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EVALUATION OF CAO BAROCLINIC QPF FOR THE ATLANTIC PROVINCES

by

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ABSTRACT

The quantitative precipitation forecasts based on the baroclinic model provided by the Central Analysis Office have been evaluated with respect to forecast accuracy of precipitation area and intensity in the Atlantic Weather Central's land area of prognostic responsibility for the period 1 April 1970 to 30 June 1970. Comparisons have been made with the quantitative precipitation forecasts based on the barotropic* model used in 1968. Definite improvements have been noted in the accuracy of forecasting positions of heaviest precipitation and maximum intensity of precipitation. Improvements in the accuracy of forecasts of precipitation areas are less apparent.

*Editor's Note: Where the author refers to the 1968 version of the Central Analysis Office quantitative precipitation forecasts there is an implication that they were based on a barotropic model. In fact an early version of the baroclinic model was used (see, for example, references 1. and 2. at the end of this paper).

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ÉVALUATION DES PRÉVISIONS QUANTITATIVES BAROCLINES DES PRÉCIPITATIONS DE BUREAU CENTRAL D'ANALYSE POUR LES PROVINCES DE L'ATLANTIQUE

par

J.A. Fitzgerald

RÉSUMÉ

L'auteur a évalué les prévisions quantitatives des précipitations basées sur le modèle barocline fourni par le Bureau central d'analyse quant à la précision de la prévision des zones de précipitation et de l'intensité des précipitations dans la zone continentale relavant du Centre météorologique de l'Atlantique chargé de faire les prévisions pour la période du 1er avril 1970 au 30 juin 1970. Il a fait des comparaisons avec les prévisions quantitatives des prévisions basées sur le modèle barotrope utilisé en 1968. Il a noté une amélioration certaine de la précision dans la prévision des positions des précipitations les plus fortes et de l'intensité maximale de la précipitation. Les améliorations dans la précision des prévisions des zones de précipitation sont moins évidentes.

EVALUATION OF CAO BAROCLINIC QPF FOR THE ATLANTIC PROVINCES

by

J. A. Fitzgerald*

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1. Introduction

Central Analysis Office (CAO) issues twice daily Quantitative Precipitation Forecasts (QPF). These QPFs are based on the CAO baroclinic model, and include 24- and 36-hour predictions which give 24-hour areal precipitation amounts for the periods ending 0000GMT and 1200GMT (or vice versa), 24 hours and 36 hours following the time of data observation.

The accuracy and usefulness of these QPFs were evaluated for the Atlantic Provinces for the period 1 April 1970 to 30 June 1970 (Figure 1). The following considerations were used in the evaluation:

(i) The amount of coincidence between forecast and observed precipitation fields (F and Ø respectively) as determined by the area in common ($F \cap Ø$). The data for this determination were abstracted from the precipitation analyses prepared at the Atlantic Weather Central (AtWC) and the quantitative precipitation forecasts issued by CAO. A grid ruled in square degrees of latitude measured at 60°N was used to measure the observed and forecast precipitation areas and their intercepted area.

(ii) The degree to which the maximum forecast intensity predicted the maximum observed intensity. This information was obtained from the same set of data used in (i) above.

(iii) The accuracy of the QPF in forecasting the location of heaviest precipitation. Relative positions of observed maximum precipitation intensity with respect to the forecast maximum precipitation intensity were obtained directly from the QPF issued by CAO and the precipitation analyses prepared at the AtWC.

*J. A. Fitzgerald is a University of New Brunswick student working in the Atlantic Weather Central in the summer of 1970 under the direction of R. V. Tyner.

Considerable reference is made to a similar paper by Tyner (1). Tabulated results marked 1968 are results which were obtained in the 1968 investigation and are included here for the purpose of comparison. Where 1968 values have been marked with an asterisk (*), a different method of calculating the results was used in the 1968 evaluation than is used in the present evaluation. In these cases the 1968 data were re-evaluated to make the results comparable with the present investigation. Where such changes have been made, an explanation is given in the text.

The evaluation has been carried out for precipitation intensities of .01 inch/24 hr., .25 inch/24 hr., .50 inch/24 hr., 1.00 inch/24 hr., 2.00 inches/24 hr., and 3.00 inches/24 hr.

2. Precipitation Fields

A tabulation of the average of F, Ø and F ∩ Ø together with the number of cases encountered that fit certain criteria is found in Table 1, e.g., in the case of the 24-hour predictions there were 178 occasions on which precipitation intensity of 0.01 inch was forecast or observed (Column IVa). Of these 178 cases there were three in which there was no observed precipitation but precipitation was forecast (Column IVb), six in which there was observed precipitation but none forecast (Column IV c), and four in which precipitation was both observed and forecast but in which the forecast and observed precipitation fields did not overlap (Column IV d). Thus, there were thirteen cases where F ∩ Ø = 0 and 165 cases where an observed precipitation field, a forecast precipitation field, and some amount of overlap simultaneously existed. Of these latter 165 cases, the average value of F was 90.0 (deg. lat.)^2 (Column Ib), the average value of Ø was 68.6 (deg. lat.)^2 (Column IIb), and the average F ∩ Ø was 56.6 (deg. lat.)^2 (Column IIIb). Of the seven forecast precipitation areas where either there was no observed precipitation or where the observed precipitation area did not overlap the forecast area, the average forecast area was 24.9 (deg. lat.)^2 (Column Ic); the average of the ten observed precipitation areas where there was either no forecast precipitation or there was no overlap was 17.7 (deg. lat.)^2 (Column IIc). The overall average of 178 cases was 84.2 (deg. lat.)^2 for the forecast precipitation area (Column Ia), 64.5 (deg. lat.)^2 for the observed precipitation area (Column IIa), and 52.5 (deg. lat.)^2 for the intercepted area (Column IIIa).

The following points arise from an examination of Table 1:

(i) Average F for .01 inch/24 hr. with the 24-hour QPF is greater than average Ø. This results from a tendency of the QPF to over-forecast the size of precipitation fields. Comparing Columns Ib with IIb it is seen that this over-forecasting persists into the higher precipitation intensities, i.e., when the QPF predicts the occurrence of a given intensity of precipitation it will forecast, on the average, too large an area.

(ii) However, in the 36-hour QPF the above-noted characteristic changes for intensities of .01 and .25 inch/24 hr. A comparison of Columns Ib and IIb shows that in those cases where precipitation is both forecast and observed with some degree of overlap, the average forecast area is approximately equal to the average observed area for intensities of precipitation of .01 and .25 inch/24 hr. For intensities of .50 inch/24 hr. and over, a significant tendency to over-estimate the size of precipitation areas persists in the 36-hour QPF.

(iii) For intensities of .25 inch/24 hr. or greater, there is a tendency for the QPF to fail to predict the correct order of magnitude of the precipitation intensity. A comparison of Column IVc with IVa reveals the large fraction of cases where precipitation is observed but not forecast. This results in a preponderance of zero values for F and accounts for the averages of Column Ia being smaller than the averages in Ib.

3. Evaluating Accuracy

Two forms of verification are available to assess the QPFs the "threat" score and the "skill" score.

The threat score (2) is defined as $\frac{N_H}{N_O + N_P - N_H}$ where N_O is the number of stations in a given sample with precipitation observed, N_P is the number of stations with precipitation forecast and N_H is the number of stations with precipitation both observed and forecast. For the purposes of this analysis the assumption is made that areas rather than individual stations may be used. With this assumption the expression for the threat score is written as $\frac{F \cap Ø}{F + Ø - F \cap Ø}$ where Ø is the area in a given sample with precipitation observed; F, the area with precipitation forecast; and $F \cap Ø$, the overlapping area, i.e., the area in which precipitation is both forecast and observed.

While having the advantages of being simple and commonly used, the threat score has severe disadvantages.

(i) The threat score does not account for chance. Generally a score of zero is considered to represent a completely erroneous prediction; however, a computer could be programmed to forecast areas completely at random and by pure chance obtain some coincidence with observed precipitation areas. The threat score in this case would not be zero but would be purely fortuitous.

(ii) The threat score is not well-defined. Consider Figure 1 and let $A\backslash x$ denote the complement in A of the set x. $A\backslash F$ will be the forecast area of "no precipitation", $A\backslash\emptyset$ will be the observed area of "no precipitation" and $A\backslash(\emptyset\cup F)$, where $\cup$ indicates the union or logical addition of sets, will be the area in which "no precipitation" is both forecast and observed. Note that as areas $A\backslash F = A - F$, $A\backslash\emptyset = A - \emptyset$, and $A\backslash(\emptyset\cup F) = A-(F+\emptyset)+F\cap\emptyset$. Let Threat 2 be the threat score dependent on "no precipitation" areas. The expression for threat 2 is $\frac{A\backslash(\emptyset\cup F)}{A\backslash F + A\backslash\emptyset - A\backslash(\emptyset\cup F)}$. Substituting the areas of the sets and simplifying yields the expression:

$$\text{Threat 2} = \frac{A + F\cap\emptyset - (F+\emptyset)}{A - F\cap\emptyset}.$$

Ideally a threat score should give the same value regardless of whether computation is carried out on the basis of precipitation or "no precipitation". Substituting a few trial values, such as 2, 3, 4 and 10, for $F\cap\emptyset$, $\emptyset$, F, and A shows that the threat score is not necessarily equal to Threat 2.

(iii) The threat score tends to decrease rapidly with decreasing forecast and observed precipitation areas. As this is also a problem with the skill score, more will be said in connection with this later in the discussion.

The skill score (3), defined as $\frac{C - X}{T - X}$, does not suffer from the first two disadvantages of the threat score. In this definition of the skill score C is the number of stations with correct forecasts and, to be considered correct, precipitation is either both forecast and observed or not forecast and not observed; T, the total number of stations; and X, the number of stations having a correct forecast by chance. Again, in this study, areas are used rather than individual stations. Hence T becomes A, the evaluation area of 155.5 (deg. lat.)^2; and C becomes $(F\cap\emptyset)\cup((A\backslash F)\cap(A\backslash\emptyset))$ or, as an area, $2F\cap\emptyset + A - (F+\emptyset)$.

To find X, two theorems of elementary probability are used:

(i) Given two sets of randomly distributed points, A and B, where B is a subset of A and x is any point in A, the probability x will be an element of B is B/A where A and B denote the respective number of points in, or areas of, sets A and B.

(ii) Given a set of randomly distributed points A and a probability P that any point in A will be an element of a set B contained in A, the number of points in (i.e., area of) B is PA.

The probability, then, that any given point in the evaluation area A will have precipitation forecast is F/A, and that it will have precipitation observed is $\emptyset/A$. If the points were randomly distributed, then the probability that precipitation was both forecast and observed at any given point would be $F.\emptyset/A^2$. Similarly, the probability that precipitation was both not forecast and not observed would be $(A-F)(A-\emptyset)/A^2$. To obtain the area in which correct forecasts would be achieved by chance, the two probabilities would be added to obtain the probability for a point to have precipitation either forecast and observed or not forecast and not observed in a random distribution of forecast precipitation areas, and this latter probability multiplied by the evaluation area A. If this is done, X is found to be $(F.\emptyset + (A-F)(A-\emptyset))/A$.

Substituting for C, X and T in the skill score and simplifying gives the expression for the skill score as

$$2\,\frac{F \cap \emptyset - F.\emptyset/A}{F + \emptyset - 2F.\emptyset/A}$$

where A is 155.5 square degrees of latitude and the other quantities are as defined for the threat score.

It was stated that the threat score, $\dfrac{F \cap \emptyset}{F = \emptyset - F \cap \emptyset}$, and the skill score, as defined in the previous paragraph, give lower scores as the areas of F and $\emptyset$ decrease. A quantitative discussion of how this tendency originates follows in Section 4.

Despite their weaknesses the threat score and the skill score provide a reasonable method of comparing the accuracy of QPFs providing the effect of the size of the verification area is taken into consideration. It must be noted, however, that the scores do not provide any absolute indication of accuracy.

4. Scores

The original 1968 threat scores and values of $\overline{F}$ did not include zero values of F and this resulted in larger average values for the forecast area than in this study. The 1968* scores listed in this paper use $\overline{F}$ which have been averaged over all cases including zero values of F so that the 1968 threat scores listed in this paper have been computed in the same manner as the 1970 threat scores.

Table 2 lists the skill scores and the threat scores for this and the 1968 investigations. The 1968 scores are consistently higher than the 1970 scores. The main reason for this relates back to the common weakness of the threat score and the skill score, viz., the tendency of the scores to fall rapidly with decreasing F and Ø. The average values of F and Ø for 1968 were consistently larger than in 1970 because a larger evaluation area (184 square degrees of latitude as opposed to 155.5 square degrees of latitude) was used in 1968, and because the 1968 evaluation was carried out in a period (2 February 1968 to 23 March 1968) when precipitation fields were larger and better developed than in the present period (1 April 1970 to 30 June 1970). The 1970 period was marked by a larger proportion of smaller, scattered and less intense precipitation fields.

To compensate for this, the skill scores have been plotted against the average of $\overline{F}$ and $\overline{Ø}$, i.e., $(\overline{F} + \overline{Ø}) \div 2$ (Figure 3A). To appreciate the significance of Figure 3A, consider Figure 3B. Each of the curves of Figure 3B represents the situation shown in Figure 3Ci, i.e., it is a plot of the skill score that would be achieved if the forecast and observed precipitation fields were two sets of concentric circles whose centres, a and b, were separated by a distance d. As the precipitation intensity increases, the forecast and observed precipitation areas decrease but the intercepted area shrinks disproportionately causing a rapid fall of the skill score for small values of $\overline{F}$ and $\overline{Ø}$.

For ease in computation, it is assumed that the forecast and observed precipitation areas are circular and equal, and that the intercepted area (see the biconvex figure, j h k m, in Figure 3Ciii) approximates the area of the circumscribed rectangle (g i n l. This approximation is very coarse; however, as it is the behaviour of this intercepted area in response to the area of the intercepting circles that is desired, rather than the actual area, the approximation will suffice.

Comparing Figure 3A with Figure 3B, a similarity in the shapes of the curves is noted with the reservation that the curves of Figure 3A, i.e., the scores achieved by the forecasts, have a somewhat sharper bend, particularly, the 1970 scores, than have the curves of Figure 3B. Curves of the shape of the 1970 skill scores would be achieved by a situation such as Figure 3Cii, i.e., circles whose centres approach one another as their areas decrease. For example, if the value of Z for .01 inch/24 hr. was 80 square degrees of latitude and the value of d was 3 degrees of latitude, the skill score would be .70; then, if for .25 inch/24 hr., Z is 20 square degrees of latitude while d is 2 degrees of latitude, the skill score would be .65. Finally, if for intensities of .50 inch/24 hr. and greater, d is 1.5 degrees of latitude while Z decreases below 10 square degrees of latitude, the skill score would follow the d = 1.5 curve in Figure 3B to zero. This example would give a curve sloping gently from the upper right to the lower left, then bending sharply near Z=10 and decreasing thereafter almost perpendicularly. It is seen, then, that if the accuracy of a forecast increases as the area decreases, the curve tends to have a "cut-off" point where a sharp bend is experienced.

Two forecasts may be said to be of equal accuracy if their skill scores, when plotted as the skill score on the ordinate against the average of the forecast area and observed area on the abscissa, are found to lie along the same d curve as obtained from Figure 3B. If the skill scores do not lie on the same d curve, then the forecast which obtains a skill score lying on the d curve to the upper left may be said to be the more accurate as this indicates that the centres of the forecast and observed areas are, on the average, closer together.

Points a_1, b_1 and c_1 of Figure 3A, i.e., the plotted skill scores for the 1968 QPF, 24-hour QPF of 1970 and 36-hour QPF of 1970, respectively, for the intensity of precipitation of .01 inch/24 hr., appear to lie on one or the d curves of Figure 3B, so the three forecasts are of equal accuracy at this forecast precipitation intensity. (Note that to illustrate this discussion the d curve for d = 3.83 degrees of latitude has been interpolated from Figure 3B and drawn on Figure 3A.) Similarly, points a_2, b_2 and c_2 appear to lie on another d curve, so the three forecasts are probably of equal accuracy for the forecast precipitation intensity of .25 inch/24 hr.

However, if we consider points a_3, b_3 and c_3, the skill scores for the QPF s for 1968, 24-hour 1970 and 36-hour 1970 for precipitation intensity of .50 inch/24 hr., it appears that point b_3 lies well to the left of a "d" curve which could be considered to pass through points a_3 and c_3. This would imply that for this precipitation intensity, the 24-hour 1970 QPF is more accurate than the 1968 or 36-hour 1970 QPF s, both of which appear to be of comparable accuracy at this intensity of precipitation. For the higher intensities, there are not enough cases considered to make comparison meaningful nor are the differences in the d curves in this region great enough to demonstrate whether one forecast is more accurate than another.

5. Relative Areas

Tables 3A-D set out the frequency of occurrence of forecast precipitation areas relative to the frequency of occurrence of observed precipitation areas of intensities of precipitation up to 1.00 inch/24 hr. For example, in Table 3B the number 24, the second entry in the first column of the 24-hour QPF, represents 24 occurrences of an observed area of precipitation of .25 inch/24 hr. which is greater than zero square degrees of latitude but less than or equal to 10 square degrees of latitude while precipitation of .25 inch/24 hr. is not forecast in the evaluation area. The broken lines enclose those cases where the forecast and observed precipitation areas fall in the same area interval; in those cases falling to the upper right of these lines, the QPF has over-forecast, and in those cases to the lower left, the QPF has under-forecast the area of precipitation.

Tables 3B-D show the tendency of the computer to fail to predict certain incidences of precipitation. This can be seen by comparing the first column with the others. The first column represents those cases where no precipitation is forecast. The first entry gives the number of times when precipitation was observed. To illustrate, Table 3C, for the precipitation intensity .50 inch/24 hr. and the 24 hour QPF, shows 66 occurrences where precipitation was neither forecast nor observed, seven where precipitation was forecast but not observed (sum of row 1 except for the entry in Column 1), 46 where precipitation was both forecast and observed (sum of all values not in row 1 or Column 1), and 55 where precipitation was observed but not forecast (sum of Column 1 except for the entry in row 1). A high proportion of the events is in this last category and this is typical of the precipitation intensities of .25 inch/24 hr., .50 inch/24 hr., and 1.00 inch/24 hr. (Tables 3B, C, D.)

If, however, the first row and column of Tables 3B-D are deleted from consideration and only those cases considered where precipitation is simultaneously observed and forecast, a marked tendency is seen for the QPF to over-forecast areas of precipitation in the 24-hour QPFs. In table 3B there are 31 incidents of over-forecasting but only 21 incidents of under forecasting; in Table 3C, 18 incidents of over-forecasting and 13 incidents of under-forecasting and in Table 3D, 12 over-forecasts and three under-forecasts. With the 36-hour QPFs this tendency is either absent or reduced.

Table 4 considers those cases where neither F nor Ø is zero, and lists frequencies and percentages of occurrence of forecast areas $\geq$ 4/3 of the observed area and forecast areas $\leq$ 2/3 of the observed area, as well as the percentage of cases where the forecast area was within 1/3 of the observed area (i.e., $4/3\ Ø > F > 2/3\ Ø$). Again, the tendency of the QPF is to over-forecast the size of precipitation areas. This is evidenced in the 24-hour QPFs by the tendency for a higher percentage of the results to be those where the forecast area $\geq$ 4/3 of the observed area. With the 36-hour QPFs this phenomenon is much reduced, being significant only for the precipitation intensity .01 inch/24 hr. Also of note is the tendency of the 1968 results to be at least comparable to, and for the intensities .25 and .50 inch/24 to be somewhat better than, the 1970 results. The reason for this is probably in the nature of the evaluation populations. The 1968 evaluation was carried out for the latter half of the winter and had a high proportion of well-developed storms with well-defined precipitation areas, whereas the 1970 evaluation period was for the late spring period and although several well-developed storm centres moved through the Maritimes in this period, it was, for the most part, a period of weak systems and disturbances in which orographic or instability considerations played a large part in determining the occurrence and intensity of precipitation. This is evidenced by the high frequency of occurrence in the 1970 examination of small precipitation areas.

Table 5 lists average values of $(F \cap Ø) \div F$, $(F \cap Ø) \div Ø$, and $2(F \cap Ø) \div (F + Ø)$. Because the QPF tends to over-forecast the size of precipitation areas, $(F \cap Ø) \div Ø$ tends to be greater than $(F \cap Ø) \div F$. In those cases where the forecast area is considerably larger than the observed area, the intercepted area $(F \cap Ø)$ tends to be the same as the observed area so that $(F \cap Ø) \div Ø$ will be approximately unity while $(F \cap Ø) \div F$ takes on small values relative to unity. Generally $2(F \cap Ø) \div (F + Ø)$ is not as strongly influenced by such extreme cases so that $2(F \cap Ø) \div (F + Ø)$ is a more reliable measure of the usefulness of the QPF. Again the 1968 results are generally better than the 1970 results and this again is probably due to the differences in the precipitation regimes in the 1968 and 1970 periods.

Figures 4A and B and Table 6 show the frequencies of occurrence of values of $2(F \cap \emptyset) \div (F + \emptyset)$. Other than the high frequency of zero values, due again to the tendency of the QPF to miss certain precipitation areas, the major point to note is the behaviour of the distribution of $2(F \cap \emptyset) \div (F + \emptyset)$ as the intensity of precipitation increases. Excluding zero values of $2(F \cap \emptyset) \div (F + \emptyset)$ it is seen that for .01 inch/24 hr., 75.7 per cent and 66.0 per cent of the values exceed .5 for the 24-hour and 36-hour QPFs, respectively. For .25 inch/24 hr., 56.3 per cent and 46.4 per cent of the values exceed .5 for the 24-hour and 36-hour QPFs, respectively; for .50 inch/24 hr., 44.7 per cent and 32.2 per cent exceed .5; and for 1.00 inch/24 hr., 25 per cent of the values exceed .5 for both the 24-hour and the 36-hour QPFs. This behaviour is indicative of the tendency at higher precipitation intensities (and smaller areas) to a reduced coincidence between F and $\emptyset$. Since the difference between the ratio $2(F \cap 0) \div (F+\emptyset)$ and the skill score $(2(F \cap \emptyset) - 2F.\emptyset \div A) \div (F+\emptyset - 2F.\emptyset \div A)$ lies in the presence of the correction factor $2\ F.\emptyset \div A$ in numerator and denominator of the skill score, the behaviour of $2(F \cap \emptyset) \div (F + \emptyset)$ is much the same as that of the skill score.

6. Relative Maximum Intensities

A tendency for the QPF to under-forecast the maximum intensity of precipitation is observed. This may be seen in Table 7 which shows the frequency of occurrence of forecast maximum intensities compared with observed maximum intensities of precipitation. For example, the third entry of the second column of the 24-hour QPF, 22, indicated that there were 22 occasions where the maximum forecast intensity of precipitation in the evaluation area was .01 inch/24 hr. while the maximum observed intensity of precipitation in the evaluation area was .25 inch/24 hr. The broken lines enclose those cases where the maximum intensity indicated in the QPF was the same as the observed so that those events to the upper right of the broken lines represent incidents of the QPF over-forecasting, and those to the lower left, under-forecasting, the intensity of precipitation. The 24-hour QPF has 105 cases of under-forecasting compared with 22 cases of over forecasting. The 36-hour QPF has, respectively, 119 and 16 "under-forecast" and "over-forecast" situations.

The tendency of the QPF to under-forecast the maximum intensity of precipitation is, in part, apparently due to the failure of the QPF to assess adequately, particularly on abrupt coasts, the effect of onshore flow on precipitation intensity. Figures 7A and 7B show the increase in precipitation intensity caused by onshore flow. Of the 39 cases in the 24-hour and 49 cases in the 36-hour QPFs where the observed maximum precipitation intensity was greater than the forecast maximum intensity by at least .50 inch/24 hr., 36 and 42 cases, respectively, involved some degree of strong onshore flow while in 9 of the 24-hour and 11 of the 36-hour QPFs the discrepancy may be attributed entirely to onshore flow.

In 1968 the following criteria for evaluating the usefulness of forecast maximum precipitation were used. If the maximum forecast intensity came within .01 inch/24 hr. of the observed, it was considered to be essentially correct. If the forecast maximum was between .01 inch/24 hr. and .50 inch/24 hr. of the observed, it was considered a useful estimate. If the forecast maximum was between .50 inch/24 hr. and 1.00 inch/24 hr. of the observed, it was considered of limited use. If the forecast error was greater than 1.00 inch/24 hr., the forecast was considered to be of little use. Table 8 lists the 1970 and 1968 results as percentages of the number of cases that were essentially correct, useful estimates, of limited use, and of little use.

In this evaluation the 1970 results show a marked improvement over the 1968 results. This could, however, again be due to the nature of the evaluated precipitation regimes, because with the weak disturbances characteristic of the 1970 period, the difference between forecast and observed maximum precipitations would tend to be small as the intensities involved were low, while with the heavy precipitations, characteristic of the 1968 period, differences would be larger because the numbers involved are larger.

7. Relative Positions of Forecast and Observed Heaviest Precipitation

To test the ability of the QPF to locate the centres of heaviest precipitation, scatter diagrams were prepared for the 24-hour and 36-hour QPFs (Figure 5). On these the centre of the diagram (╬) represents the position of the forecast centre of maximum precipitation while the plotted points represent the position of the observed centre of maximum precipitation relative to the forecast. The situations considered were those storm centres east of the Great Lakes but over the continent. The position plotted by the circled cross (⊠) represents the average north-south and east-west displacement of the observed centres of maximum precipitation relative to the forecast centres. The regression lines were obtained by correlating the points by the method of least squares.

A general tendency for the QPF to forecast the precipation maximum to the south and west of the observed maximum should be noted. The average displacement of the observed precipitation maximum from the forecast maximum was 1.04 degree North and .88 degree East for the 24-hour QPF and .88 degree North and 1.40 degree East for the 36-hour QPF. The points tend, although with a considerable degree of scatter, to lie along a northeasterly direction: N 68^{o}.1 E for the 24-hour QPF and N 67^{o}.2 E for the 36-hour QPF.

Tables 9A and 9B break down the results shown in Figure 5 according to percentage of cases having a given displacement, either the absolute displacement as in Table 9A or as the relative displacement west or east and north or south as in Table 9B. In Table 9B a displacement of the observed position of maximum precipitation relative to the forecast to the east is taken to be positive; to the west, negative. Similarly, a displacement to the north has a positive sign and a displacement to the south, negative. The 1968 results have been included for purposes of comparison; however, in 1968 the scatter diagram used the observed centre of maximum precipitation intensity as the centre of the diagram and the forecast position was plotted with respect to this. To make the 1968 results compatible with the 1970 results, the 1968 scatter diagram must be rotated by 180 degrees about both the north-south and west-east axes, which is done, for the purposes of Table 9B, by reversing the signs of the 1968 co-ordinates to obtain the 1968* results.

In general it is seen that a better grouping is achieved for the 1970 results than for those of 1968. The average displacement and standard deviation of the average displacement for the 24-hour QPF 1970 are respectively 2.9 and 1.5 degrees of latitude, for the 36-hour QPF 1970, 3.3 and 1.9 degrees of latitude. The 1968 results had a larger average displacement, 3.9 degrees of latitude, and a greater standard deviation, 2.5 degrees of latitude. The improvement shown in the 1970 forecasts has occurred in spite of the fact that the 1968 evaluation period had a higher percentage of well-developed systems than the 1970 evaluation period.

Figure 6 shows the percentage of cases whose displacement was less than, or equal to a given displacement for the 1970 and 1968 forecasts. Interpolating on these graphs shows that, for the 24-hour QPF, 50 per cent of the cases encountered have the forecast maximum precipitation falling within 2.7 degrees of the observed maximum, for the 36-hour QPF, 50 per cent of the cases are within 3.0 degrees while for the 1968 QPF. 50 per cent are within 3.4 degrees, i.e., the 1970 forecasts locate the precipitation maximum more accurately than did the 1968 forecasts.

8. Conclusions

Based on the amount of coincidence between forecast and observed precipitation fields, the present quantitative precipitation forecasts based on the baroclinic model seem, at first glance, to be less successful than the quantitative precipitation forecasts based on the barotropic model used in 1968. However, there are seen to be mitigating factors, notably the differences in the precipitation regimes and the sizes of the precipitation areas. Taking these factors into account it is probable that the QPFs based on the baroclinic model show some improvement over those based on the barotropic, although a definite statement concerning improvement or lack of improvement in the accuracy of the QPFs cannot be made because of the lack of a truly satisfactory method of evaluating such accuracy.

The 1970 QPFs as well as the 1968 QPFs, predicted precipitation areas that are larger than those observed. This was the case for all intensities of precipitation except for the intensities of .01 and .25 inch/24 hr. with the 36-hour QPF.

The maximum intensity of precipitation is generally underforecast with both the baroclinic-based QPF used in 1970 and the barotropic-based QPF used in 1968. However, the 1970 QPF predicts consistently closer to the maximum observed intensity of precipitation than was the case in 1968. Some of the tendency to underforecast maximum intensity is attributable to the fact that the QPF often gives little or no indication of the occurrence of heavy precipitation caused by the effects of local terrain.

With respect to the accuracy of the QPF in forecasting the location of heaviest precipitation, the baroclinic QPF of 1970 consistently predicts the positions of maximum intensity more accurately and with a somewhat more regular pattern than did the 1968 barotropic QPF.

APPROVED,

J.R.H. Noble,
Administrator,
Canadian Meteorological Service.

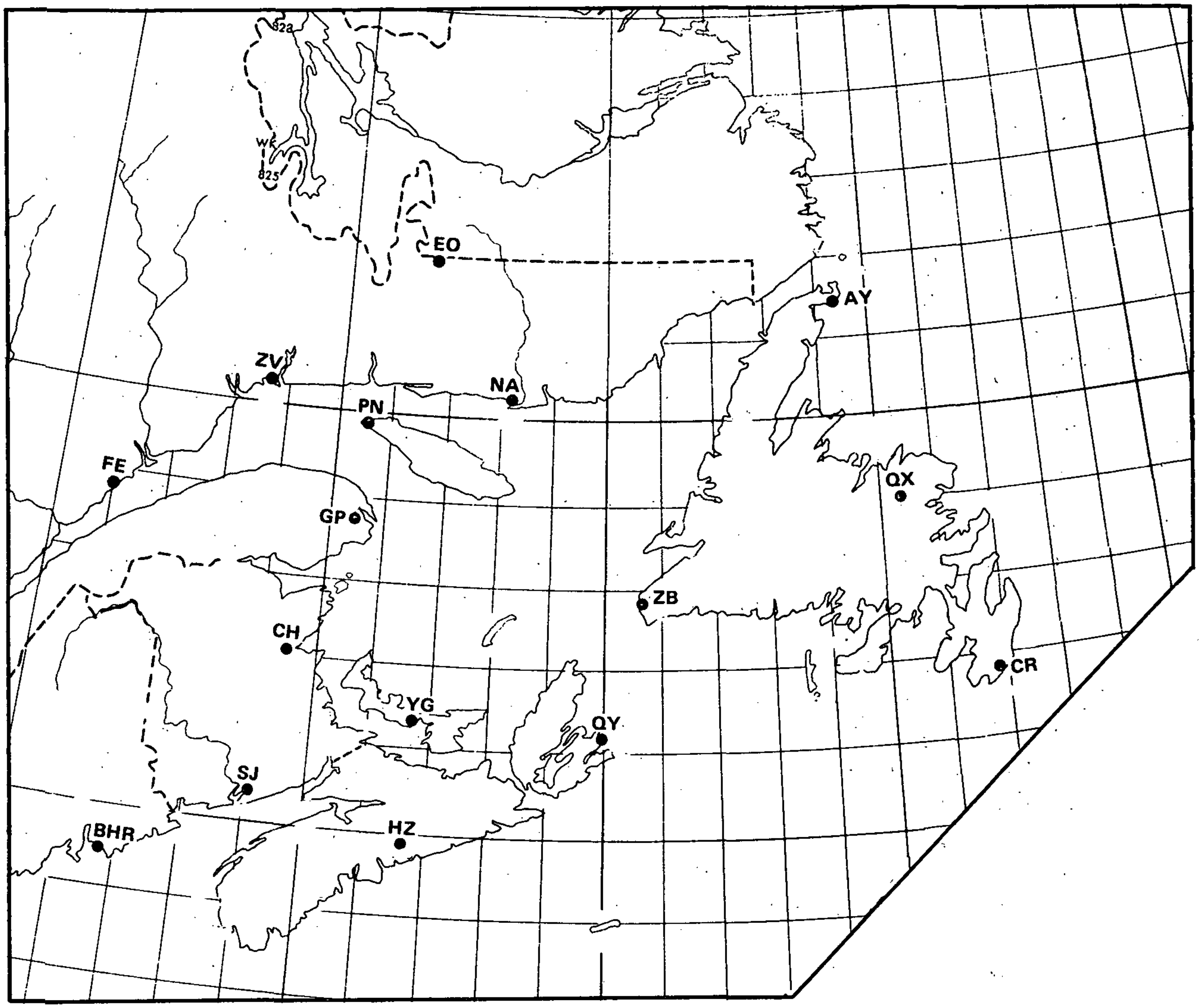


Figure 1.

EVALUATION AREA

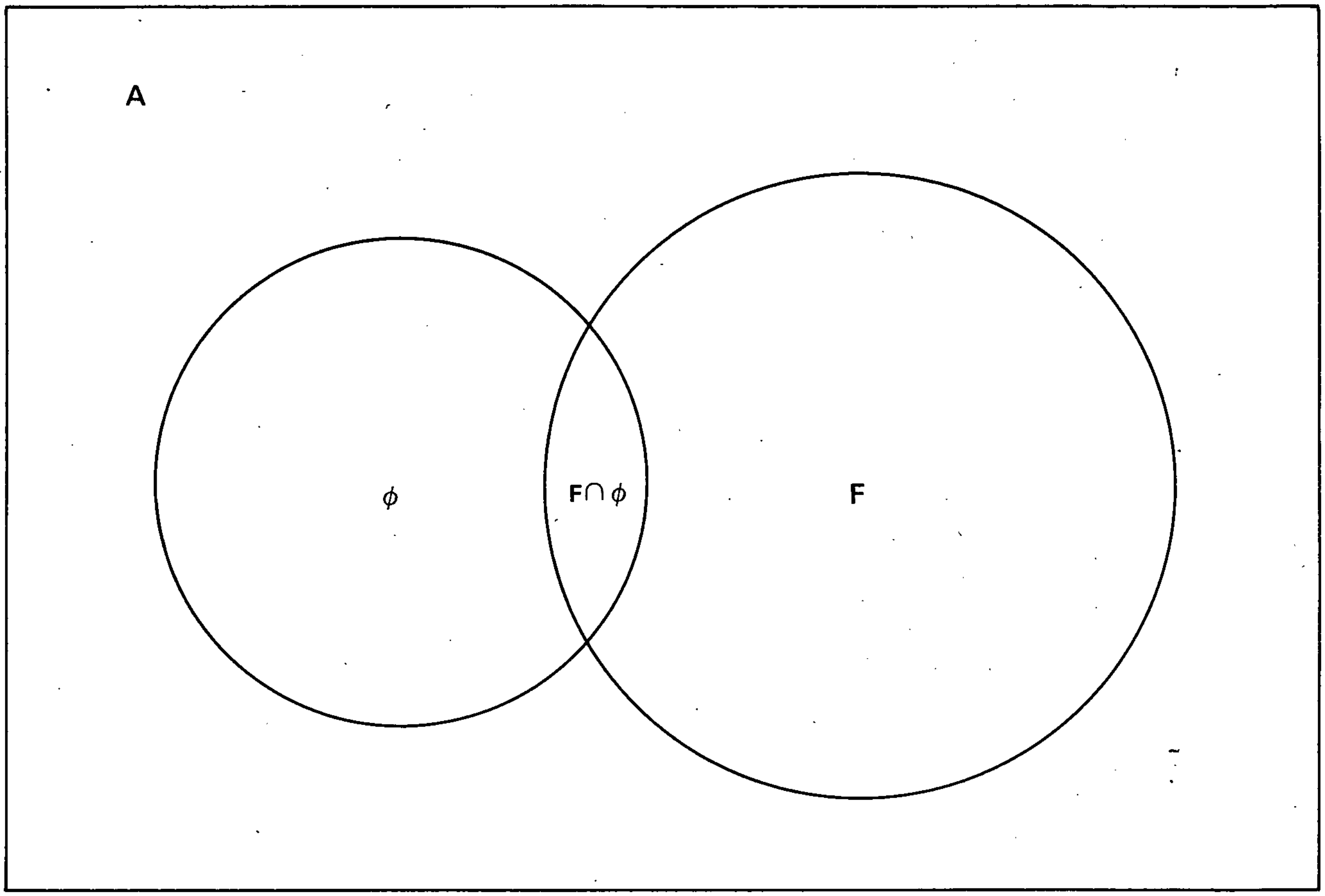


Figure 2.

VENN DIAGRAM

Figure 3A.

Skill v. $(\bar{F} + \bar{\phi}) \div 2$

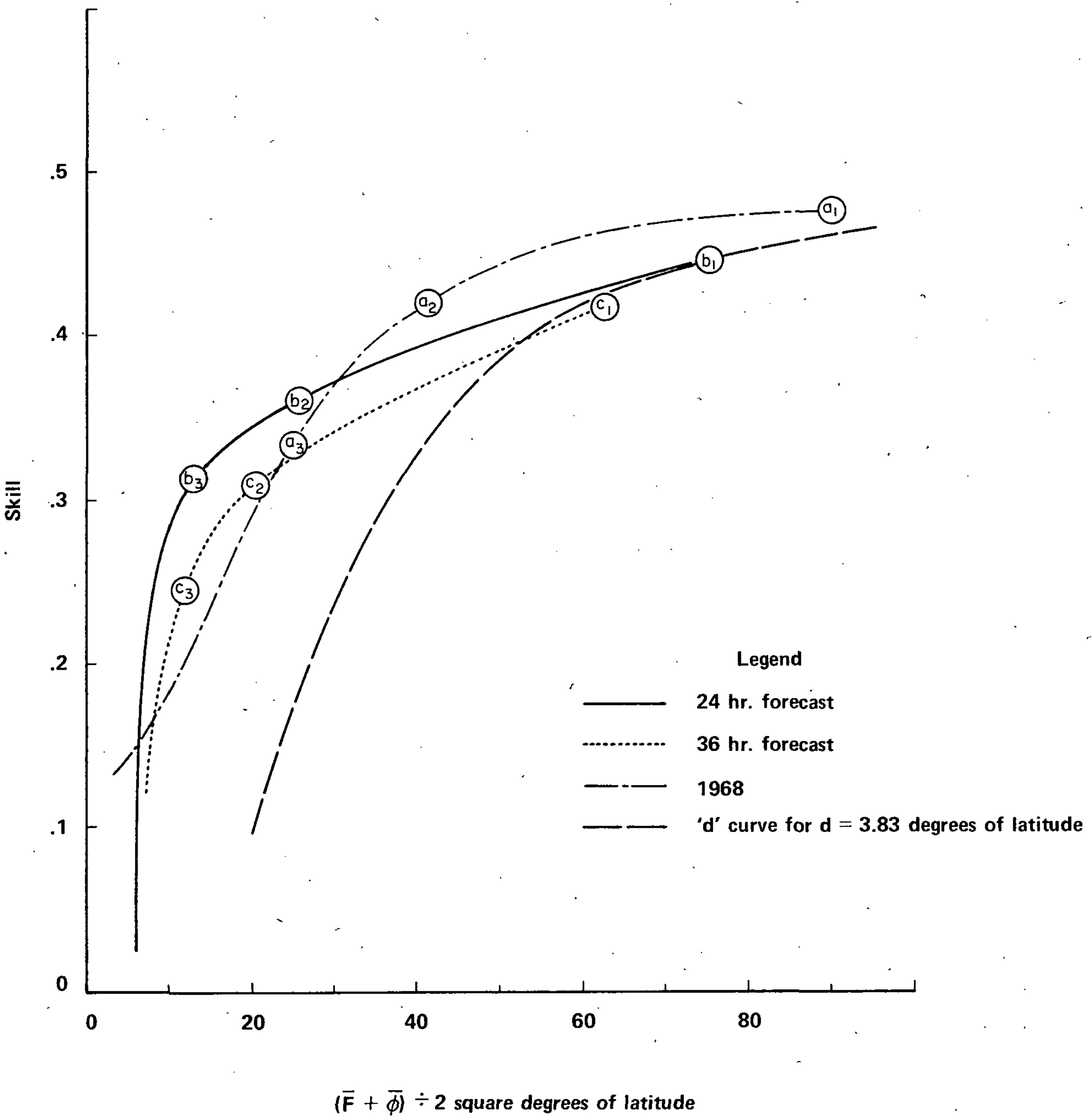


Figure 3B.

Plots of SKILL vs. Z for various d.

$$Z = (\bar{F} + \bar{\phi}) \div 2$$

$$SKILL = (F \cap \phi - Z^2 \div 156) \div (Z - Z^2 \div 156)$$

$$F \cap \phi = (4\sqrt{Z \div \pi} - 2d)\sqrt{Z \div \pi} - \tfrac{1}{4} d^2$$

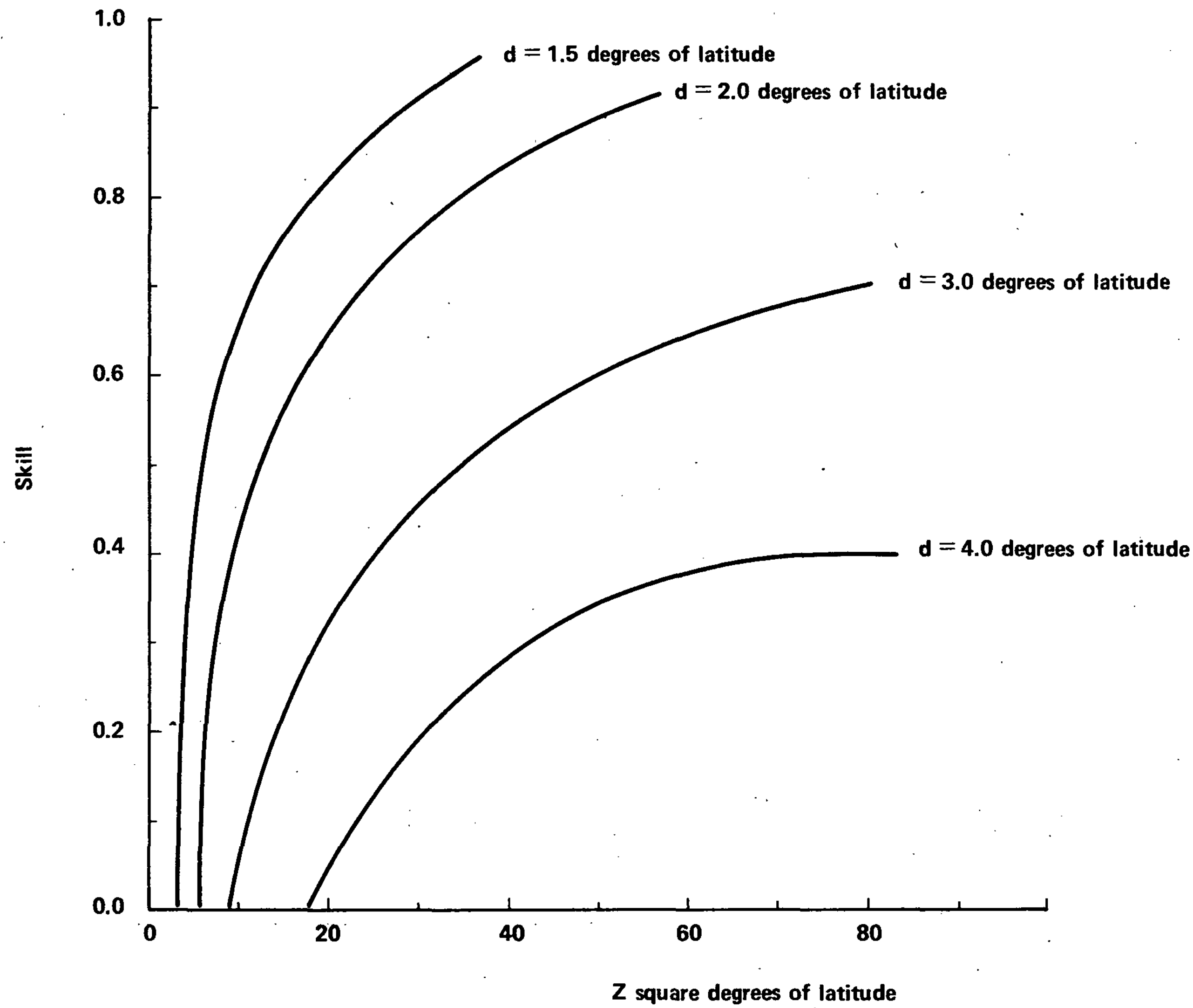
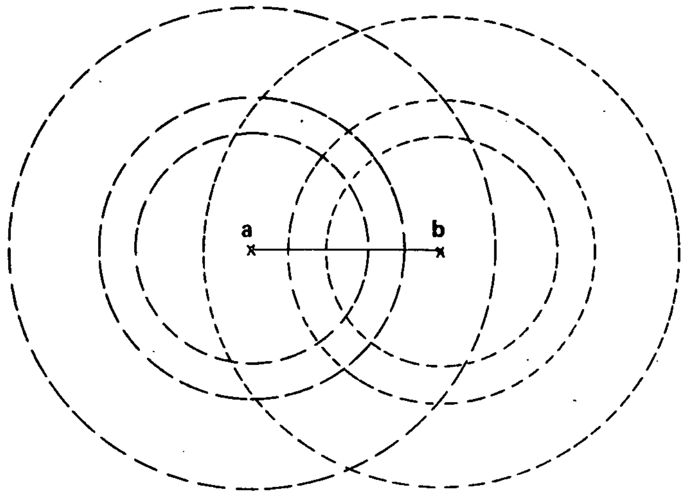


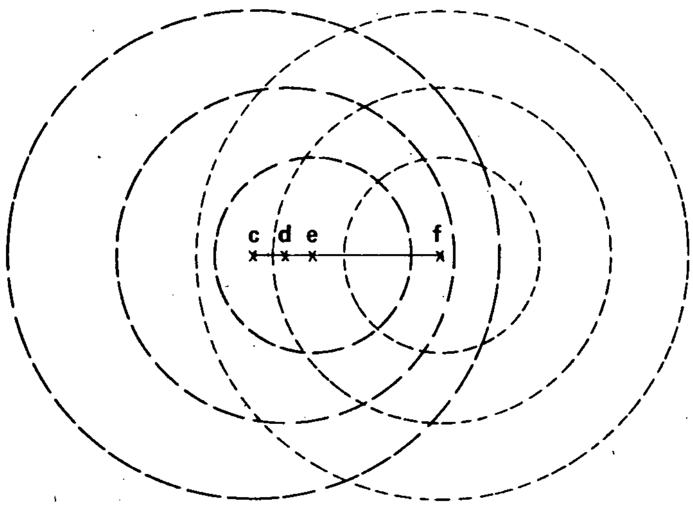
Figure 3C.

Behavior of intercepting circles with decreasing radii at: i) fixed distances apart and ii) decreasing distances.

Situation i.



Situation ii.



Situation iii.

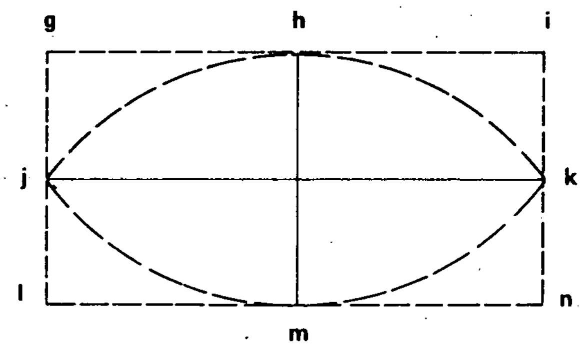
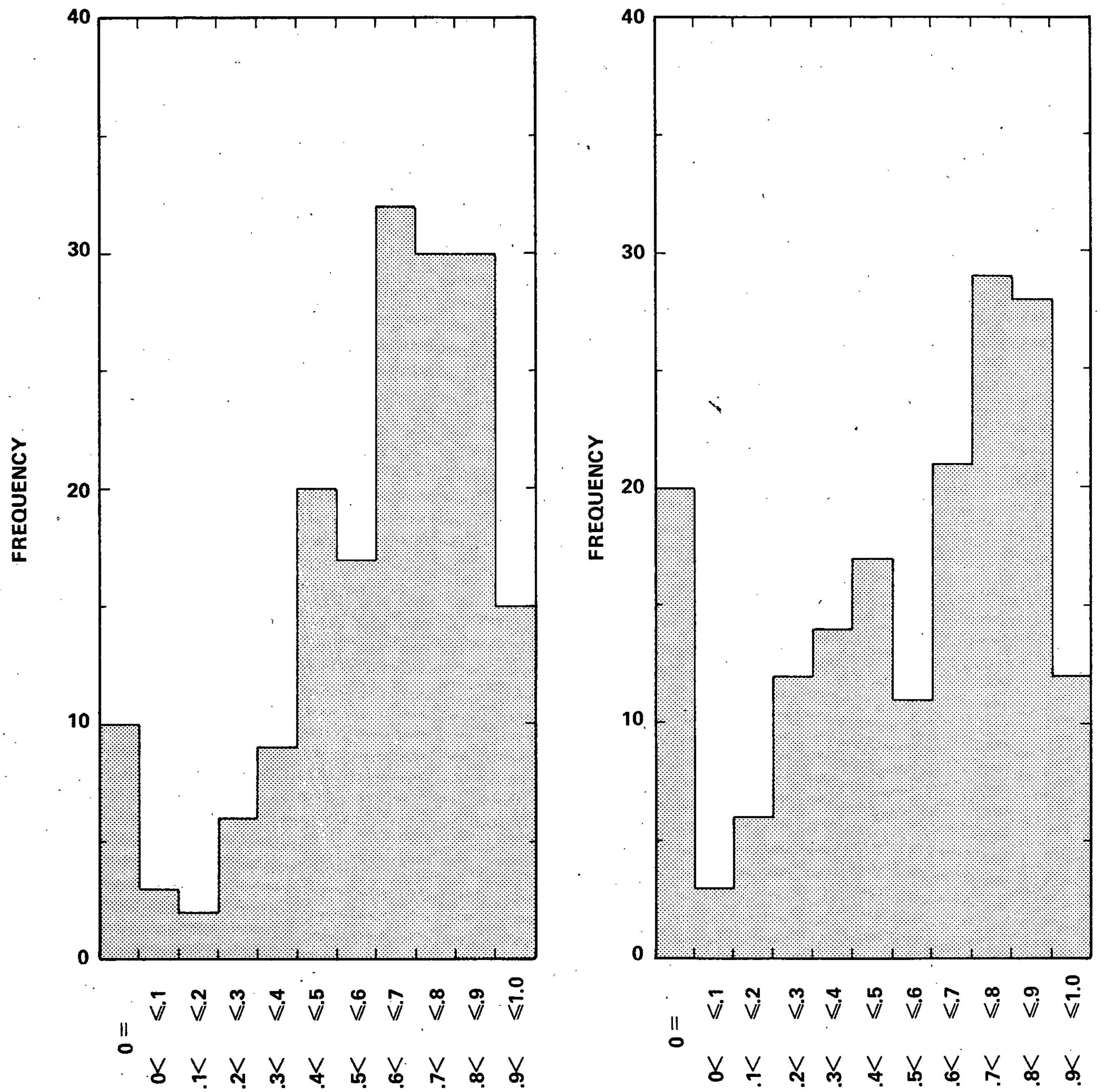


Figure 4A.

FREQUENCY OF OCCURRENCE OF VALUES OF $2\ F \cap \phi \div (F + \phi)$ for .01 inches / 24 hours

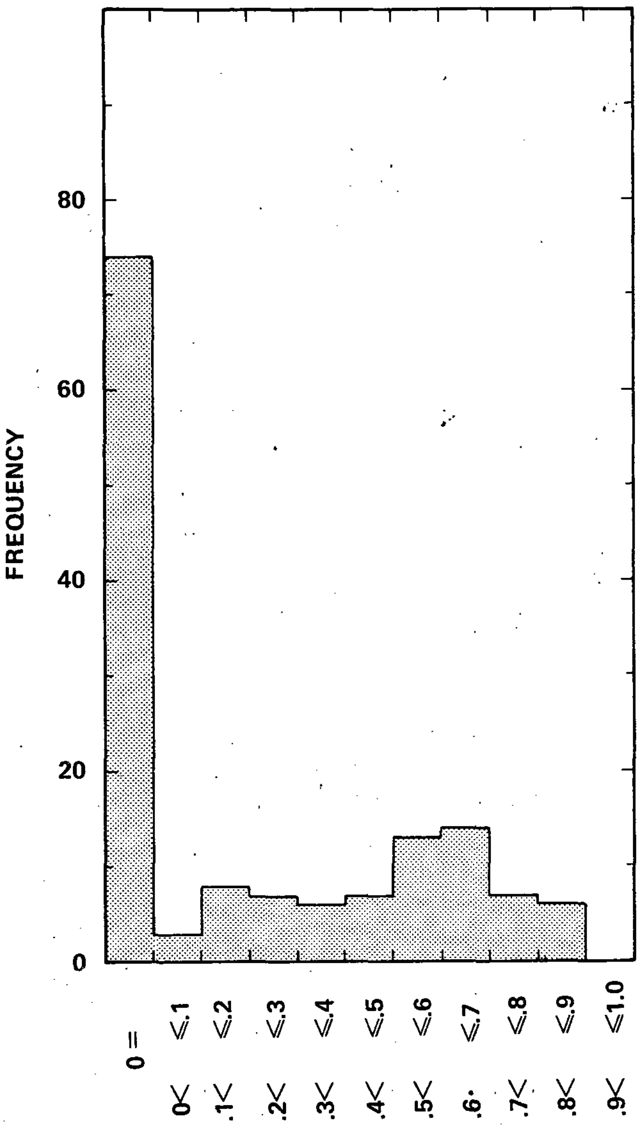


$2\ F \cap \phi \div (F + \phi)$ for 24 hr. progs.

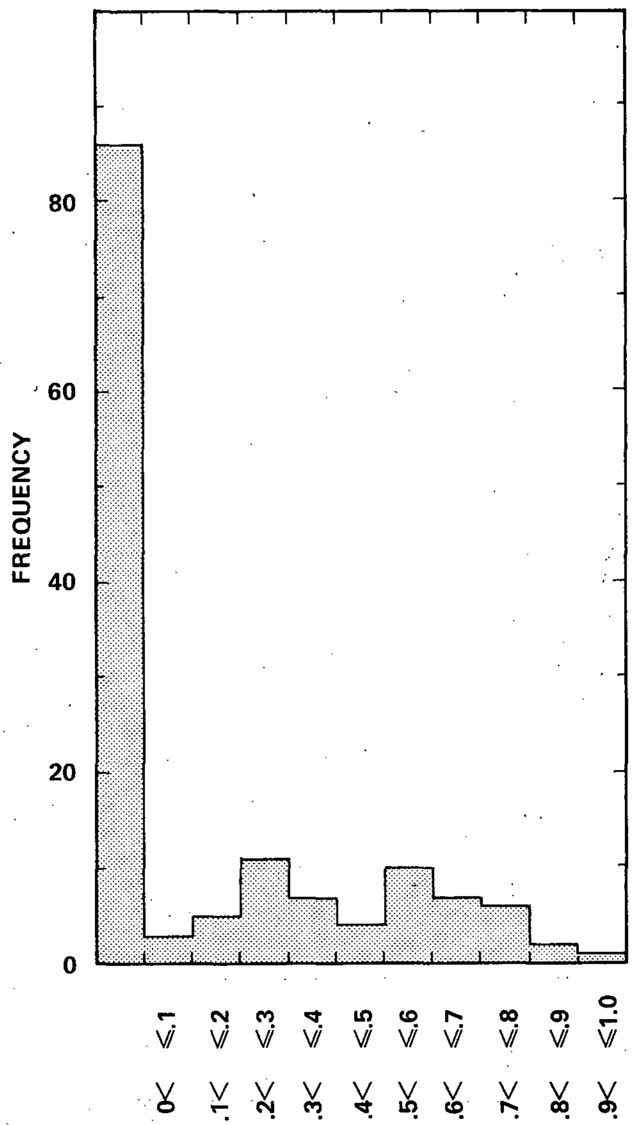
$2\ F \cap \phi \div (F + \phi)$ for 36 hr. progs.

Figure 4B.

FREQUENCY OF OCCURRENCE OF VALUES OF 2 $F \cap \phi \div (F + \phi)$ for .25 inches/ 24 hours



2 $F \cap \phi \div (F + \phi)$ for 24 hr. progs.



2 $F \cap \phi \div (F + \phi)$ for 36 hr. progs.

Figure 5

Scatter diagrams of the positions of maximum observed intensity relative to the position of forecast maximum intensity.

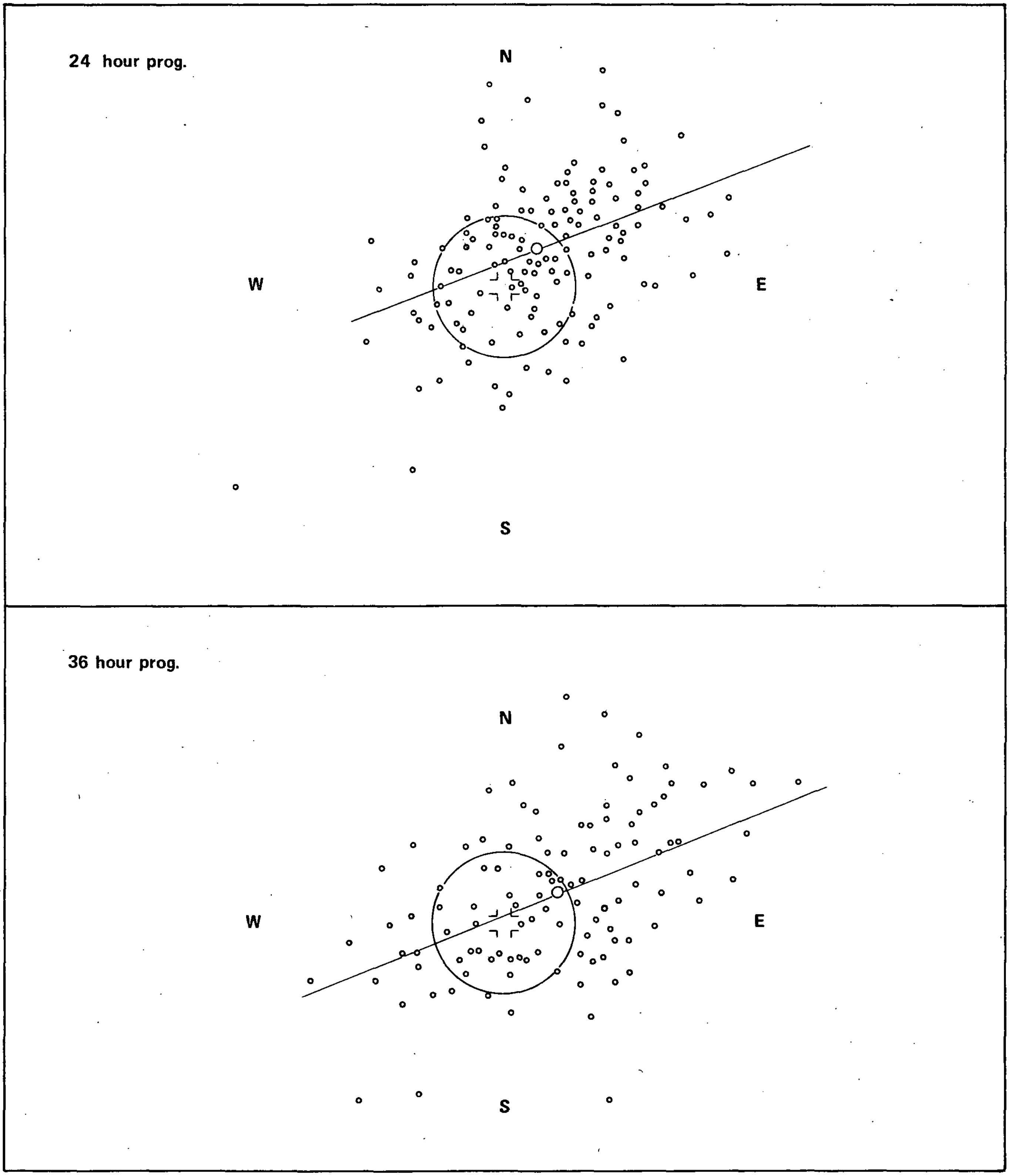
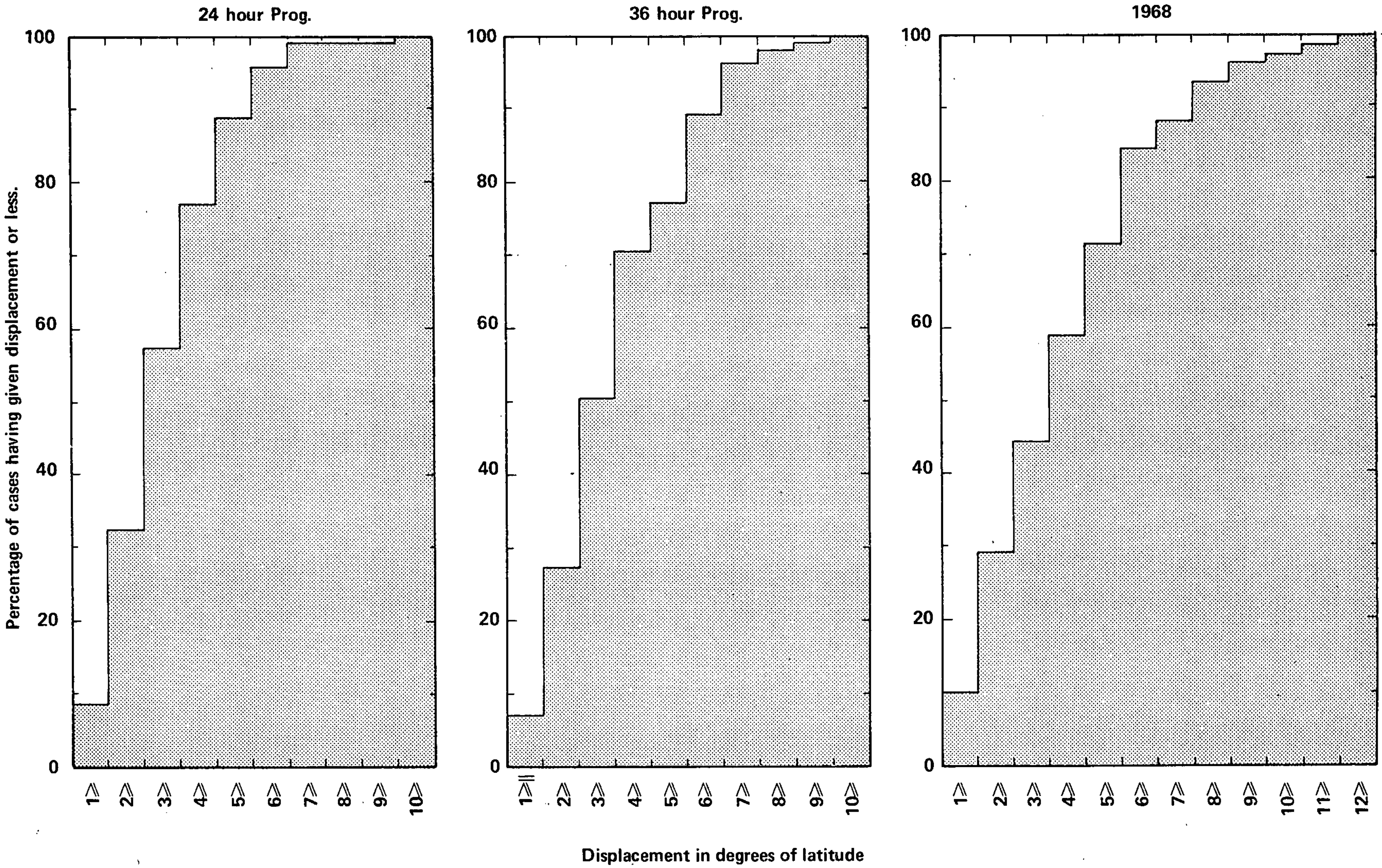


Figure 6

Breakdown of positions of Observed heaviest precipitation relative to Forecast heaviest precipitation by percentage of cases having given displacement or less.



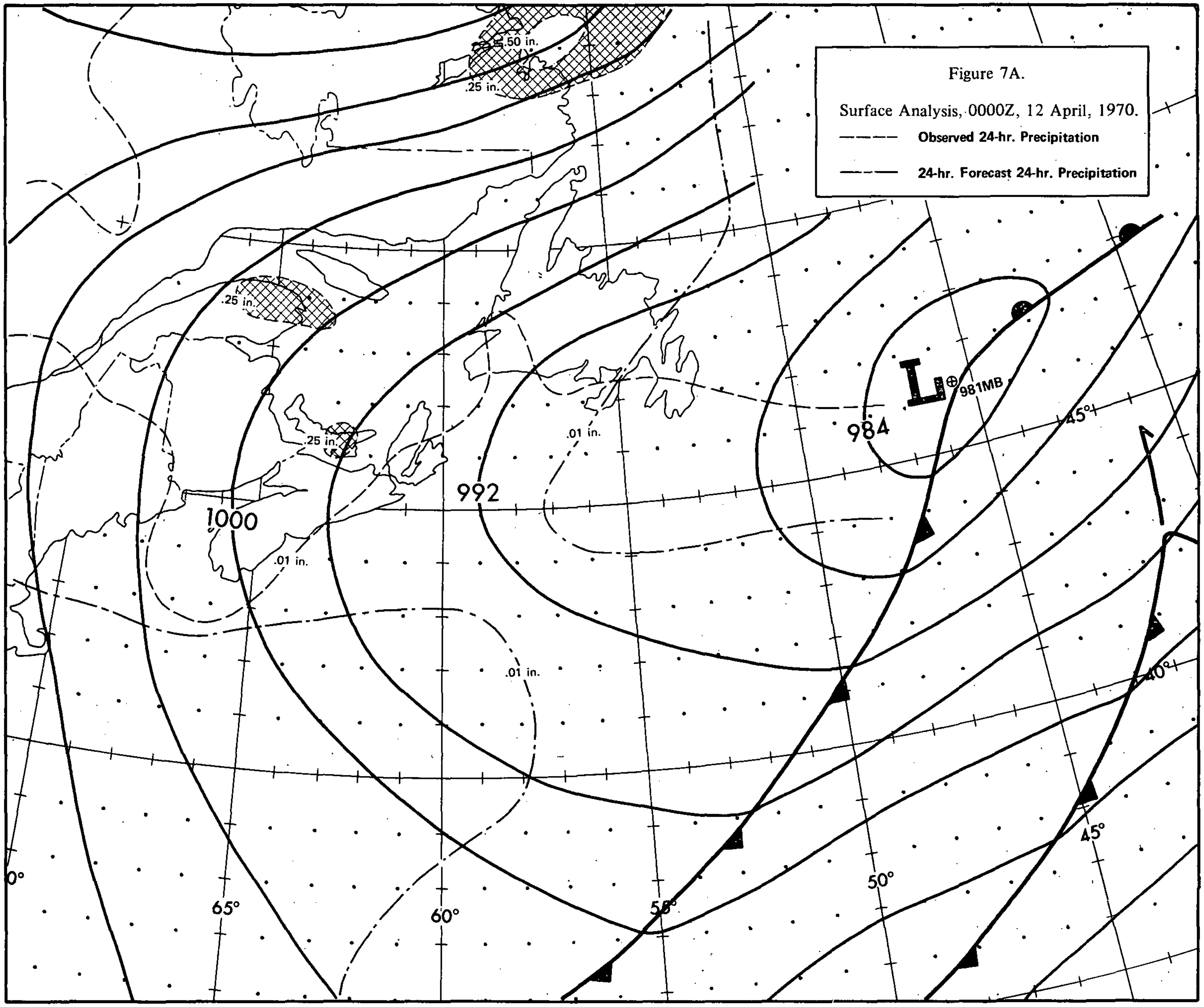


Figure 7A.
Surface Analysis, 0000Z, 12 April, 1970.
Observed 24-hr. Precipitation
24-hr. Forecast 24-hr. Precipitation
.50 in.
.25 in.
.25 in.
.25 in.
.01 in.
.01 in.
.01 in.
981MB
984
992
1000
45°
40°
45°
50°
55°
60°
65°
70°

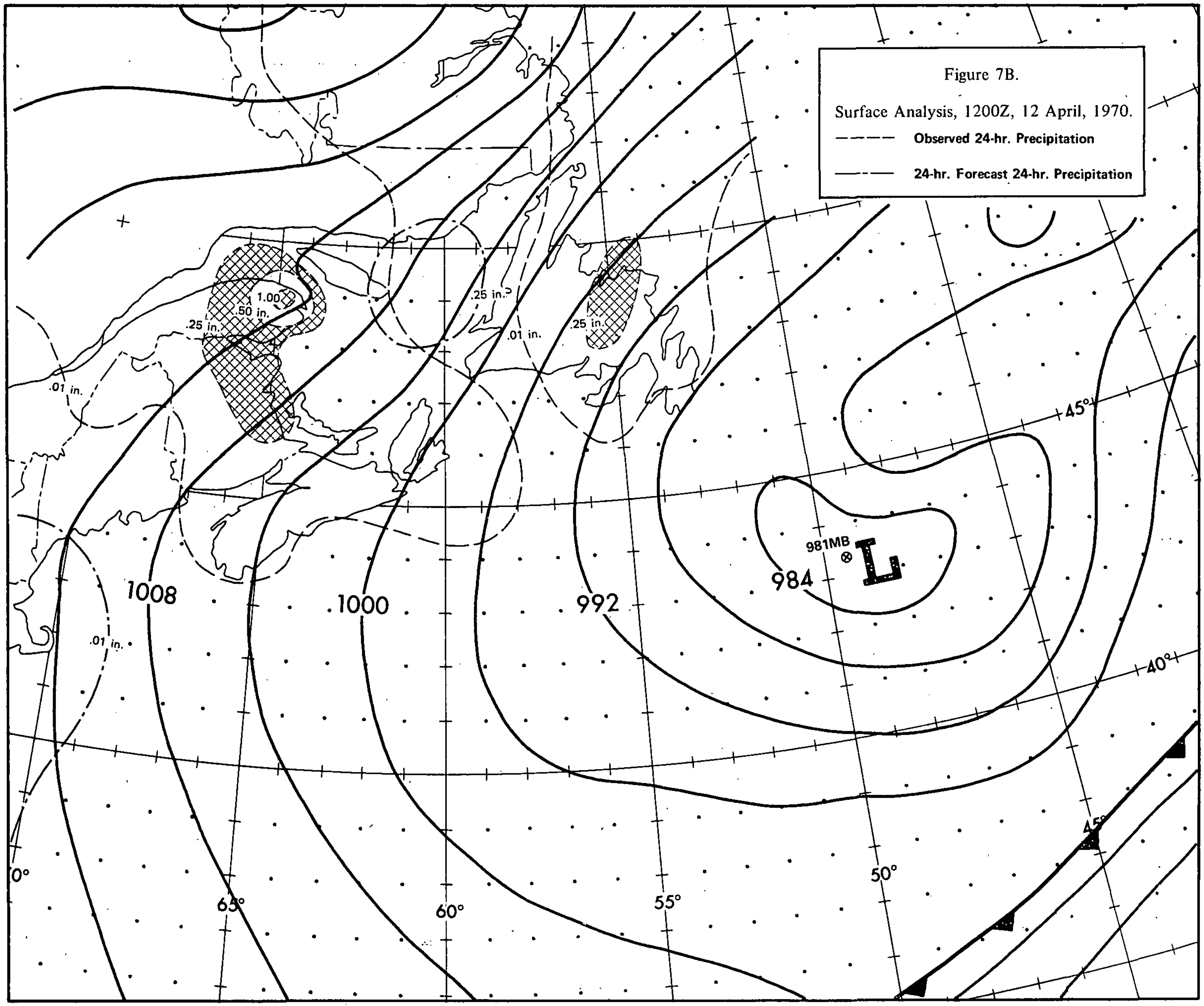


Figure 7B.

Surface Analysis, 1200Z, 12 April, 1970.

------ Observed 24-hr. Precipitation

—·—·— 24-hr. Forecast 24-hr. Precipitation

TABLE I

Average Values of Field Areas (in square degrees of latitude)

		I			II			III		IV			
	Intensity inches/24 hr	a	b	c	a	b	c	a	b	a	b	c	d
		$\overline{F}$ for all cases	$\overline{F}$ for $F \cap \emptyset \neq 0$	$\overline{F}$ for $F \neq 0$ $F \cap \emptyset = 0$	$\overline{\emptyset}$ for all cases	$\overline{\emptyset}$ for $F \cap \emptyset \neq 0$	$\overline{\emptyset}$ for $\emptyset \neq 0$ $F \cap \emptyset = 0$	$\overline{F \cap \emptyset}$ for all cases	$\overline{F \cap \emptyset}$ for $F \cap \emptyset \neq 0$	Total number of cases	Number $F \neq 0$, $\emptyset = 0$	Number $\emptyset \neq 0$, $F = 0$	Number $F, \emptyset \neq 0$, $F \cap \emptyset = 0$
24 hr Prog	.01	84.2	90.0	24.9	64.5	68.6	17.7	52.5	56.6	178	3	6	4
	.25	24.9	48.3	11.7	25.0	41.5	12.0	11.6	24.9	142	8	52	16
	.50	12.6	33.1	5.9	12.5	23.4	7.2	4.6	13.0	112	7	57	8
	1.00	8.4	32.5	10.3	5.9	14.7	4.2	1.6	8.1	60	5	37	6
	2.00	7.8	25.0	3.0	2.6	2.2	3.9	0.36	1.2	14	3	7	0
	3.00	11.0	—	44.0	3.0	—	3.0	0.0	—	4	0	3	1
36 hr Prog	.01	61.7	69.5	16.3	63.7	68.2	34.8	41.2	46.8	185	3	16	3
	.25	16.0	39.2	7.5	25.9	41.5	16.4	8.4	21.0	138	4	75	4
	.50	9.2	31.4	3.4	13.7	24.2	9.7	3.4	12.0	105	2	67	6
	1.00	7.5	35.0	13.3	6.1	14.2	5.2	1.1	7.4	60	4	41	6
	2.00	9.8	33.7	7.2	2.4	2.3	3.7	0.21	1.0	14	4	6	1
	3.00	8.8	—	26.5	2.0	—	3.0	0.0	—	6	2	4	0

TABLE 2

Comparison of Skill Scores and Threat Scores

Intensity inches/24 hr.	Threat Scores			Skill Scores		
	24 hr Prog	36 hr Prog	1968*	24 hr Prog	36 hr Prog	1968*
.01	0.546	0.489	0.630	0.446	0.425	0.477
.25	0.303	0.250	0.425	0.363	0.313	0.420
.50	0.226	0.175	0.267	0.313	0.246	0.332
1.00	0.128	0.090	0.133	0.191	0.128	0.183
2.00	0.036	0.018	0.081	0.046	0.011	0.143
3.00	0.0	0.0	0.0	-0.030	-0.021	0.0

TABLE 3A

Frequencies of Occurrence of Specified Areas for the Intensity .01 inches/24 hr.

24 hour Prog.

Forecast Area in Square Degrees of Latitude

40 80 120

Observed Area (square degrees of latitude) 40 80 120

32	19	4	1
5	27	25	11
	2	19	17
		2	16

36 hour Prog.

Forecast Area in Square Degrees of Latitude

40 80 120

Observed Area (square degrees of latitude) 40 80 120

38	9	2	
21	28	16	2
2	7	18	12
		4	13

TABLE 3B

Frequencies of Occurrence of Specified Areas for the Intensity .25 inches/24 hr.

24 hour Prog.

Forecast Area (In square degrees of latitude)

Observed Area (square degrees of latitude)	0	0–10	10–20	20–40	40–80	80–120	> 120
0	30	20	5	1			
0–10	24	13	4	1	2		
10–20	18	1	1	7	1		
20–40	10	5	3	5	6	4	
40–80	1	3	2	5	9	3	1
80–120					2	1	2

36 hour Prog.

Forecast Area (in square degrees of latitude)

Observed Area (square degrees of latitude)	0	0–10	10–20	20–40	40–80	80–120	> 120
0	35	3		1			
0–10	31	8		1	1		
10–20	23	3	1	2			
20–40	16		2	7	3	1	
40–80	7	1	3	8	5	1	1
80–120					2	1	3

TABLE 3C

Frequencies of Occurrence of Specified Areas for the Intensity .50 inches/24 hr.

24 hour Prog

Forecast Area (in square degrees of latitude)

Observed Area (square degrees of latitude)	0	0–5	5–10	10–20	20–40	40–80	>80
0	66	5	1	1			
0–5	29	5	1	1	1	2	
5–10	13			1	1		
10–20	10	3	1	4	3	2	1
20–40	3	2	1	4	4	3	
40–80					2	2	2

36 hour Prog

Forecast Area (in square degrees of latitude)

Observed Area (square degrees of latitude)	0	0–5	5–10	10–20	20–40	40–80	>80
0	70	2					
0–5	34	1			1	1	
5–10	13			5			
10–20	15		2		2	2	
20–40	8	2		3	1	1	1
40–80	1			1	1	2	2

TABLE 3D

Frequencies of Occurrence of Specified Areas for the Intensity 1.00 inches/24 hr.

24 hour Prog.

Forecast Area (in square degrees of latitude)

Observed Area (square degrees of latitude)	0	0–3	3–10	10–20	20–40	>40
0	115	2	1	2		
0–3	17	1	2		3	1
3–10	16			2		
10–20	4	1	2	2	1	
20–40						3

36 hour Prog.

Forecast Area (in square degrees of latitude)

Observed Area (square degrees of latitude)	0	0–3	3–10	10–20	20–40	>40
0	113	1	1	1		1
0–3	20	1	1	1		2
3–10	14	1				
10–20	6		3		1	1
20–40			1		1	1

TABLE 4

Degree to which Forecast Areas Approximated Observed Areas where Neither F nor Ø Equalled Zero.

	Intensity inches/24 hr.	Number of cases considered	Number where $F \geq 4/3\,\emptyset$	Number where $F \leq 2/3\,\emptyset$	%age where $F \geq 4/3\,\emptyset$	%age where $F \leq 2/3\,\emptyset$	%age of cases where $4/3\,\emptyset > F > 2/3\,\emptyset$
24 hour prog.	.01	169	74	10	43.8	5.9	50.3
	.25	82	36	22	43.9	26.8	29.3
	.50	48	21	13	43.7	27.1	29.2
	1.00	18	14	2	77.8	11.1	11.1
	2.00	4	3	0	75.0	0.0	25.0
	3.00	1	1	0	100.0	0.0	0.0
36 hour prog.	.01	166	42	26	25.3	15.7	59.0
	.25	59	22	24	37.3	40.7	22.0
	.50	36	15	14	41.7	38.9	19.4
	1.00	15	8	6	53.3	40.0	6.7
	2.00	4	3	0	75.0	0.0	25.0
1968	.01	73	33	5	45.2	6.8	48.0
	.25	34	14	6	41.2	17.6	41.2
	.50	23	8	8	34.8	34.8	30.4
	1.00	9	6	2	66.7	22.2	11.1
	2.00	1	1	0	100.0	0.0	0.0

TABLE 5

Averages of $F \cap \emptyset \div (F, \emptyset, \text{ and } 1/2F + 1/2\emptyset)$ Excluding Cases where $F \cap \emptyset = 0$

	24 hour Prog			36 hour Prog.			1968
Intensity inches/24 hr	average value of: $\frac{F \cap \emptyset}{F}$	$\frac{F \cap \emptyset}{\emptyset}$	$2\frac{F \cap \emptyset}{F + \emptyset}$	average value of: $\frac{F \cap \emptyset}{F}$	$\frac{F \cap \emptyset}{\emptyset}$	$2\frac{F \cap \emptyset}{F + \emptyset}$	average value of: $2\frac{F \cap \emptyset}{F + \emptyset}$
.01	.600	.792	.626	.639	.657	.568	.630
.25	.553	.632	.544	.573	.519	.492	.618
.50	.469	.489	.400	.475	.429	.318	.454
1.00	.364	.530	.378	.361	.599	.234	.378
2.00	.286	.696	.124	.191	.733	.066	.308

TABLE 6

(Complement to Figures 4A and 4B)

Frequencies of Occurrence of Values of $2(F \cap \emptyset) - (F + \emptyset)$ for Precipitation Intensities of .50 inches/24 hr., 1.00 inches/24 hr., and 2.00 inches/24 hr. (x)

	Intensity inches/24 hr.	Values of $2(F \cap \emptyset) - (F + \emptyset)$: $x = 0$	$0 < x \leq .1$	$.1 < x \leq .2$	$.2 < x \leq .3$	$.3 < x \leq .4$	$.4 < x \leq .5$	$.5 < x \leq .6$	$.6 < x \leq .7$	$.7 < x \leq .8$	$.8 < x \leq .9$	$.9 < x \leq 1.0$
for: 24-hr Prog.	.50	71	7	4	3	4	3	8	3	4	1	1
	1.00	48	3	2	1	1	2	1	1	1		
	2.00	10	1	1	1							
for: 36-hr Prog.	.50	77	7	4	4	2	2	4	3	1	1	
	1.00	52	2	2	1	1		2				
	2.00	12	2									

TABLE 7

Frequencies of Occurrence of Maximum Forecast Precipitation Intensities with Maximum Observed Precipitation Intensities

24 hour Prog.

Maximum Forecast Intensity (inches/24 hr.)

Maximum Observed Intensity (inches / 24 hr.)	0	.01	.25	.50	1.00	2.00	3.00
0		2	1				
.01	6	21	4	3			
.25		22	9	4			
.50		23	15	5	4	1	
1.00		8	8	17	9	2	
2.00		1	2	1	1	4	1
3.00					1		

36 hour Prog.

Maximum Forecast Intensity (inches/24 hr.)

Maximum Observed Intensity (inches / 24 hr.)	0	.01	.25	.50	1.00	2.00	3.00
0	1	2					
.01	8	23	3	1			
.25	1	27	6	1			
.50	3	27	7	3	2	2	
1.00	3	16	13	7	5	2	
2.00			2	1	2		3
3.00					1	1	

TABLE 8

Usefulness of Q.P.F. as an Indication of Maximum Intensity of Precipitation.

COMMENT	Difference between maximum Forecast and maximum Observed precipitation. inches / 24 hr. (x)	percentage of 24-hr Progs.	percentage of 36-hr Progs.	percentage of 1968 Progs.
Essentially Correct	$x \leqslant .01$	32.0	27.8	18.1
Useful Estimate	$.01 < x \leqslant .50$	53.1	45.6	33.8
Limited Usefulness	$.50 < x \leqslant 1.00$	11.4	23.1	24.7
Little Value	$1.00 < x \leqslant 2.00$	3.5	3.5	11.7
Little Value	$2.00 < x$	0.0	0.0	11.7

TABLE 9 A&B

Positions of Maximum Observed Intensity Relative to Maximum Forecast Intensity as Percentages of Cases Occurring within Certain Intervals.

TABLE 9A Absolute displacement in degrees of latitude (x)

	$0 \leqslant x \leqslant 1$	$1 < x \leqslant 2$	$2 < x \leqslant 3$	$3 < x \leqslant 4$	$4 < x \leqslant 5$	$5 < x \leqslant 6$	$6 < x \leqslant 7$	$7 < x \leqslant 8$	$8 < x$
24 hr Prog.	8.9	23.7	25.2	19.3	11.8	6.7	3.7	0.0	0.7
36 hr Prog.	7.1	20.6	23.2	19.6	7.2	11.6	7.1	1.8	1.8
1968	10.3	19.2	15.4	14.1	12.8	12.8	3.8	5.1	6.5

TABLE 9B Relative displacement West or East and North or South in degrees of latitude (x)

		$x \leqslant -7$	$-7 < x \leqslant -5$	$-5 < x \leqslant -3$	$-3 < x \leqslant -1$	$-1 < x \leqslant 1$	$1 < x \leqslant 3$	$3 < x \leqslant 5$	$5 < x \leqslant 7$	$7 < x$
West-East	24 hr Prog.	0.8	0.0	3.0	13.3	33.3	31.8	13.3	4.5	0.0
	36 hr Prog.	0.0	0.9	4.6	12.5	25.0	30.3	19.6	6.2	0.9
	1968*	1.3	0.0	9.0	21.8	28.2	20.5	10.2	7.7	1.3
South-North	24 hr Prog.	0.0	1.5	0.7	15.6	31.1	37.8	9.6	3.7	0.0
	36 hr Prog.	0.0	0.0	2.7	14.3	36.6	26.8	16.9	2.7	0.0
	1968*	2.6	6.4	10.2	21.8	30.8	15.4	9.0	3.8	0.0

References

1. Tyner, R. V., 1968: Evaluation of Quantitative Precipitation Forecasts in the Atlantic Provinces. Canada, Department of Transport, Meteorological Branch, Technical Memoranda Series, TEC-687.

2. Davies, D., and M. Olson, 1968: Operational Forecasts of 24-hour Precipitation Amount from the Central Analysis Computer. Canada, Department of Transport, Meteorological Branch, Technical Memoranda Series, TEC-670.

3. Miyakoda, H., J. Smagorinsky, R. F. Strickler, and G. D. Hembree, 1969: Experimental Extended Predictions with a Nine-level Hemispheric Model. Monthly Weather Review, Vol. 97. No. 1.

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