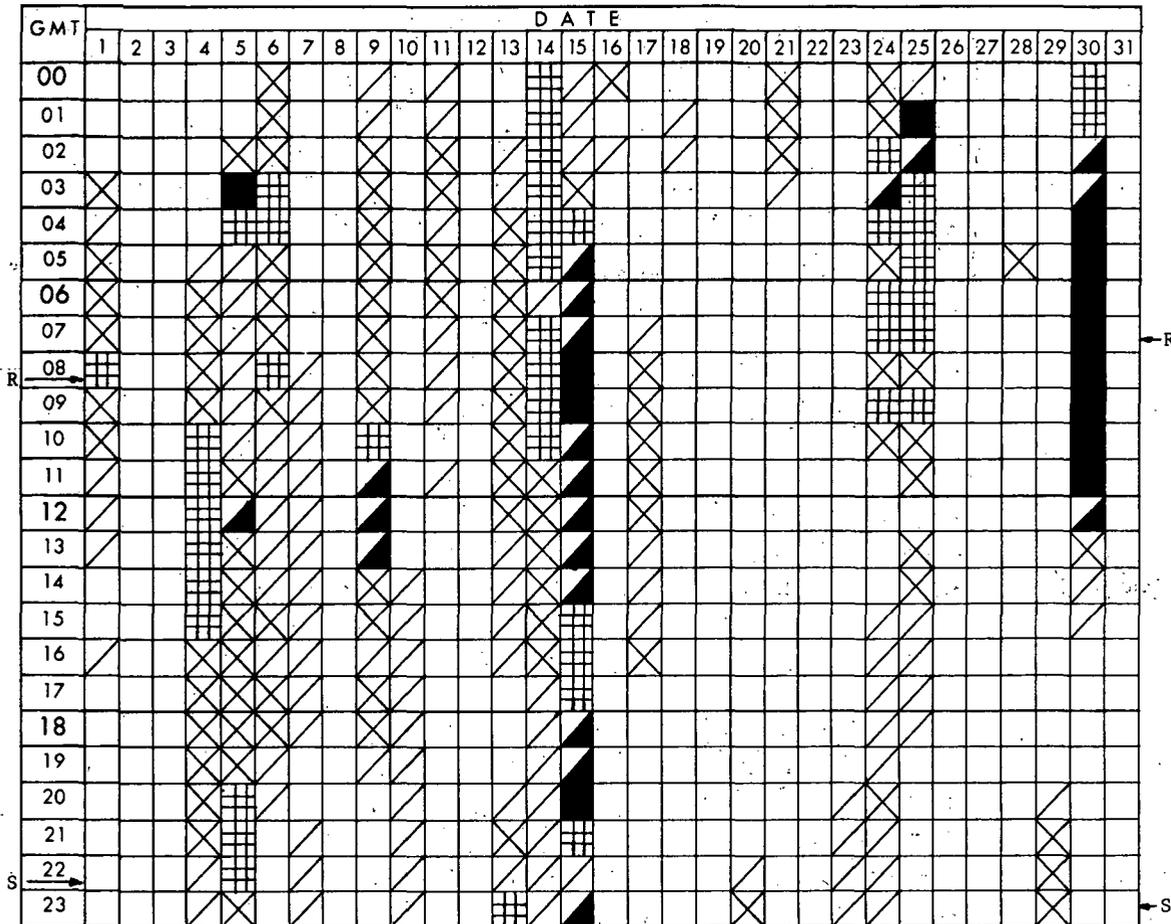


Figure 3

CIR-4074
TEC-530
23 July 64.

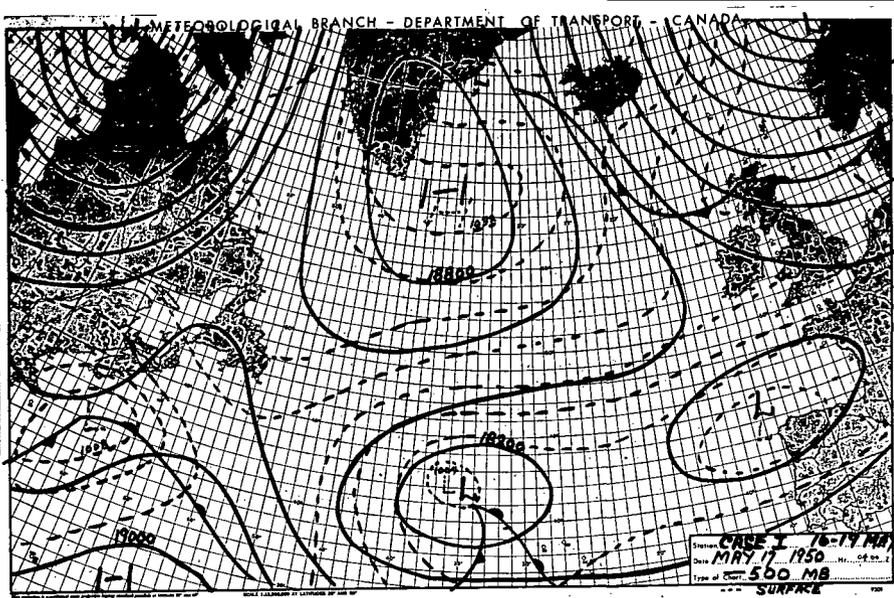


FIGURE 4

CASE I 16 - 19 TH MAY 1950

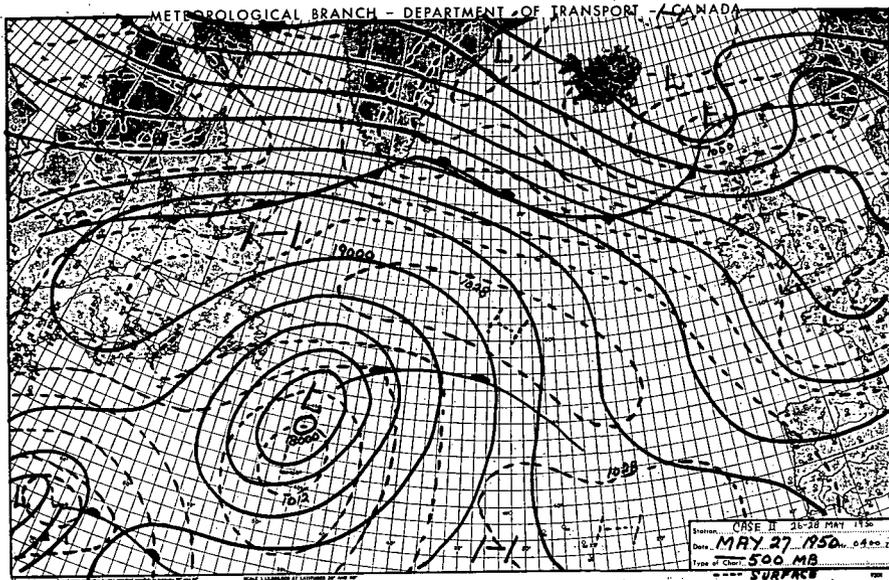


FIGURE 5

CASE II 26 - 28 TH MAY 1950

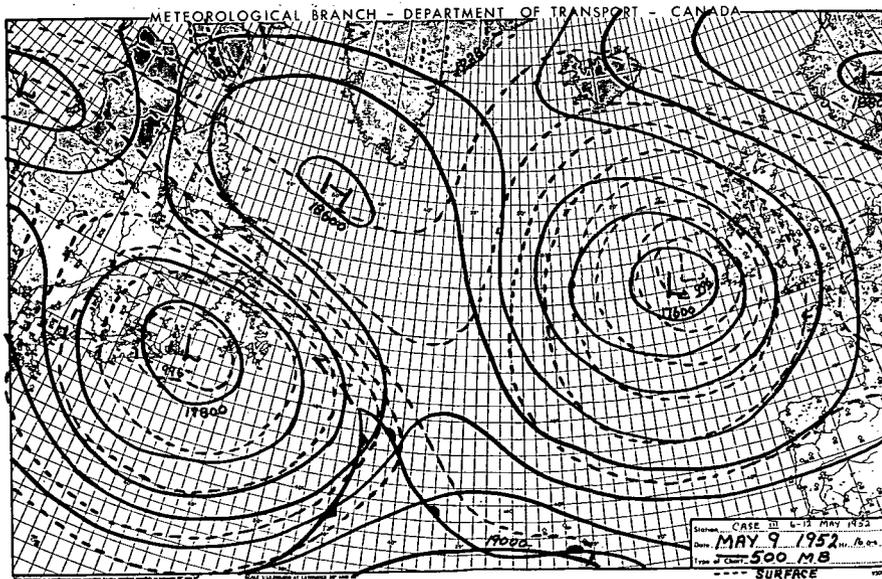


FIGURE 6

CASE III 6 - 12 TH MAY 1952

CIR-4074
TEC-530
23 July 64.

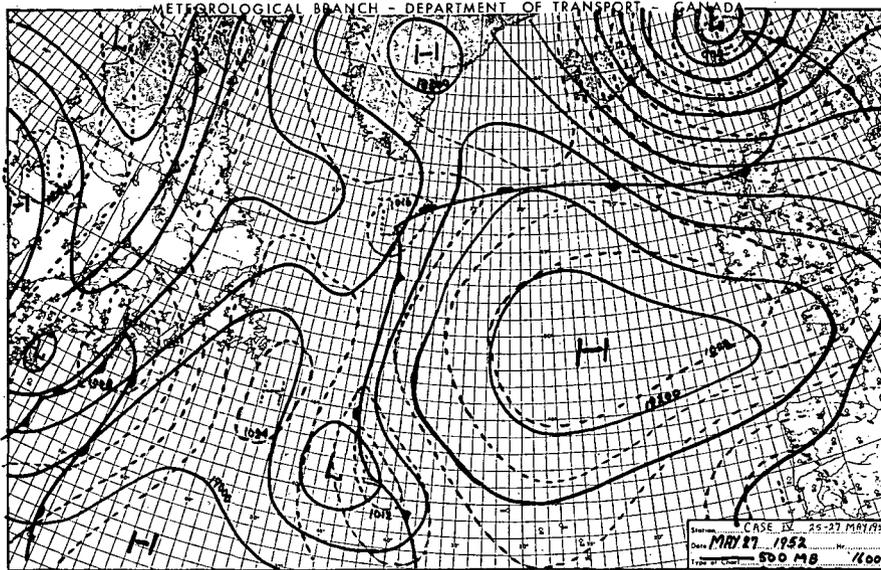


FIGURE 7

CASE IV 25 - 27 TH MAY 1952

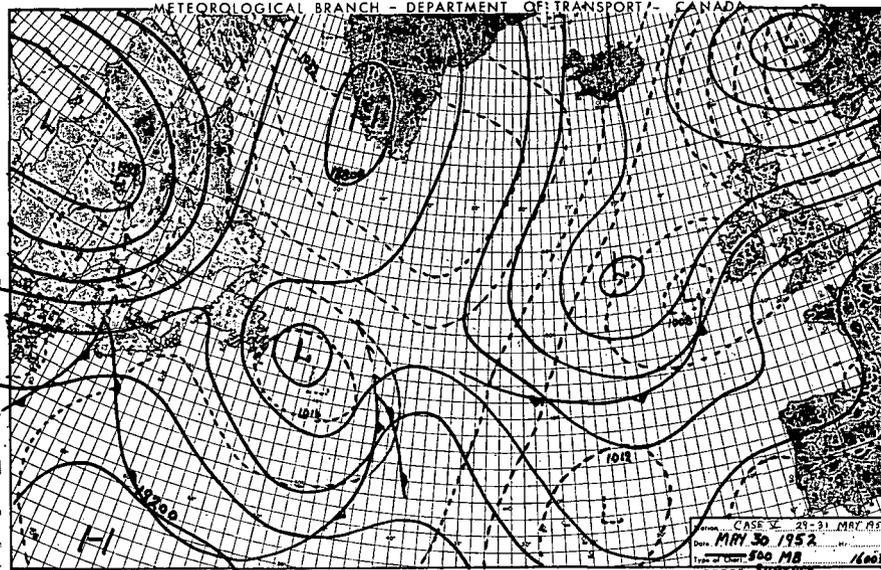


FIGURE 8

CASE V 29 - 31 ST MAY 1952

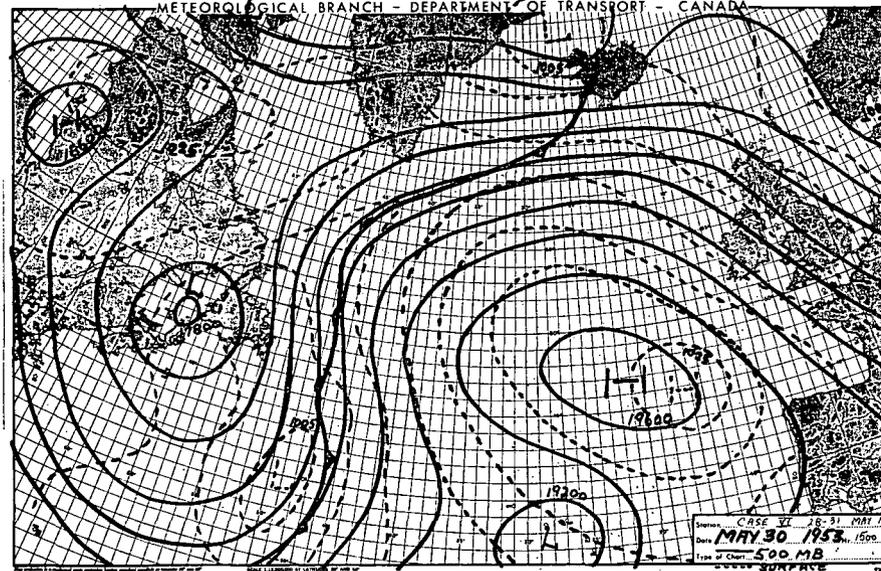


FIGURE 9

CASE VI 28 - 31 ST MAY 1953

CIR-4074
TEC-530
23 July 64.

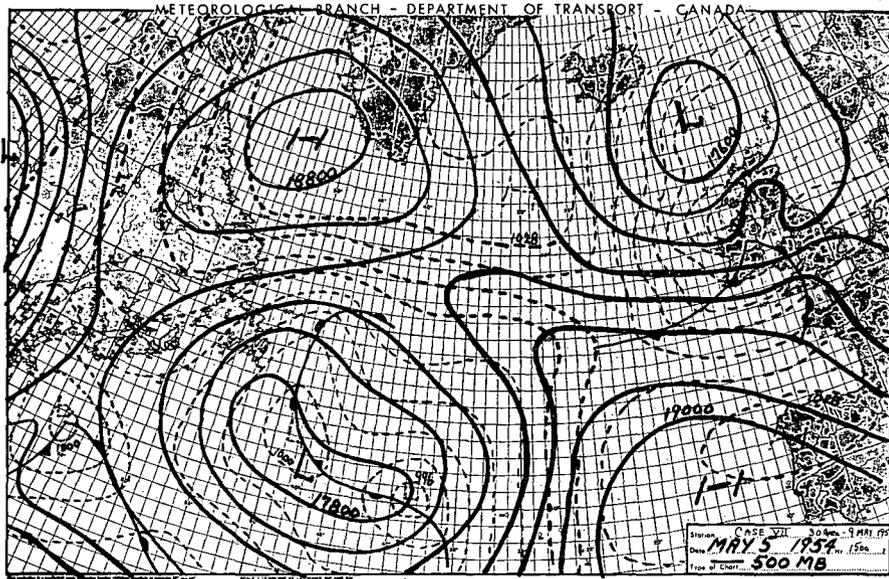


FIGURE 10

CASE VII 30 - 8 TH MAY 1954

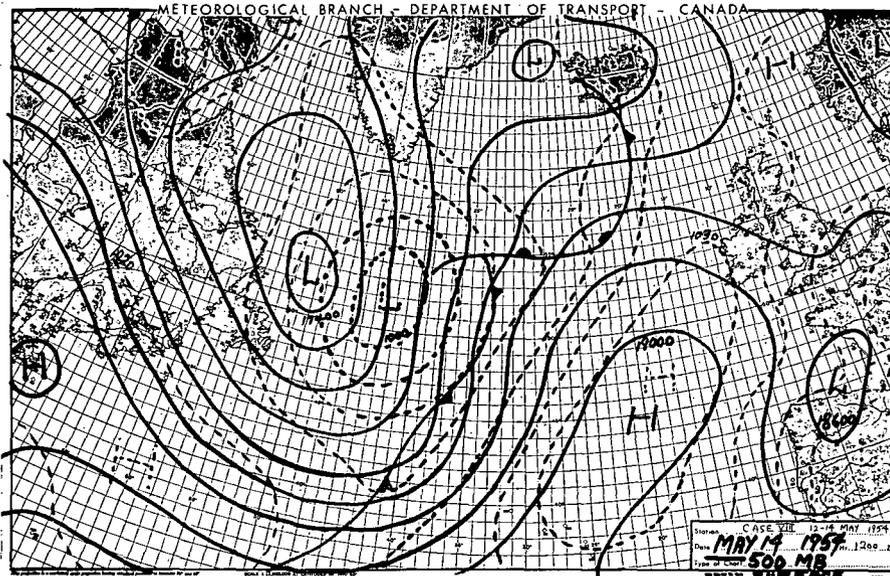


FIGURE 11

CASE VIII 12 - 14 TH MAY 1954

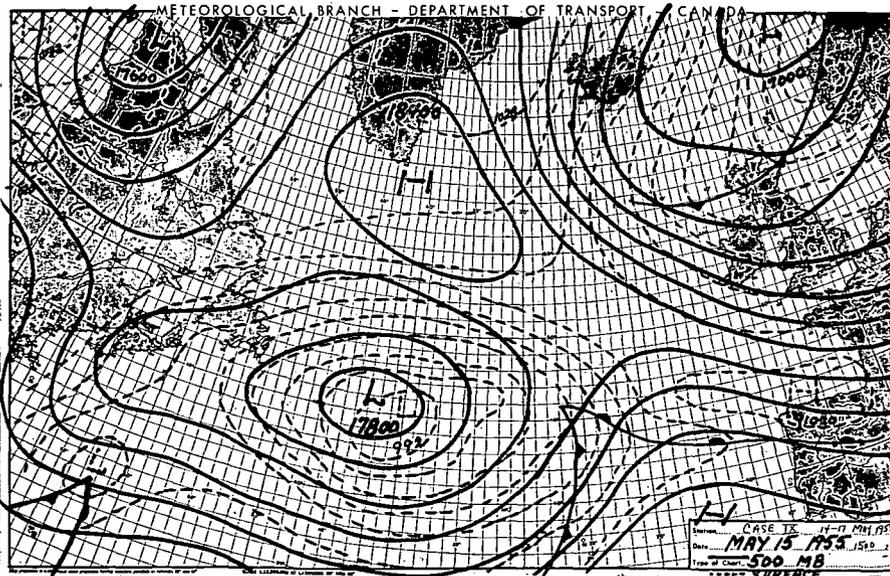


FIGURE 12

CASE IX 14 - 17 TH MAY 1954

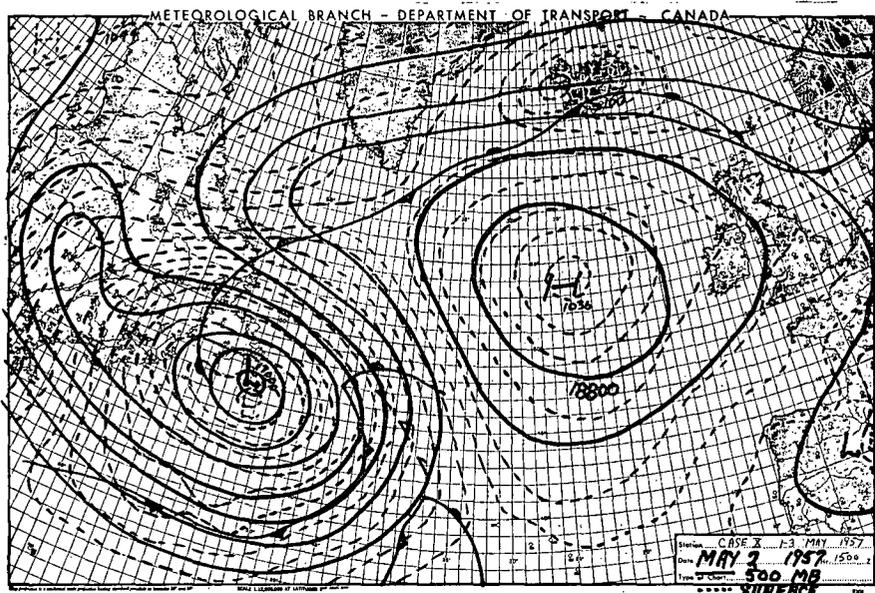


FIGURE 13 CASE X 1 - 4 TH MAY 1957

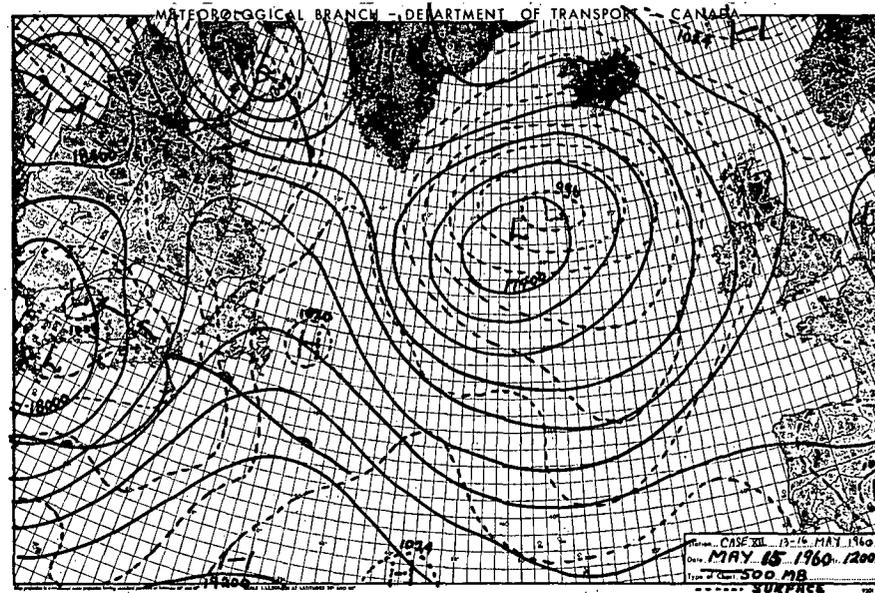


FIGURE 15 CASE XII 13 - 16 TH MAY 1960

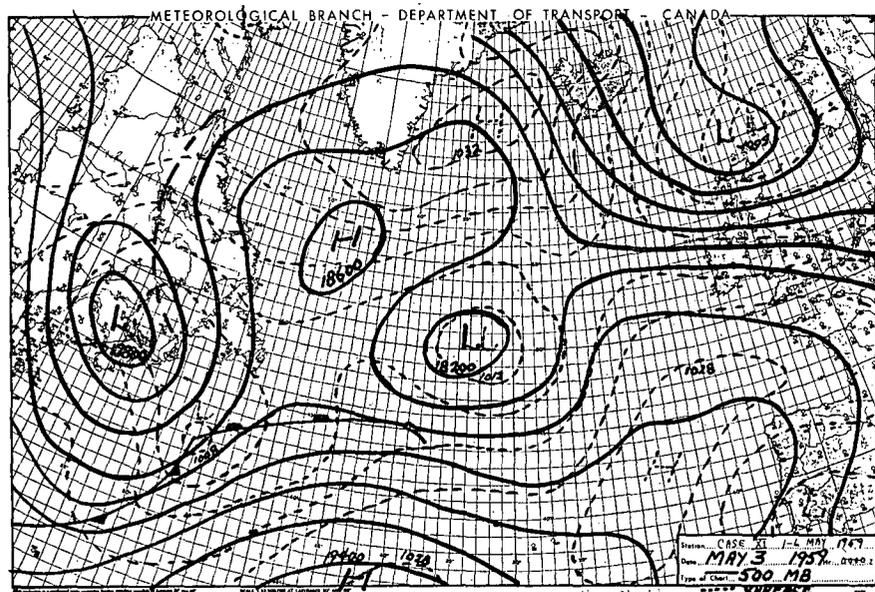


FIGURE 14 CASE XI 1 - 4 TH MAY 1959

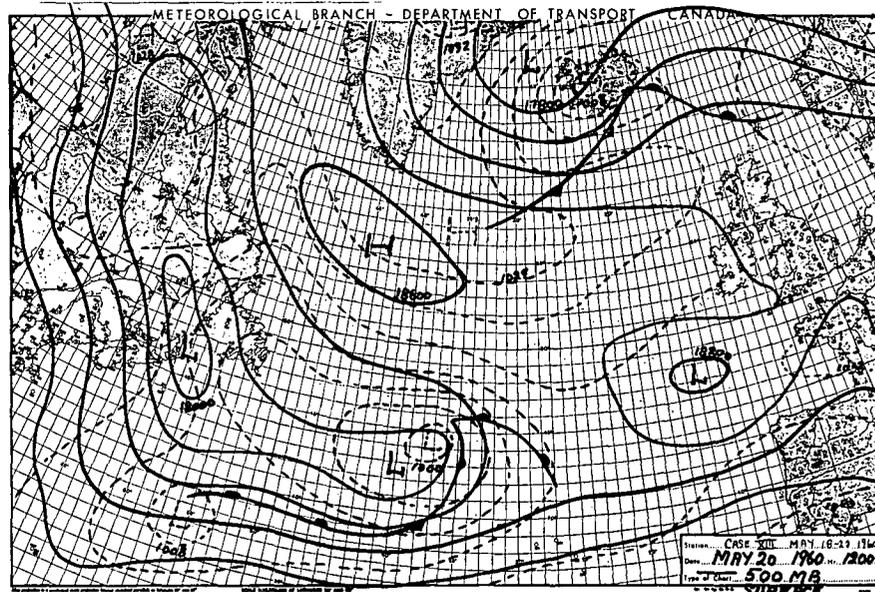


FIGURE 16 CASE XII 18 - 22 TH MAY 1960

BLOCKING SEQUENCE MAY 15 - 24 1960

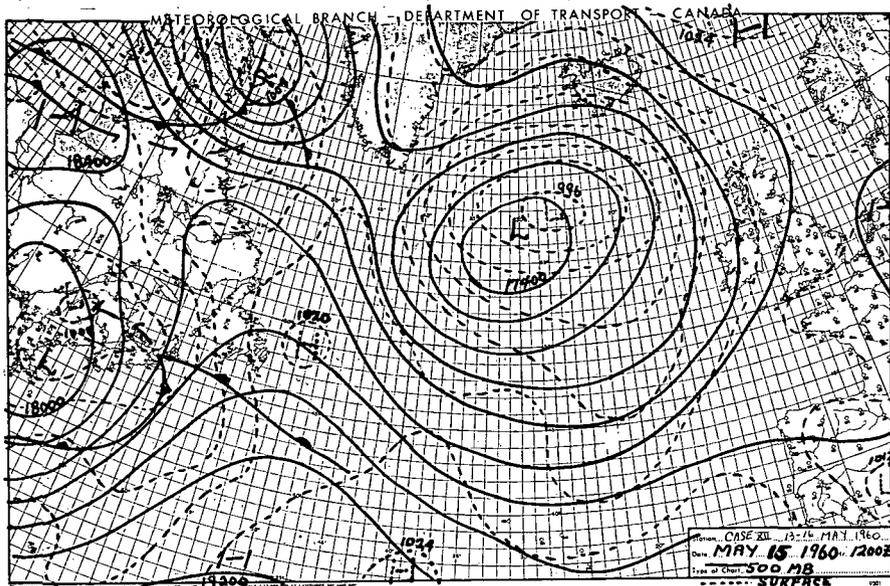


FIGURE 17

MAY 15 1960

SURFACE - - - - -

500 MB _____

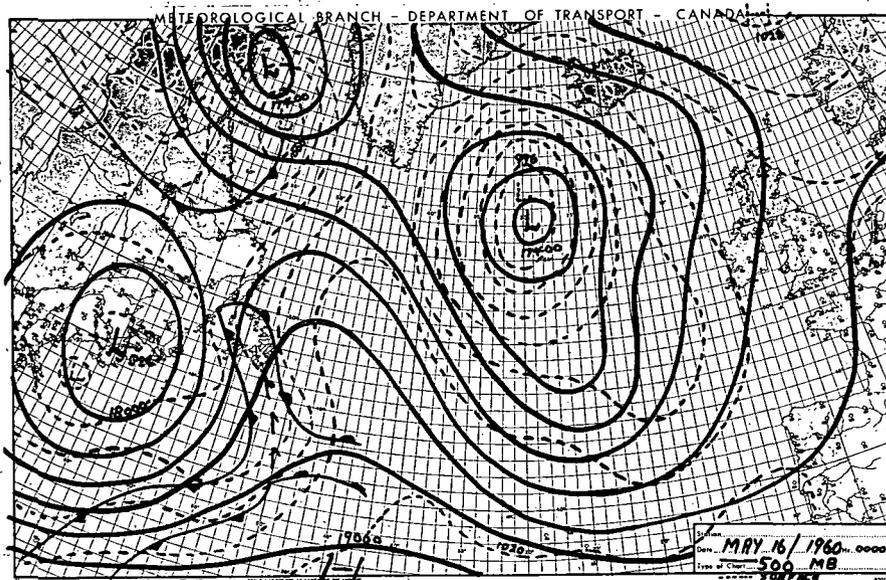


FIGURE 18

MAY 16 1960

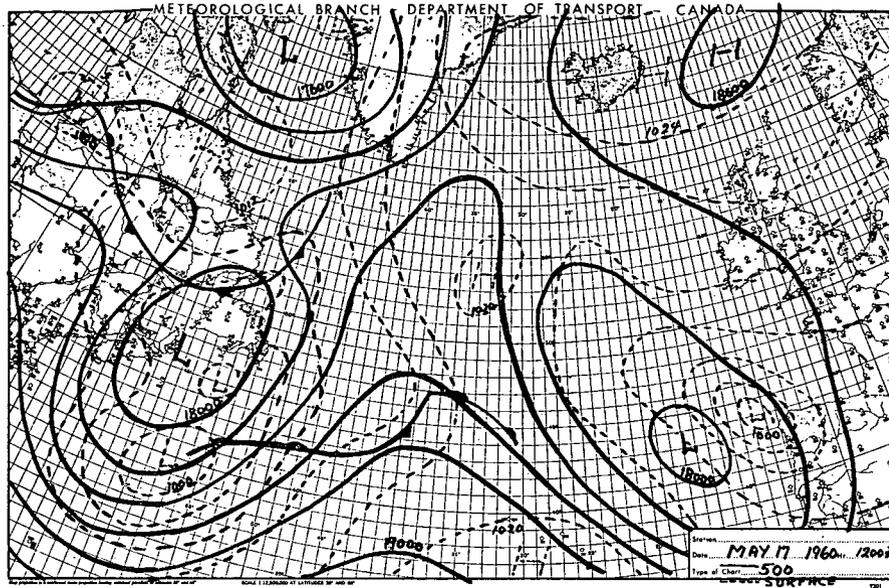


FIGURE 19

MAY 17 1960

SURFACE - - - - -

500 MB _____

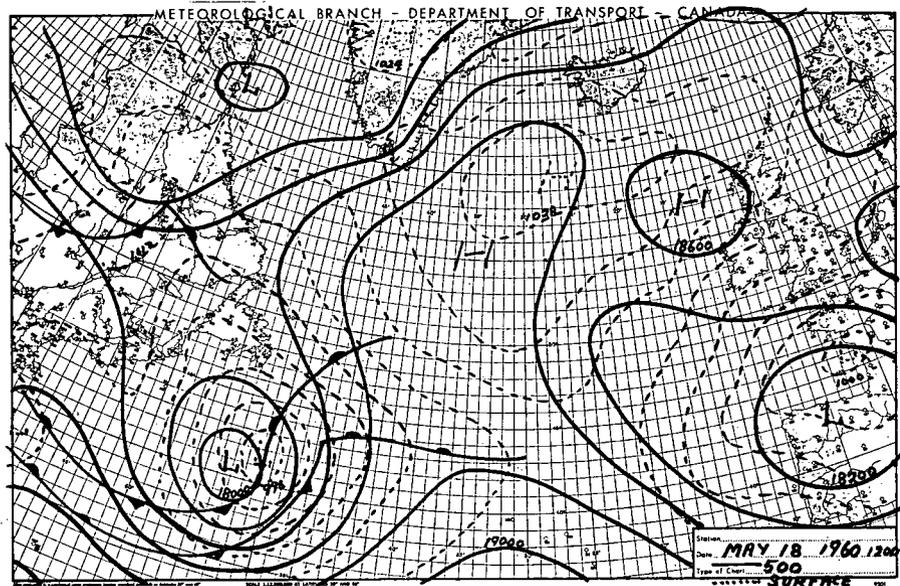


FIGURE 20

MAY 18 1960

BLOCKING SEQUENCE MAY 15 - 24 1960
CONTINUED

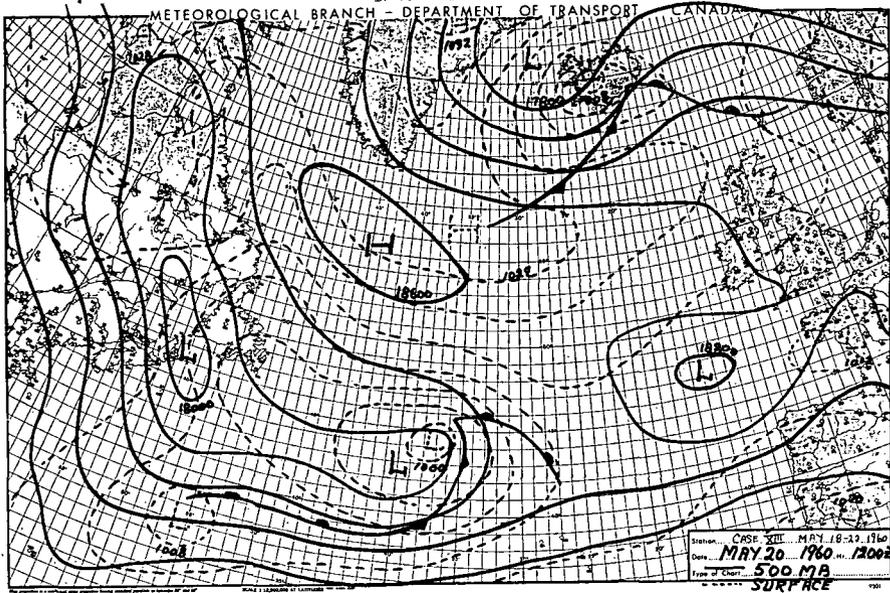


FIGURE 21

MAY 20 1960

SURFACE - - - - -

500 MB _____

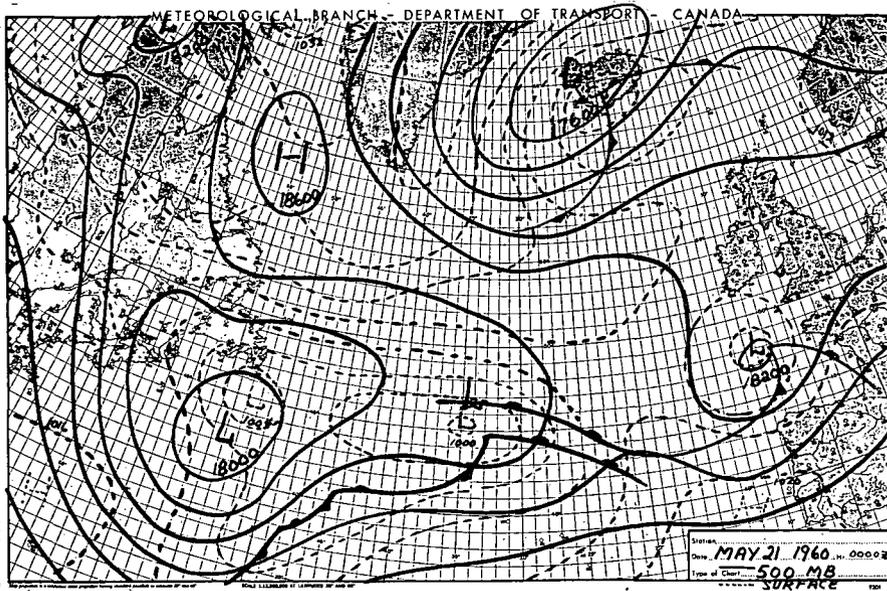


FIGURE 22

MAY 21 1960

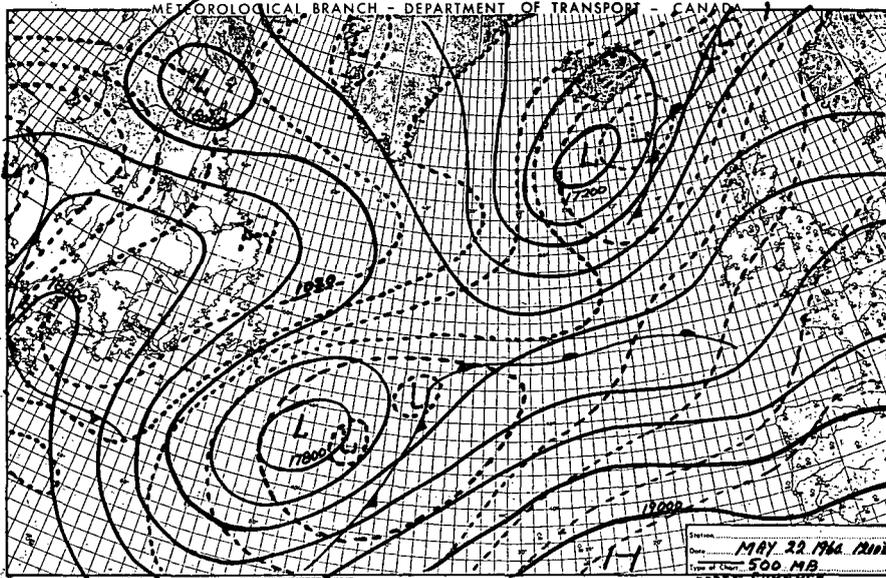


FIGURE 23

MAY 22 1960

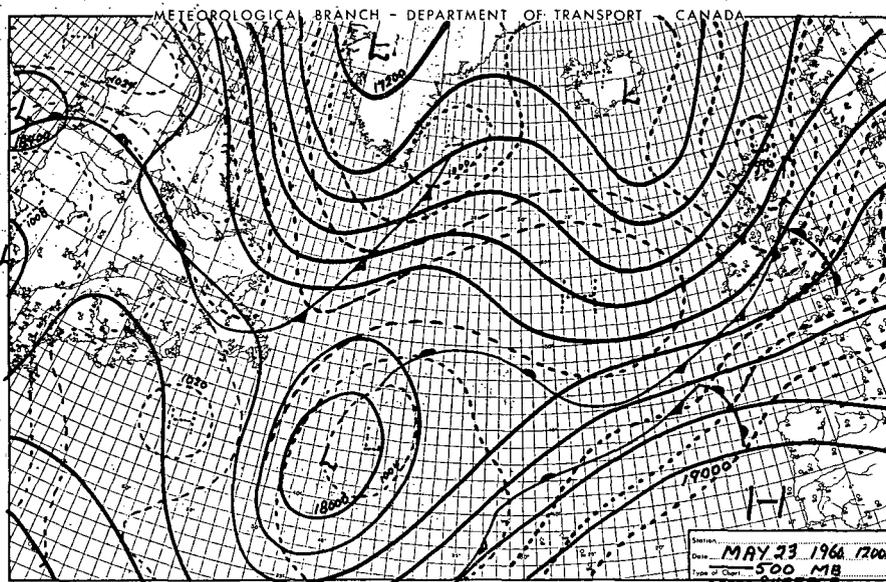


FIGURE 24

MAY 23 1960

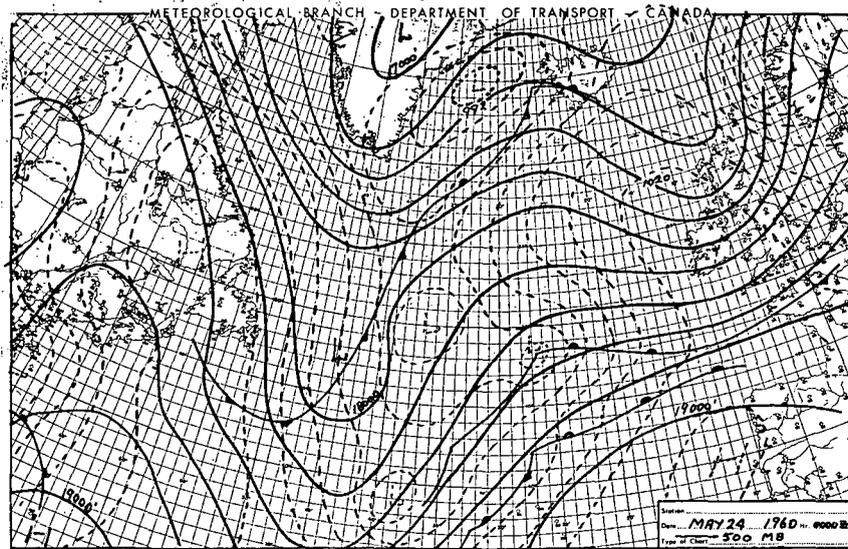


FIGURE 25

MAY 24 1960

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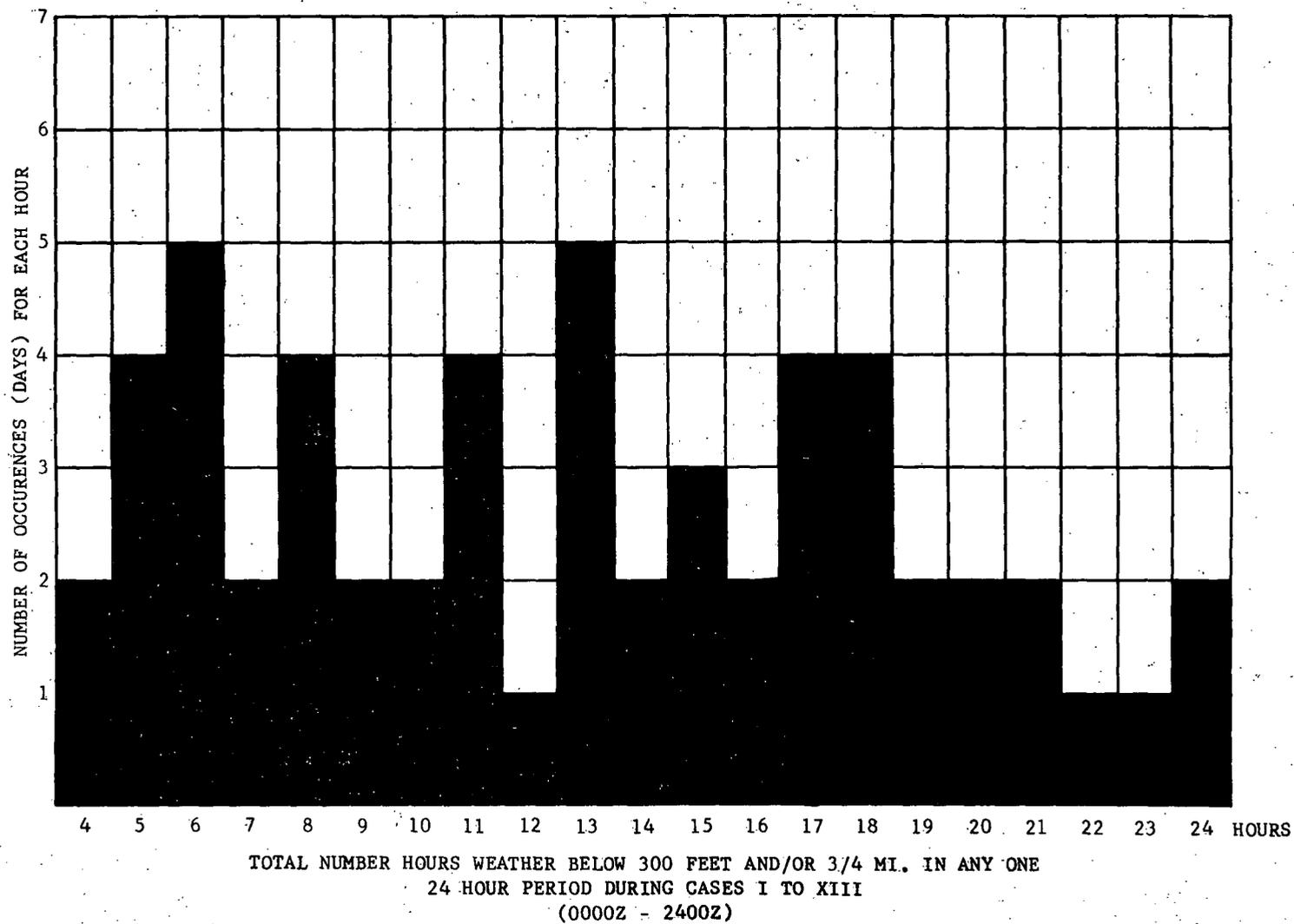


Figure 26

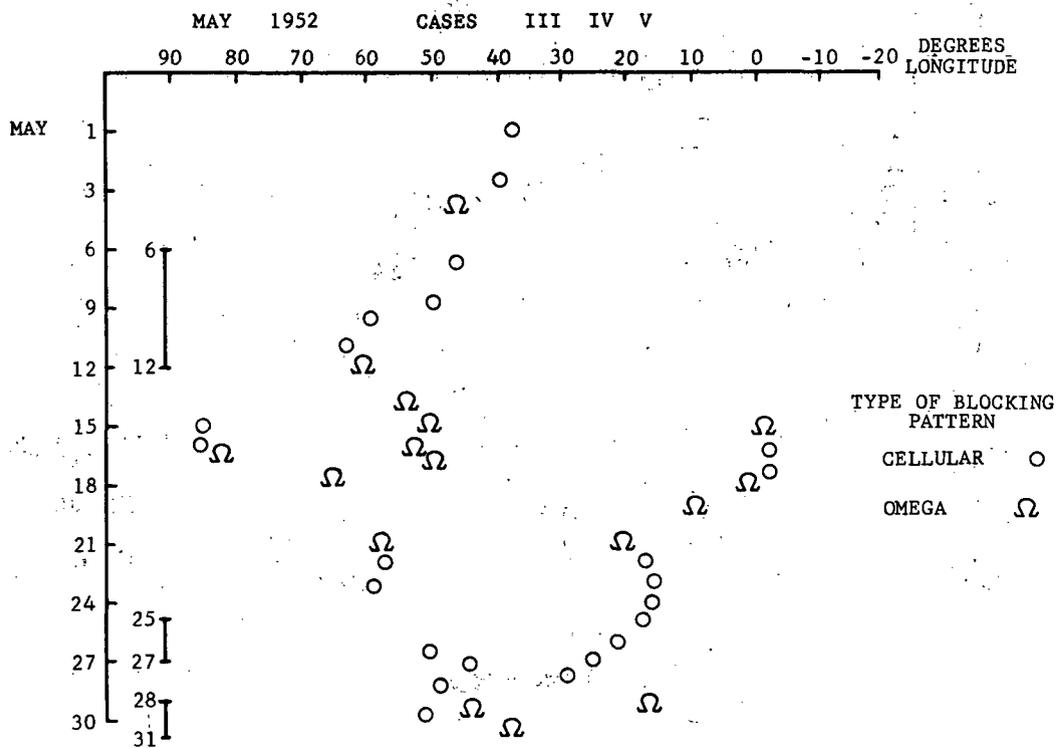
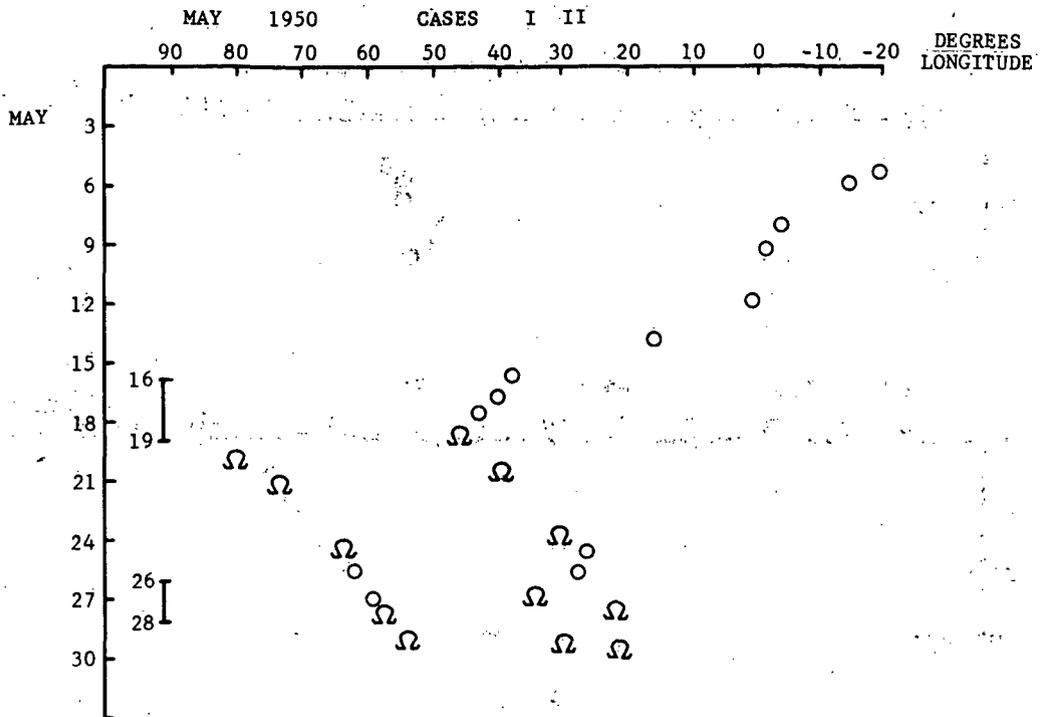


Figure 27

CIR-4074
TEC-530
23 July 64.

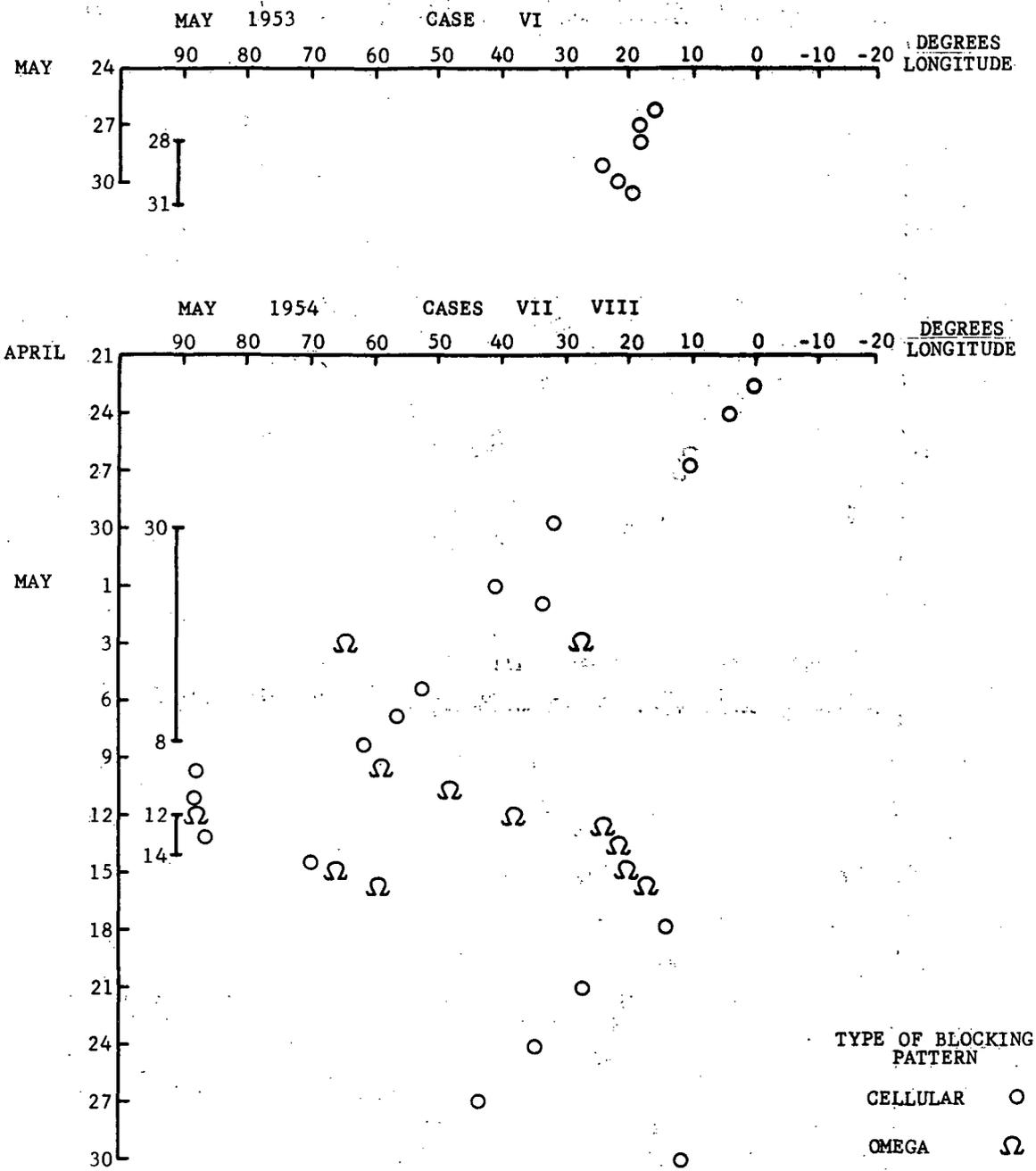


Figure 28

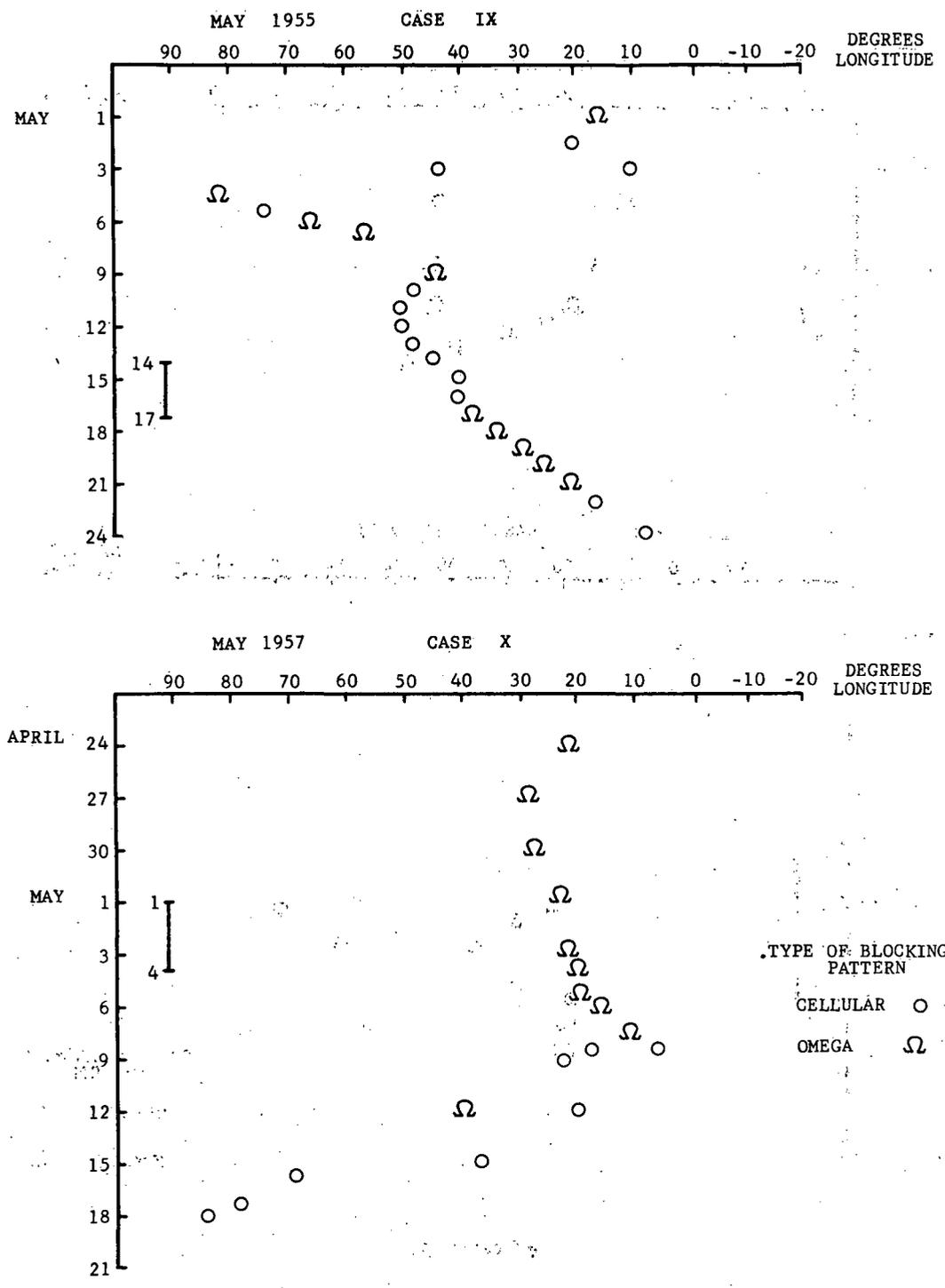


Figure 29

CIR-4074
 TEC-530
 23 July 64.

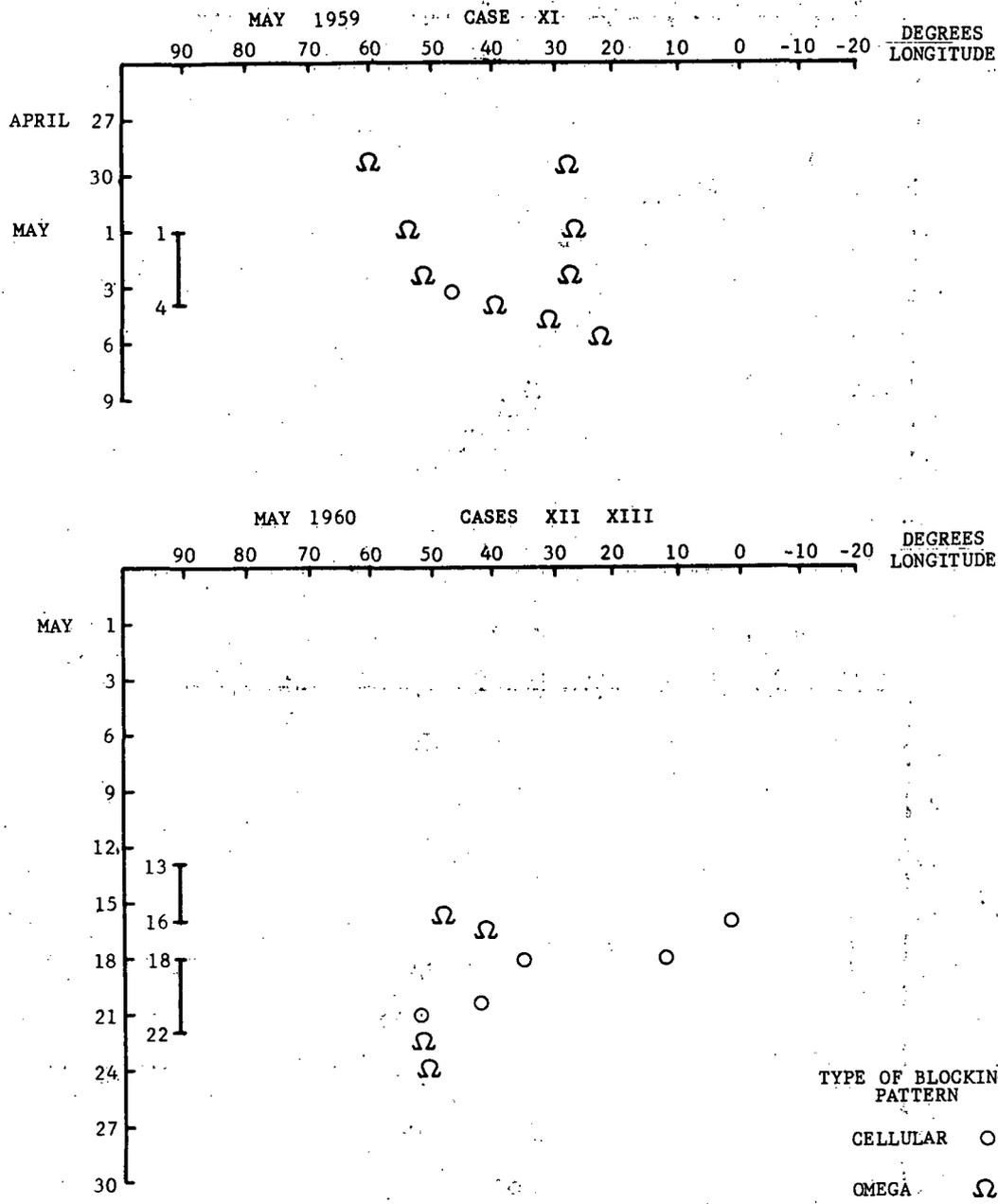


Figure 30

SUNRISE 0800Z + 30 MIN.

SUNSET 2300Z + 30 MIN.

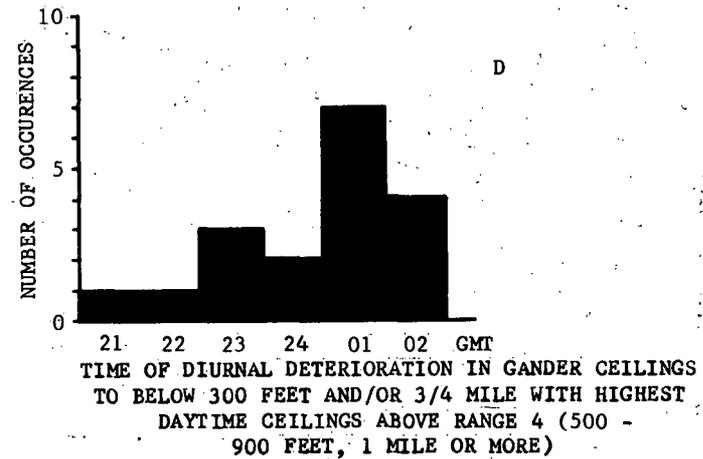
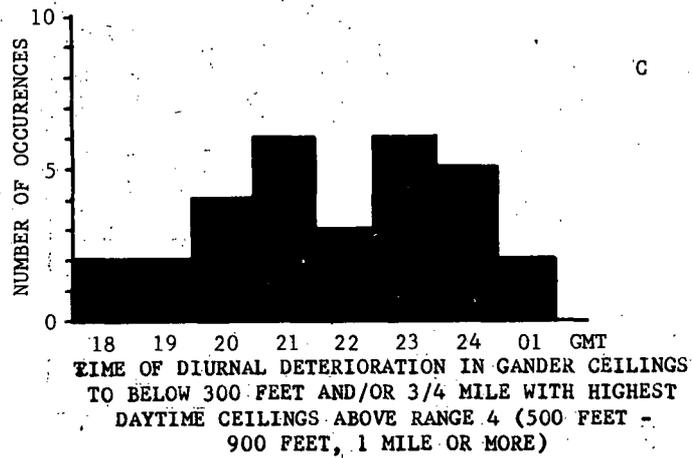
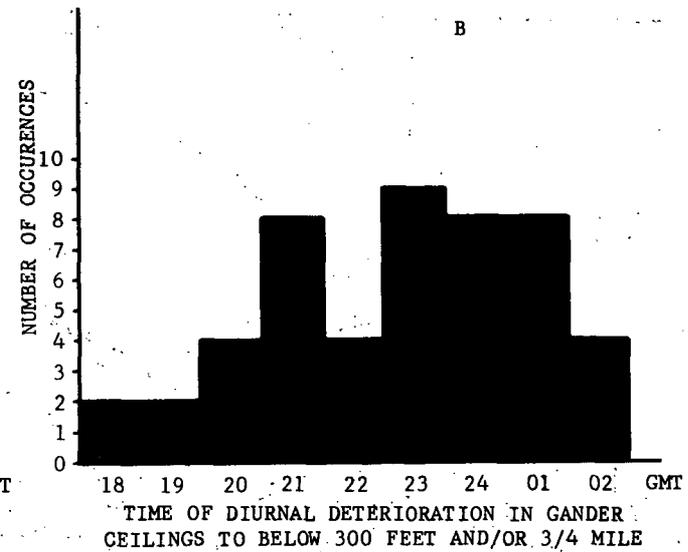
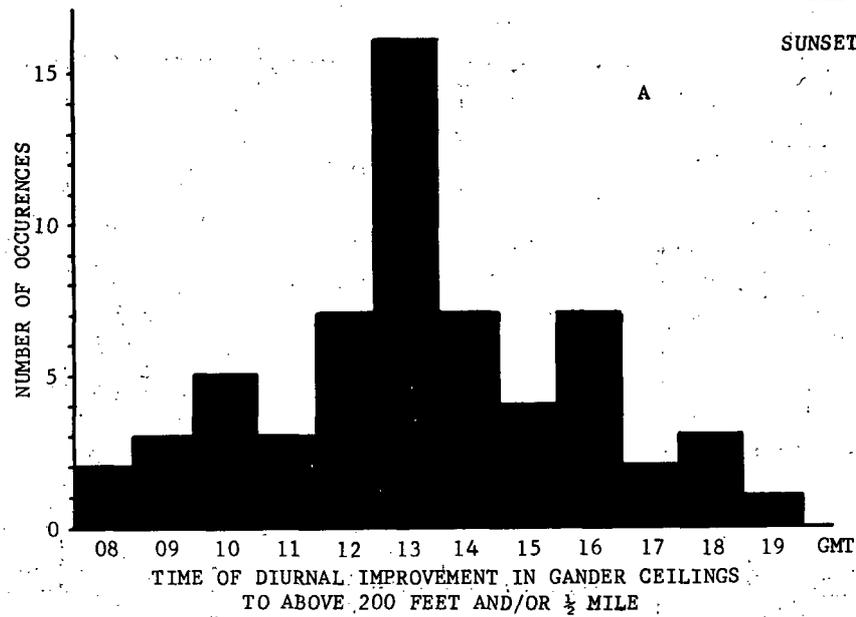


Figure 31

CIR-4074
TEC-530
23 July 64.

CIR-4074
 TEC-530
 23 July 64.

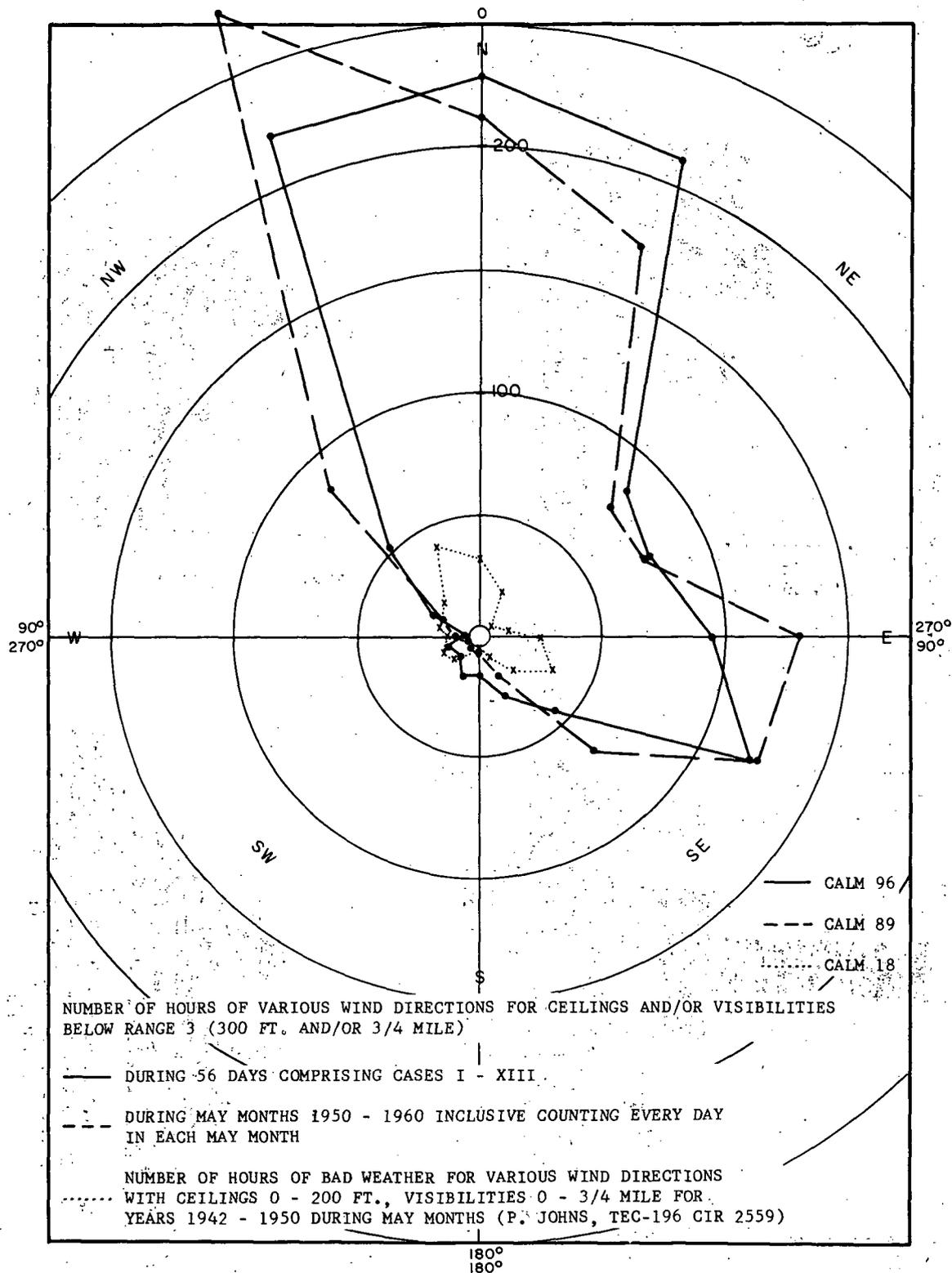


Figure 32

CIR-4074
TEC-530
23 July 64.

UDC: 551.509.324.1
: 551.509.314

Canada

Department of Transport - Meteorological Branch

"Blocking" Circulations Over the North Atlantic and
Their Influence on Gander Terminal Weather During May
by R. F. Cake

16 pps. 35 figs. 12 refs. 3 tables.

Subject reference: Gander Airport: Forecasting low
ceilings and Visibility.

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