VOL. 5, No. 4.

Royal Meteorological Society

A GRAPHICAL METHOD for FORECASTING CEILING and VISIBILITY as applied to TORBAY AIRPORT, NEWFOUNDLAND

R. E. Munn

CANADIAN BRANCH

25¢

VOL. 5 NO. 4

Published by

ROYAL METEOROLOGICAL SOCIETY, CANADIAN BRANCH

1954 EXECUTIVE COMMITTEE

President....................................Dr. D. P. McIntyre
Vice-President....................................F. D. Thompson
Secretary....................................K. T. McLeod
Treasurer....................................J. G. Potter

Councillors-at-Large

D. Strachan....................................Vancouver, B.C.
C. E. Thompson....................................Edmonton, Alta.
J. A. McPherson....................................Toronto, Ont.
B. A. Power....................................Montreal, Que.
R. E. Munn....................................Halifax, N.S.

Secretariat

Editor.................................... M.G. Hagglund

Vice-President for Canada
On Council of Royal Meteorological Society, London................
.....F. W. Benum

Copies of this publication at 25¢ each are obtainable by writing to:

The Secretary,
Royal Meteorological Society, Canadian Branch,
315 Bloor Street West,
Toronto 5, Ontario.

A GRAPHICAL METHOD FOR FORECASTING CEILING AND VISIBILITY AS APPLIED TO TORBAY AIRPORT, NEWFOUNDLAND

by

R. E. Munn

Meteorological Service of Canada

Presented at a regular meeting of the Royal Meteorological Society, Canadian Branch, Thursday, October 7, 1954, by A.H. Mason, Research and Training Section, Meteorological Headquarters.

A GRAPHICAL METHOD FOR FORECASTING CEILING AND VISIBILITY AS APPLIED TO TORBAY AIRPORT, NEWFOUNDLAND

by R. E. Munn

SUMMARY

The synoptic maps for the five-year period 1949 to 1953 are used to extract Torbay ceilings and visibilities, and the five associated variables -- time of year, time of day, geostrophic wind speed, isobaric direction and curvature. Two hundred and eighty-eight graphs are drawn relating the variables.

Comparative tests are made with the subjective forecasts issued for Torbay by the Main Meteorological Office at Gander. The conclusion is reached that the graphs are of value.

1. INTRODUCTION

1.1 Most methods of forecasting ceiling and visibility are to a great extent subjective. Gordon E. Dunn (1) concluded his address to the Canadian Branch of the Royal Meteorological Society with these significant remarks: "Techniques for translating even the most perfect prognostic chart into the actual weather are almost non-existent and the attention of meteorological research is invited to the vacuum existing here."

1.2 Klein (2) argues that "although considerable success has recently been attained by going directly from the current weather map to the future weather without using a prognostic map, it is the writer's belief that, in the long run, both our understanding of the weather and our ability to forecast it will be improved most by separate consideration of the two fundamental forecast problems, the prognosis of the circulation and its interpretation in terms of weather." This study is concerned with the latter problem.

1.3 It is not uncommon to hear the expression "experienced forecaster". The implication seems to be that theoretical knowledge must be supplemented by field training in local weather peculiarities. The Meteorological Service of Canada has published an excellent book (3), "Meteorological Conditions at Selected Airports in Canada, Newfoundland and Labrador", carefully summarizing the experience of field forecasters.

1.4 The initial impetus for this paper was provided by a desire to determine whether subjective experience gained in dealing with the vagaries of ceiling and visibility provided a sound basis for the guidance of forecasters and, if so, whether it could be expressed quantitatively.

1.5 It might be pointed out that the forecaster, consciously or otherwise, has been conditioned by how the ceiling and visibility reacted in a previous similar situation. The dangers inherent in an exclusively subjective approach are that: (a) the synoptic conditions may be only misleadingly similar to those of an earlier occasion; insolation, sea or land temperature, snow cover or air mass properties may be just slightly, but nevertheless critically, different, and, (b), the forecaster requires a prodigious memory to keep all factors in proper perspective for all the terminals in his district.

1.6 Torbay Airport was chosen for first consideration because it has the reputation of being "the most perverse" terminal in Eastern Canada.

2. GEOGRAPHICAL FEATURES OF TORBAY

2.1 Torbay is situated in the Avalon Peninsula of Newfoundland a few miles from St. John's. Figure 1, taken from "Meteorological Conditions at Selected Airports" (3), shows the proximity of the sea in nearly all directions. The elevation, 483 feet m.s.l., is almost that of Gander, 493 feet, where Bindon and Moakler (4) reported orographic lifting as an important factor in creating conditions of low ceiling and visibility. The role of pack-ice is also very real. In March, Bindon and Moakler (4) note, "the east coast of Labrador is extended approximately 200 miles as a meteorologically effective land area."

3. COLLECTION OF DATA

3.1 Sea-level synoptic charts for 0030Z, 0630Z, 1230Z and 1830Z were used for the five years 1949 to 1953, inclusive. The conclusions are, therefore, not necessarily valid for any other times of the day. The maps used were those drawn by the forecasters at the Dominion Public Weather Office, Halifax. The isobars were not changed in any way unless revision was necessitated by the availability of delayed map reports, designated as such by having been plotted in red ink, which were not available to the original analyst.

3.2 Ceiling and visibility values were read from each map in the synoptic code. In those cases where the ceiling value was not plotted, it was necessary to go back to the synoptic or the hourly weather reports.

3.3 In addition, five independent variables were tabulated--synoptic time, month of the year, geostrophic wind speed, isobaric direction, and isobaric curvature.

3.4 As this great mass of data was accumulated, various methods were attempted to bring it into useful form. The usual statistical approach failed because ceiling and visibility are not continuous functions. For example, a code 5 ceiling does not necessarily become a code 6 ceiling by a slight shift of wind; rather, the cloud may dissipate at that level and the ceiling may go directly to code 9.

3.5 The graphical method, then, appeared to hold the only hopeful avenue of approach.

4. MONTH OF THE YEAR

4.1 After various combinations had been tried, it was decided to draw separate sets of graphs for each two-month period beginning with Jan.-Feb., and ending with Nov.-Dec.

4.2 It might be noted that by using the time of year as a variable we may neglect another variable, sea temperature, and, to some extent, ice conditions. However, Hare (5) states that "in February 1947 strong east winds destroyed the Labrador pack completely, and temperatures were strikingly above normal for the rest of the winter over Newfoundland". It might be expected, then, that the graphs would be in error when ice conditions deviate greatly from normal. However, subjective forecasts would also be in error unless the forecaster were aware of such deviations.

5. TIME OF DAY

5.1 Separate graphs were drawn for each of the four synoptic times. This variable, along with the time of year, assured that insolation and radiation were being considered.

6. GEOSTROPHIC WIND DIRECTION

6.1 Geostrophic, rather than surface, winds were used for two reasons: (1) Land and sea breeze effects are prevalent at Torbay. (2) The graphs are intended for use with the forecaster's surface prognostic chart. The geostrophic wind can be read directly from this chart but the determination of the surface wind is an entirely new problem.

6.2 The geostrophic wind was separated into twelve directions -- 360°, 030°, 060°- - - 300°, 330°. A separate graph was used for each direction, making a total of 288 graphs. (6 seasons x 4 synoptic periods x 12 directions).

7. GEOSTROPHIC WIND SPEED

7.1 This was read directly from the map using the geostrophic wind scale and was plotted as the ordinate on each graph in miles per hour and in knots. No correction was made for isallobaric effects because it was too difficult to secure an accurate pressure-tendency field at a coastal station surrounded by vast gaps in the synoptic reporting network.

8. ISOBARIC CURVATURE

8.1 This was used as the abscissa of each graph. It is one of the most important of the variables taken into consideration.

8.2 Theoretically, vorticity is a much more important quantity than curvature. However, the theoretical advantages are offset by the difficulty of securing an accurate measurement of the vorticity.

8.3 A celluloid scale was constructed with concentric circles marked upon it. Radius of curvature was measured in units taken from the hodograph form, 2399-1. When the Meteorological Division changed the scale of the synoptic working maps from 1:10,000,000 to 1:12,500,000, the radius of curvature of the scale had to be reduced accordingly.

Fig. 2A gives the scale for the latter base map. For circular isobars the radius of curvature was read directly from this scale. Radii of curvature greater than a hundred units were arbitrarily classified as having infinite radius of curvature, i.e., zero curvature.

8.4 For non-circular curves, the theory is given in most calculus texts (6). For example, the radius of curvature at a point of inflexion is infinite.

8.5 After a little practice with the use of the scale, the radius of curvature can be read at any point on an isobar. For doubtful cases, the drawing of several normals will indicate the point of their intersection, with an accuracy of at least ± 10 units. However, to this figure must be added errors caused by (a) observational, coding and plotting errors of the mean sea level pressures, and (b) inaccurate drawing of the isobars due to sparse data over the adjacent Atlantic Ocean. The same comment, of course, applies to wind direction and wind speed, and for this reason, if for no other, the graphs will not give 100% accuracy (Refer to para. 17).

8.6 Fronts were treated as a real discontinuity of curvature. Fig. 2(B) gives an example of readings made around a frontal low. When a front was placed right through the Torbay station circle by the analyst (in less than 1% of the cases), it was necessary to decide on which side to read the curvature. Wind, pressure tendency, and temperature were used as criteria rather than ceiling and visibility in order not to introduce bias.

9. THE GRAPHS

9.1 On the 288 graphs, the ceiling and visibility for each observation were plotted. (Refer to para. 9.4.1) It was found that lines could be drawn dividing the graphs into areas enclosing roughly similar ceilings and visibility values.

9.2 The assumption was made, and it appears valid from the results, that values of ceilings (and visibilities) at Torbay, although not continuous functions in the statistical sense, are nevertheless consistent cyclically around the year, around the day and around the compass. Thus, although the very first graph was sketched on the basis of the data it alone contained, thereafter numerous cross-checks were available. A lighted glass tracing table was used for this purpose. The author's five years of forecasting for the Torbay terminal, prior to 1949, was also an invaluable aid; similar graphing for an unfamiliar terminal would have been much more difficult.

9.3 Quite naturally there were gaps or inconsistencies arising for three reasons:

9.3.1 Missing data: for some of the higher wind speeds, particulary in the summer, there were relatively few observations. This could result in certain areas of any one graph being completely bereft of plotted values of ceiling and visibility. For example, let us say that a section of the July-August, 030°, 0630 GMT, graph was bare. A method of cross-reference was then employed, using the 0030 GMT and 1230 GMT graphs, the 360° and 060° graphs, and the May-June and Sept.-Oct. graphs to obtain probable values which would maintain the cyclic relationship of the graphs.

9.3.2 Inconsistent data: in a few cases the weight of evidence for a particular section of a graph gave a probable ceiling (or visibility) inconsistent with the cyclically related graphs. Consistency was considered to be a primary objective. Thus the selected value for any area does not in all cases represent the majority of observations in that area.

9.3.3 Serial correlation: this is a very complicated problem for which there appears to be no solution. It is very likely that in some instances too many observation from some particular weather regime have made the graphs biased. Panofsky (7) mentions the impossibility of defining meteorological populations and of drawing random samples from them.

9.4 Two other aids were used to achieve consistency:

9.4.1 Observations for the month prior to the two-month period in question were plotted in red on the graphs. Observations for the following month were plotted in green.

9.4.2 Observations from the eastern semi-circle for July-August, 1948, were measured and plotted in purple on the July-August graph (after converting the coded visibility reports to their approximate linear values). During that particular year easterly winds were more prevalent and this helped to fill a gap.

9.5 With so many graphs, there are still likely to be inconsistencies. The attached copies do not show the plotted data. * However, in a box at the right-hand corner of each are plotted the ceiling and visibility frequencies for the entire graph not including red, green or purple data. In each area where there are are five or more observations, the distribution is also given.

9.6 The first line of the box lists ceilings according to the international synoptic code. Frequencies of each ceiling classification are given in the second line. The numbers on the third line are the upper limits of visibility ranges in the synoptic code, e.g., 10 represents visibilities of code 08, 09 and 10. The fourth line gives the frequencies in each visibility range. Some thought was given to using the central rather than the upper value of each range. However, confusion might arise as to boundary values.

9.7 Each area is labelled with what is considered to be the most probable ceiling and visibility. The delineation of these areas is necessarily a subjective procedure and some tests must be made for reality. Obviously it would be possible, by drawing sufficiently snake-like curves, to include nearly all the observations of any real or imaginary distribution.

10. TESTS

10.1 When three years of data, 1949-1951, inclusive, had been plotted, the areas were tentatively sketched in. The 1952 observations were then compared with those indicated by the graphs and those forecast by the Main Meteorological Office, Gander.

10.2 Next, the 1952 data were incorporated into the graphs. Then the tests were applied again for the first two months of 1953 to determine whether an additional year's observations improved the scores significantly. Finally, the 1953 observations were incorporated into the graphs.

* The 288 graphs are temporarily being held by the Canadian Branch, R.M.S., Toronto.

11. ANALYSIS OF THE 1952 TESTS

11.1 Gander issues forecasts of Torbay terminal weather four times daily, four hours after the international synoptic hours, each forecast having a valid period of twelve hours.

11.2 Let the first synoptic hour which occurs within the forecast period be YT3 and the second YT 9;

e.g. in FA QX 162200Z-171000Z, YT3 is 0030Z and YT9 is 0630Z

11.3 YT3 is a time approximately three hours later than the time of latest hourly observations on which the forecast is based. It seems to be a fair assumption that YT3 will almost invariably be associated with a "perfect" (mentally) surface prognostic chart for that time. As indicated in 1.1 and 1.2 the graphical method is based on the assumption of a "perfect" prognostic chart. This condition is satisfied when we apply the graphs to an actual synoptic chart. It is therefore proposed to compare the accuracy of the Gander forecast at time YT 3 with the expected ceilings and visibilities given by the graphs for an independent 12-month set of snynoptic maps.

11.3.1 It might be noted that the Gander forecaster will have the following advantages: (1) ability to utilize the persistence factor by knowing the ceiling and visibility at the time of issuance; (2) knowledge of the weather at adjacent terminals such as Argentia and Gander; and (3) auxiliary aids such as upper air charts and tephigrams.

11.4 In the case of YT9 we cannot assume that the forecast is necessarily based on a "perfect" prognostic chart; this comparison was made, however, as a matter of interest.

11.5 An objective right or wrong test was then applied to each forecast ceiling and visibility.

11.5.1 The ceiling was converted to the synoptic code and was marked right if it were within a range of one code figure, e.g., forecast 2,500' - code 5, right if code 4, 5 or 6, otherwise wrong.

11.5.2 The visibility was converted to the synoptic code and it was marked right if it were within half or double the forecast value inclusive, e.g., forecast 2 miles - code 16, right if code 08 to 32 inclusive, otherwise wrong. Code 80, 81 and 82 were verified down to code 40 inclusive, and code 40 and above were verified at all higher values.

11.6 From the point of view of the dispatcher, the tests were too strict because remarks at the end of FA QX were ignored. However, the graphs give only the most probable values and, therefore, for comparison it was considered fair to mark the FA QX in this way.

12. VARIATION OF FORECAST ACCURACY WITH THE TIME OF DAY

12.1

	NO. OF CORRECT CEILINGS			NO. OF CORRECT VISIBILITIES			
	YT3	YT9	Graphs	YT3	YT9	Graphs	Total Possible
0030Z	231	208	241	270	246	298	366
0630Z	236	182	235	254	211	266	366
1230Z	245	205	235	272	256	283	366
1830Z	260	213	242	293	276	306	366
TOTALS	972	808	953	1,089	989	1,153	1,464

Bimonthly totals from which these figures are compiled are given in Appendix A.

12.2 For ceilings, the graphs were not as accurate as YT3, but much more so than YT9. The Gander forecasts showed a diurnal variation of accuracy but the graphs did not.

12.3 For visibilities, the graphs were more accurate than both YT3 and YT9. All three showed a diurnal variation of accuracy.

13. VARIATION OF FORECAST ACCURACY WITH GEOSTROPHIC WIND DIRECTION AT SYNOPTIC TIME

(not necessarily the forecast direction of FA QX)

13.1 Percentage Correct

Wind	Ceiling			Visibility			No. of
Direction	YT3	YT9	Graphs	YT3	YT9	Graphs	Obs.
360°	69%	62%	62%	81%	79%	82%	103
030	65	53	58	64	52	57	130
060	73	51	58	58	50	54	78
090	80	67	65	65	45	57	51
120	76	64	69	57	47	71	90
150	66	50	56	58	53	64	103
180	56	46	58	61	49	70	142
210	55	46	63	75	66	83	126
240	65	49	70	83	79	93	217
270	68	65	74	88	88	93	162
300	70	61	76	93	84	93	135
330	69	57	61	82	80	90	127
							1,464

13.2 For ceilings, the graphs were more accurate than YT3 for direction 180° to 300°, inclusive. For visibility, the graphs were more accurate than YT3 except for directions 030°, 060°and 090°.

14. TIME BIAS

14.1 In this analysis, and in that following in Section 15, only those cases when the ceiling and/or visibility were/was marked incorrect were considered.

14.2 Percentage Cases Forecast Value Was Too Low

	Ceiling			Visibility		
	YT3	YT9	GRAPHS	YT3	YT9	GRAPHS
0030Z	71%	61%	44%	69%	62%	43%
0630Z	64	60	54	57	65	58
1230Z	61	56	51	53	55	42
1830Z	53	47	40	48	43	33
All cases	63	56	47	57	58	46

14.3 If we arbitrarily assume all values between 40%and 60% to be normal, then the Gander forecasts were too pessimistic at 0030Z and 0630Z, otherwise normal. The graphs were normal except that visibility at 1830Z was too optimistic.

15. GEOSTROPHIC WIND DIRECTION BIAS

15.1 Percentage Cases Forecast Value Was Too Low

	Ceiling			Visibility		
	YT3	YT9	GRAPHS	YT3	YT9	GRAPHS
360°	56%	44%	69%	65%	59%	42%
030	63	48	52	60	56	46
060	65	43	53	56	47	51
090	50	35	72	33	32	50
120	41	41	61	51	38	69
150	60	48	64	42	38	51
180	76	69	54	70	67	40
210	74	79	55	77	79	41
240	64	64	32	69	72	31
270	55	59	29	50	65	25
300	70	64	19	44	67	22
330	62	57	43	75	75	38

15.2 The trends are not very clear-cut but it would seem that: (1) incorrect Gander forecasts were too pessimistic for south to southwest winds and that, (2) incorrect graphical forecasts were too optimistic for southwest to northwest winds.

16. 1953 OBSERVATIONS

16.1 When the tests mentioned in Section 11 to 15 were completed, the data were plotted and the graphs redrawn where necessary. The final question to be decided was whether an additional year's observations would improve the accuracy of the graphs significantly. The tests were therefore continued in January and February of 1953.

16.2 The results were as follows:

	No. of Correct Ceilings			No. of Correct Visibilities			
	YT3	YT9	Graphs	YT3	YT9	Graphs	Total Possible
0030Z	38	36	34	45	40	48	59
0630Z	38	25	35	43	40	53	59
1230Z	40	28	37	47	40	46	59
1830Z	38	38	35	41	45	46	59
Totals	154	127	141	176	165	193	236

	No. of Correct Ceilings			No. of Correct Visibilities			
Wind Direction	YT3	YT9	Graphs	YT3	YT9	Graphs	Total Possible
360°	9	6	12	16	16	16	18
030	13	9	14	10	9	14	18
060	9	4	7	8	3	7	10
090	6	6	5	2	3	5	9
120	4	2	4	5	4	5	7
150	3	2	2	3	3	2	5
180	15	13	11	12	10	14	21
210	19	15	13	18	16	19	26
240	15	13	12	19	15	23	27
270	14	19	21	23	25	25	28
300	16	11	12	20	20	21	23
330	31	27	28	40	41	42	44
Totals	154	127	141	176	165	193	236

16.3 In order to do a significance test, it will be necessary to assume that the graphs for Nov. - Dec., Jan. - Feb., and Mar. - Apr. have equal accuracy. Listed below, then, are the mean number of correct forecasts to be expected for 236 cases based on 1952 data for Jan. - Feb., Mar. - Apr., and Nov. - Dec. (See bimonthly tables in Appendix A.

	Expected No. of Correct Ceilings			Expected No. of Correct Visibilities			
	YT3	YT9	Graphs	YT3	YT9	Graphs	Total Possible
0030Z	37	33	37	42	38	47	59
0630Z	40	30	40	42	33	44	59
1230Z	40	35	39	40	39	41	59
1830Z	40	32	39	44	40	46	59
TOTAL I	157	130	155	168	150	178	236

	Expected No. of Correct Ceilings			Expected No. of Correct Visibilities			
	YT3	YT9	Graphs	YT3	YT9	Graphs	Total Possible
360°	14	12	13	15	15	15	18
030	12	10	11	11	9	11	18
060	7	5	6	6	5	6	10
090	8	6	6	5	4	5	9
120	5	4	5	4	2	5	7
150	3	2	3	3	3	3	5
180	12	10	12	12	8	14	21
210	14	12	16	19	16	20	26
240	17	11	19	21	21	25	27
270	18	19	20	23	24	25	28
300	15	13	16	21	18	21	23
330	31	26	29	34	32	39	44
TOTAL II	156	130	156	174	157	189	236
ACTUAL TOTAL III	154	127	141	176	165	193	236

16.4 Totals I and II are not the same because the time distributions are the same in 1952 and 1953 (25% for each synoptic time) but the wind direction distributions are not. For example, referring back to section 13, the percentage of 360° winds in 1952 was $\frac{103}{1464} \times 100 = 7.0\%$. In Jan. - Feb., 1953, the percentage was $\frac{18}{236} \times 100 = 7.6\%$.

16.5 Consider now Totals I, II and III:

16.5.1 Ceiling. For YT3 and YT9 the figures are are quite comparable. For the graphs totals III are actually lower than we would expect. There is certainly no evidence here to show that an extra year's data have improved the curves.

16.5.2 Visibility. If we considered totals I and III separately, we might be led to believe that the Gander and the graphical forecasts had improved in 1953. However, totals II and III are so similar that it appears unnecessary to proceed with any significance tests.

17. COMPARISON OF TORBAY DATA OBTAINED FROM SYNOPTIC CHARTS DRAWN AT THE D.P.W.O., HALIFAX, AND THE M.M.O., GANDER

17.1 In order to show that there is a useful relationship between the ceiling (and visibility) at Torbay and the synoptic chart, it is necessary first to establish that two forecasters working independently from independent past history, will draw reasonably similar isobaric configurations.

17.2 In May, 1953, the January, 1952, synoptic charts, with the exception of that for 1830 GMT of January 31st, were obtained from the Main Meteorological Office, Gander. The sample of 123 charts was considered to be sufficiently large to be representative.

17.3 The isobaric data for Torbay from these charts were applied to the finalized graphs. Comparison was then made with:

17.3.1 Results obtained from the Halifax charts applied to the finalized graphs, and

17.3.2 Results obtained from the Halifax charts applied to graphs based on only 1949, 1950 and 1951 data.

17.4

	Number of Correct Ceilings	Number of Correct Visibilities
Data from Gander charts applied to finalized graphs	81	90
Data from Halifax charts applied to finalized graphs	85	94
Data from Halifax charts applied to initial graphs	76	86

17.5 Since the January, 1952, data from the Halifax charts are included in the finalized graphs, one would expect the highest accuracy in that case. The fact that all three sets give quite similar results indicates that differences in isobaric analysis from one office to another are not sufficiently large to invalidate the graphs.

17.6 Figures 4, 5 and 6 show the magnitude of the differences in this test.

18. PHYSICAL SIGNIFICANCE OF THE GRAPHS

18.1 An analysis of the physical properties underlying each part of each graph is beyond the scope of this paper. Two points only will be mentioned.

18.1.1 Nowhere has it been implied that, given similar synoptic conditions at the same time of year, different types of weather will have similar effects on the ceiling and visibility. For example, suppose a section of a graph is labelled 200 feet and half a mile. The fact is that the majority of observations in that area did have the same obstruction to vision, perhaps snow, rather than a variety of types.

18.1.2 It would seem that the length of time the wind has been blowing from a particular quarter would have some effect on the ceiling and visibility. This factor has not been taken into account directly. However, the subdivision into six two-monthly periods does, on the average, incorporate the seasonal variations in the rates of motion of pressure systems. When these speeds are greatly different from normal for the time of year, graphical indications should be examined very carefully.

19. CONCLUSION

19.1 A set of 288 graphs is presented which may be applied to a surface prognostic chart for any designated future synoptic time. If the prognostic chart is perfect then the accuracy of the resultant Torbay ceilings and visibilities will be quite comparable to a 3-hour short-range forecast for Torbay issued subjectively by Gander. When we consider the additional aids available to the Gander forecaster, the results are very favourable.

19.2 For long-range planning the graphs are likely to give the best forecasts. For short-range forecasts, the graphs should not be used categorically but should serve as a guide, particularly to inexperienced forecasters. It is my belief that a combination of the graphs and the present subjective methods would produce a significant improvement in accuracy.

19.3 The method can be applied to any other terminal if time is made available to collect the data. Although graphs are are displayed for only the four synoptic times, similar graphs could be constructed for the intermediate 3-M times.

20. ACKNOWLEDGEMENTS

20.1 The writer wishes to express his thanks to Mr. R.A. Hornstein, Officer-in-Charge at Halifax, for facilitating the study and editing the drafts of this paper, and to Mrs. G.J. Holland and Mr. D.G. Snow of Halifax office for plotting graphs.

APPENDIX A

BIMONTHLY TOTALS OF THE 1952 TEST (see para. 12)

	Ceilings			Visibilities			
	YT3	YT9	GRAPHS	YT3	YT9	GRAPHS	Possible
0030Z J – F	39	38	41	45	45	49	60
MA – A	35	30	39	43	36	49	61
M – J	39	31	41	43	38	46	61
J – A	30	30	51	49	48	56	62
S – O	37	34	36	50	44	50	61
N – D	41	35	33	40	35	48	61
TOTALS	231	198	241	270	246	298	366
0630Z J – F	38	33	46	42	37	45	60
M – A	42	33	36	42	28	45	61
M – J	41	32	35	38	33	39	61
J – A	34	29	36	35	33	43	62
S – O	39	28	40	50	43	49	61
N – D	42	27	42	47	37	45	61
TOTALS	236	182	235	254	211	266	366
1230Z J – F	48	37	43	40	36	43	60
M – A	35	34	35	39	41	43	61
M – J	38	32	36	43	38	47	61
J – A	41	34	44	51	52	57	62
S – O	42	31	39	56	49	53	61
N – D	41	37	38	43	40	40	61
TOTALS	245	205	235	272	256	283	366
1830Z J – F	51	40	41	43	40	48	60
M – A	39	34	41	50	43	49	61
M – J	46	35	42	48	47	51	61
J – A	42	38	43	55	54	58	62
S – O	47	41	37	55	53	55	61
N – D	35	25	38	42	39	45	61
TOTALS	260	213	242	293	276	306	366

REFERENCES

1. Dunn, Gordon E.: "The Public Weather Service Program at Chicago", Royal Meteorological Society, Canadian Branch, Vol. 2, No. 2, Feb., 1951.

2. Klein, William H.: "Winter Precipitation as Related to the 700 mb. Circulation": "Bull. Amer. Met. Soc.", Vol. 29, Page 439.

3. Meteorological Service of Canada: "Meteorological Conditions at Selected Airports in Canada, Newfoundland and Labrador": 1946.

4. Bindon, H.H., and Moakler, J.J.: "A Study of Fog and Thick Weather at the Gander Transatlantic Airport": TEC-64, CIR-1637, June, 1949

5. Hare, F.K.: "The Climate of the Island of Newfoundland: "A Geographical Analysis": "Geographical Bulletin", No. 2, 1952.

6. Gibson: "Elementary Treatise on the Calculus": MacMillan and Co., Ltd., pgs. 352-359.

7. Panofsky, H.A.: "Significance of Meteorological Correlation Coefficients": "Bull. Amer. Meteor. Soc.", Vol. 30, Page 326.

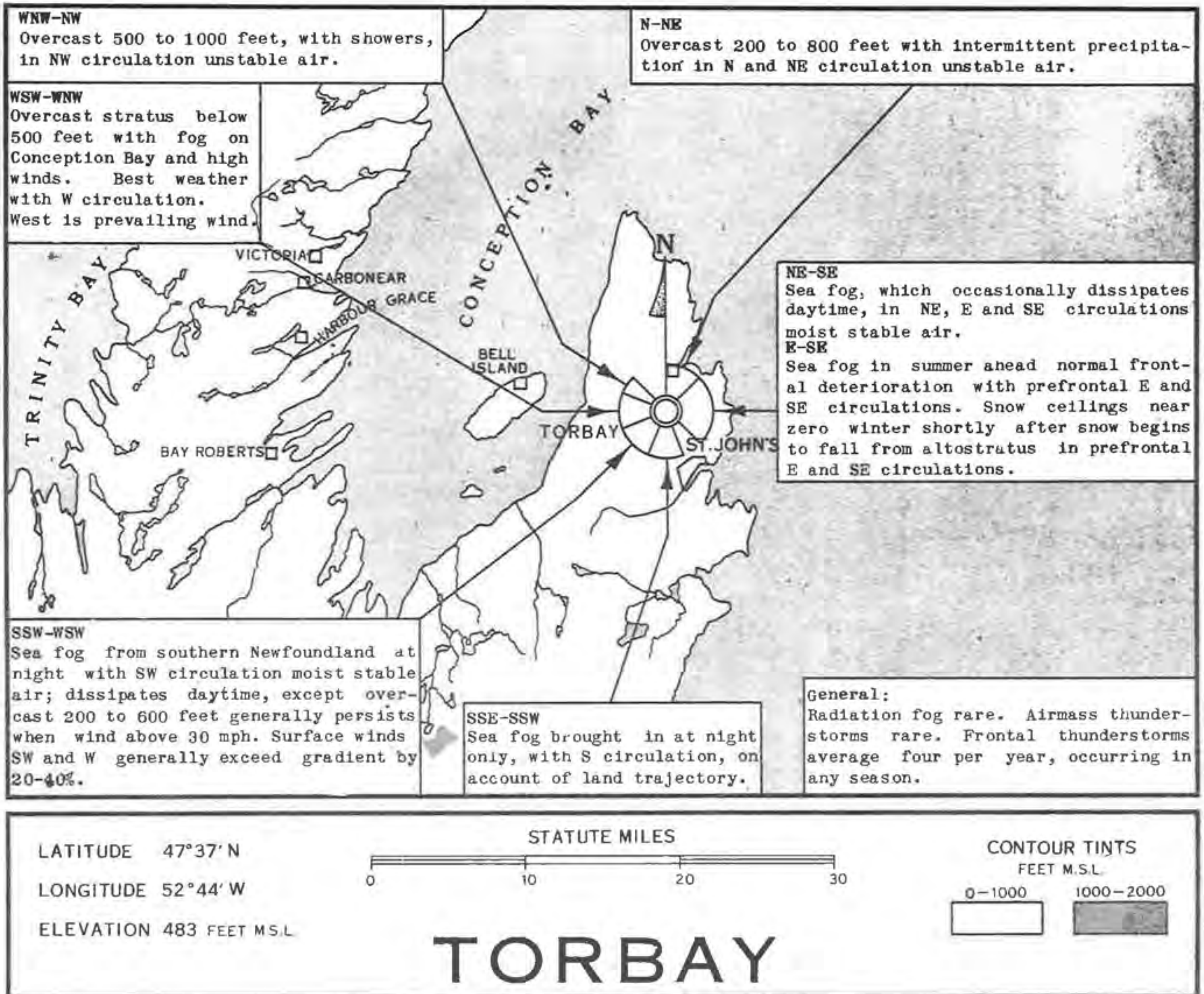


Figure 1. (Reproduced from "METEOROLOGICAL CONDITIONS AT SELECTED AIRPORTS")

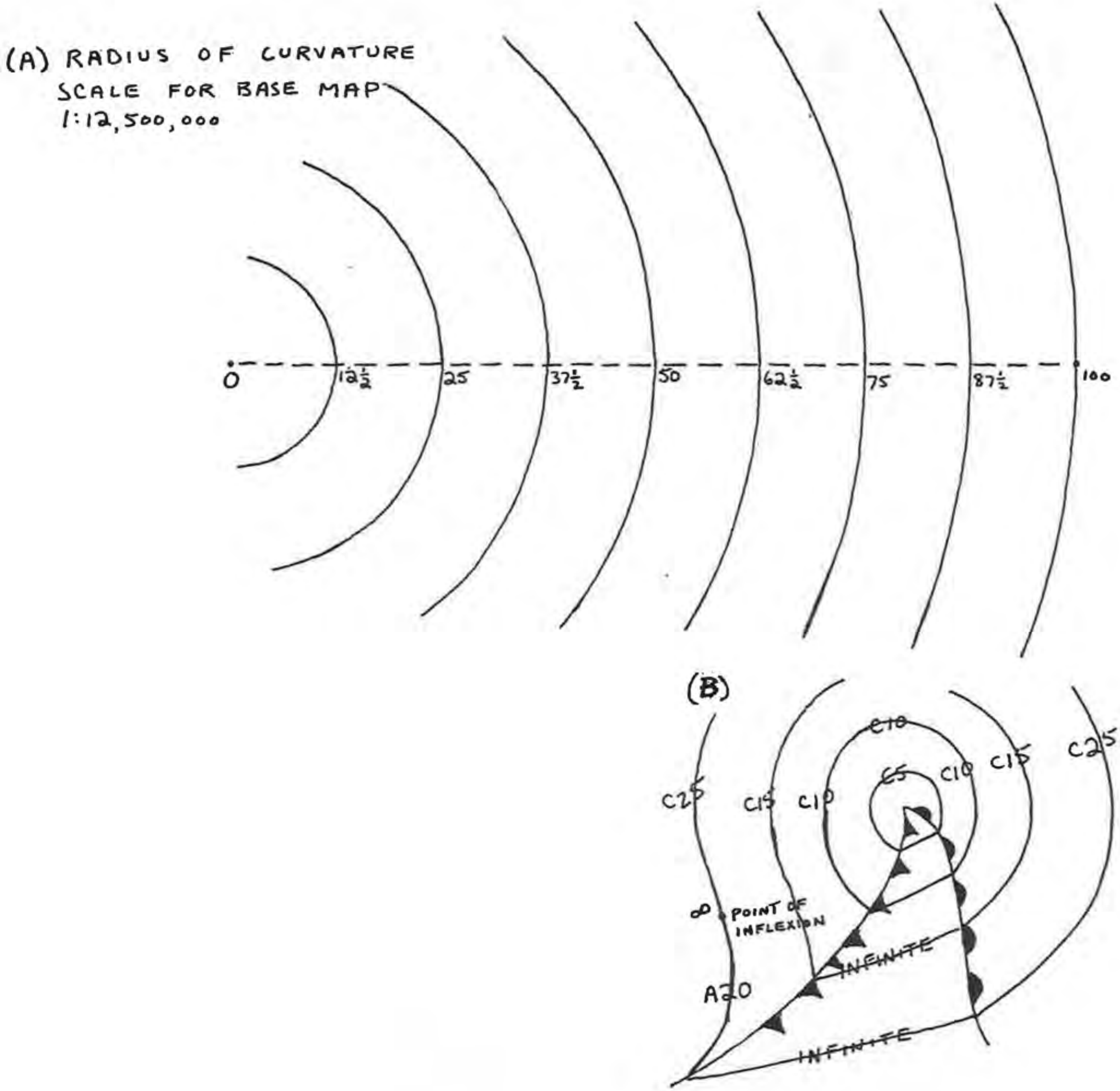

(A) RADIUS OF CURVATURE
SCALE FOR BASE MAP
1:12,500,000
0
12½
25
37½
50
62½
75
87½
100
(B)
C10
C5
C10
C15
C25
C25
C15
C10
∞ POINT OF INFLEXION
INFINITE
A20
INFINITE

FIGURE 2

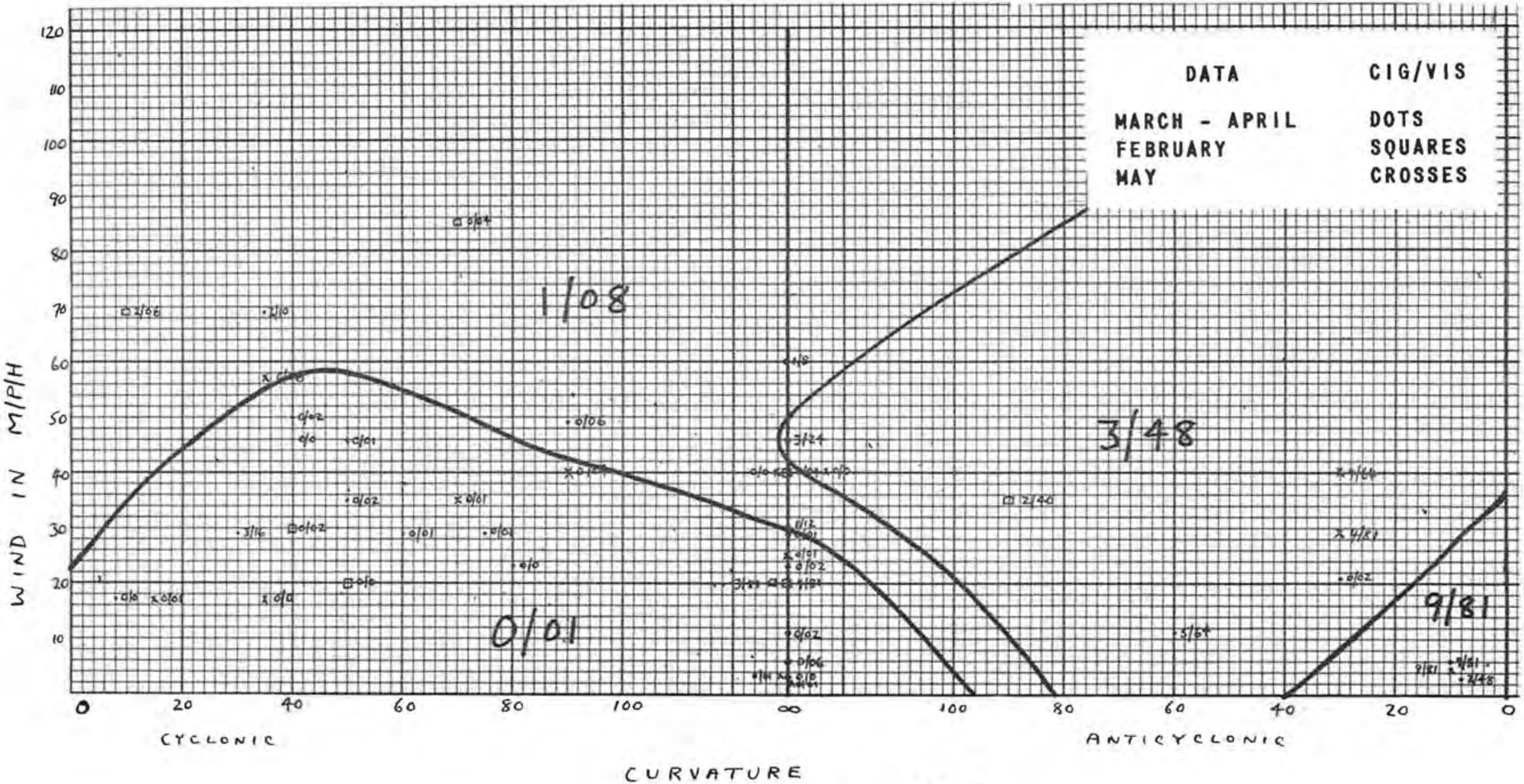
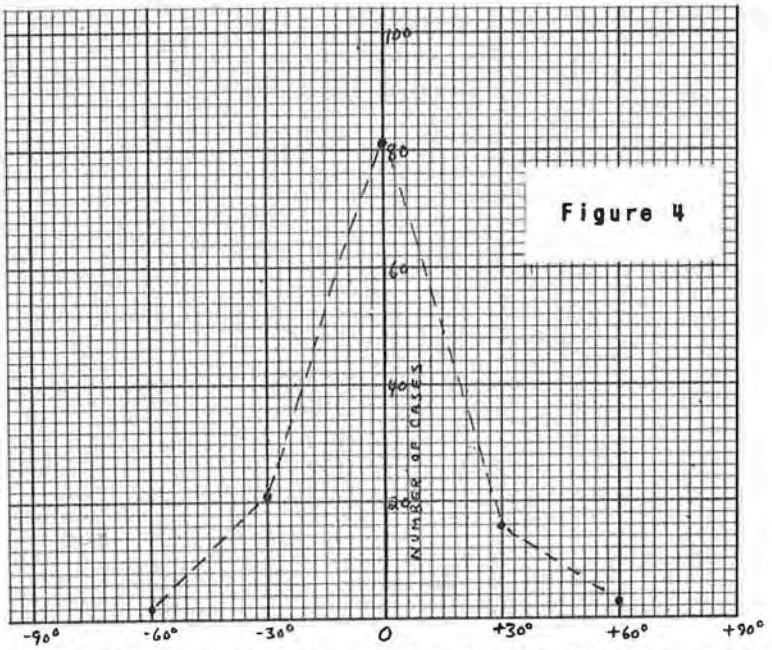
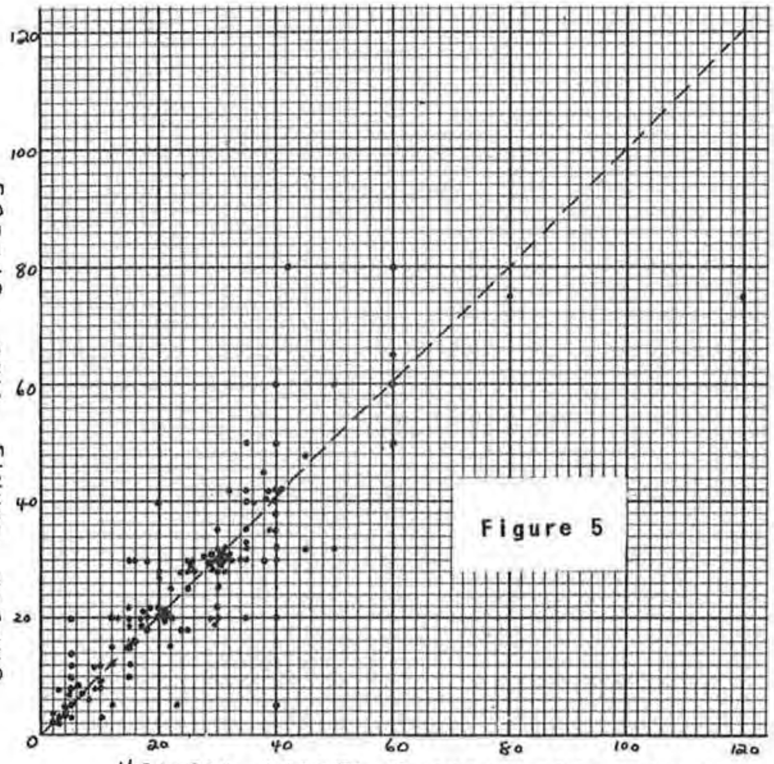

DATA
CIG/VIS
MARCH - APRIL
DOTS
FEBRUARY
SQUARES
MAY
CROSSES
1/08
0/01
3/48
9/81
WIND IN M/P/H
CYCLONIC
ANTICYCLONIC
CURVATURE

Figure 3



DEVIATION OF GEOSTROPHIC WIND DIRECTION TAKEN FROM GANDER JANUARY 1952 CHARTS FROM DIRECTION TAKEN FROM HALIFAX CHARTS. (CLOCKWISE POSITIVE)



HALIFAX CHARTS JANUARY 1952 WIND SPEEDS IN KNOTS

AVERAGE ABSOLUTE DIFFERENCE = 5.8 KNOTS

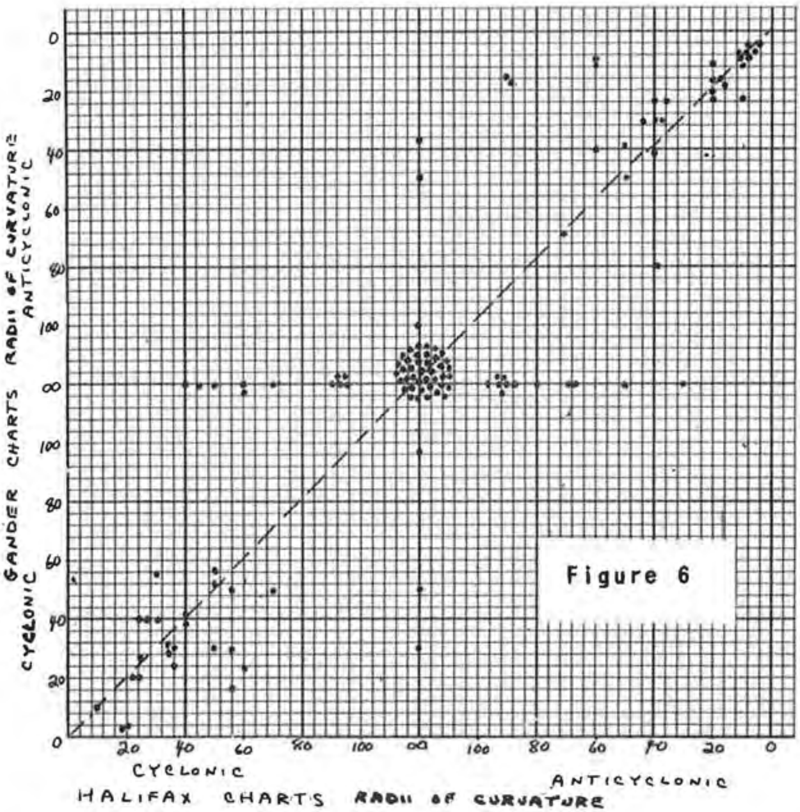

GANDER CHARTS RADII OF CURVATURE
ANTICYCLONIC
CYCLONIC
0
20
40
60
80
100
∞
100
80
60
40
20
0
CYCLONIC
ANTICYCLONIC
HALIFAX CHARTS RADII OF CURVATURE

Figure 6