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CANADA

DEPARTMENT OF TRANSPORT

METEOROLOGICAL BRANCH

Technical Memoranda

EVALUATION OF SURFACE PROGNOSTIC CHARTS FOR THE ATLANTIC PROVINCES AND WESTERN NORTH ATLANTIC FOR A WINTER SEASON

by

R.V. TYNER

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CANADA - DEPARTMENT OF TRANSPORT - METEOROLOGICAL BRANCH
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EVALUATION OF SURFACE PROGNOSTIC CHARTS FOR THE ATLANTIC PROVINCES AND WESTERN NORTH ATLANTIC FOR A WINTER SEASON

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ABSTRACT

A comparison of the accuracy of the surface isobaric prognostic charts prepared by the Central Analysis Office, Montreal, and by the Atlantic Weather Central, Halifax, is carried out for the period 1 November 1968 to 28 February 1969 over the area of forecast responsibility of the Atlantic Weather Central.

EVALUATION DES CARTES DE SURFACE PREVUES POUR LES PROVINCES DE L'ATLANTIQUE ET L'OUEST DE L'ATLANTIQUE NORD PENDANT L'HIVER

par

R.V. Tyner

RESUME

L'auteur compare l'exactitude des cartes de surface isobare prévues, préparées par le Bureau central d'analyse de Montréal et le Centre météorologique de la région de l'Atlantique d'Halifax, du 1er novembre 1968 au 28 février 1969, pour la région de prévision qui relève du Centre météorologique de la région de l'Atlantique.

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(Manuscript received September 8, 1969)

1. INTRODUCTION

An earlier evaluation of the surface prognostic charts for the Atlantic Provinces and western North Atlantic (1), carried out from 7 May to 8 August 1968, showed that the Atlantic Weather Central (At. W. C.) added little or nothing to the accuracy of the surface isobaric prognostic charts produced by the Central Analysis Office (CAO).

The previous evaluation (1) was carried out during the late spring and early summer of 1968, an unusually quiet period as far as storm development in the verification area was concerned. It was considered that a further analysis of the surface isobaric prognostic charts prepared by the two offices during a winter season was required before a definite conclusion could be reached concerning the value of the contribution made by the At. W. C. to the accuracy of the prognostic product made available to Weather Offices in the Atlantic Region. Accordingly, at the request of the Regional Meteorologist, Mr. C. E. Stevens, the study was undertaken for the winter of 1968-69. It covers the period from 1 November 1968 to 28 February 1969.

As in the previous analysis, the At. W. C. surface isobaric prognostics were verified against the final surface analyses prepared at the At. W. C.; the CAO prognostics were verified against the final surface analyses prepared at the CAO.

Unfortunately, as far as this study was concerned, several regrettable changes in the nature of the prognostic material received at the At. W. C. forced some modifications in the original plan. It was hoped to carry out, over a period of some months, as a concurrent verification study, an evaluation of the ESSA PE computer-produced surface isobaric prognostic charts in order to determine the impact of those prognostics on those prepared by the At. W. C. and the CAO. In late November 1968 the chart size of the PE prognostic relayed on the national facsimile circuit

was so much reduced that almost fifty per cent of the evaluation area was no longer transmitted; this section of the verification program was therefore abandoned after the analysis of only 41 cases. In December the CAO revised its program and began providing prognostic charts 36 and 42 hours from datum time instead of 30 and 36 hours from datum time. Thus the period over which comparison of the prognostic charts valid for 30 hours and for 42 hours was greatly curtailed, approximately 100 of the 30-hour prognostics and 40 of the 42-hour prognostics being available for study as compared to 165 of the 36-hour prognostics.

As in the previous study, pressure gradients were evaluated by a method based on that of Teweles and Wobus (2), over an overlapping grid having grid points chosen at intervals of 5 degrees latitude and 5 degrees longitude, and covering an area from 30°W to 70°W and from 60°N to 35°N (1). Evaluation of the At. W. C. and CAO prognostics was also carried out with respect to:

(a) accuracy of forecasts of locations and depths of surface low pressure centres;

(b) accuracy of forecasts of deepening or filling of low pressure centres;

(c) success of prognostics in predicting the formation of new centres.

2. VERIFICATION SCORES

The statistic used as a score for the accuracy of the forecast pressure gradient,

$$S = 100 \frac{\sum |e_g|}{\sum |G_L|} ,$$

where e_g is the error in the forecast pressure gradient, and G_L the larger of the observed or forecast pressure gradient gives a score varying between zero and 200, with zero implying a perfect forecast.

Verification scores were obtained for the At. W. C. prognostics for 30 hours, and for the CAO prognostics for 30 hours (100

examples), 36 hours (165 examples) and 42 hours (40 examples). Values of the mean, standard deviation, and standard error of the mean are set out in Table 1A. Values of these statistics for the verification scores of the 36-hour PE prognostics (41 examples) and the corresponding 30-hour At. W. C. prognostics and 36-hour CAO prognostics are set out in Table 1B.

Table 1A

	Prognostic Charts					
Statistic	CAO 30 hrs.	At. W. C. 30 hrs.	CAO 36 hrs.	At. W. C. 30 hrs.	CAO 42 hrs.	At. W. C. 30 hrs.
Mean	52.1	53.3	58.6	56.7	63.5	57.7
Standard Deviation	11.0	10.1	10.9	10.7	12.1	9.4
Standard Error of the Mean	1.1	1.0	.85	.84	1.9	1.5

Table 1B

	Prognostic Charts		
Statistic	PE (36 hr)	At. W. C. (30 hr)	CAO (36-hr)
Mean	52.7	53.6	54.8
Standard Deviation	8.0	8.3	11.6
Standard Error of the Mean	1.25	1.3	1.8

The distributions of the verification scores for the CAO 30- and 36-hour prognostics and for the At. W. C. 30-hour prognostics with which they have been compared are displayed in Figures 1A, 1B.

All of these distributions are approximately normal and show some positive skewness. Since the distributions of the scores for the CAO 30-hour and 36-hour prognostics and for the 30-hour

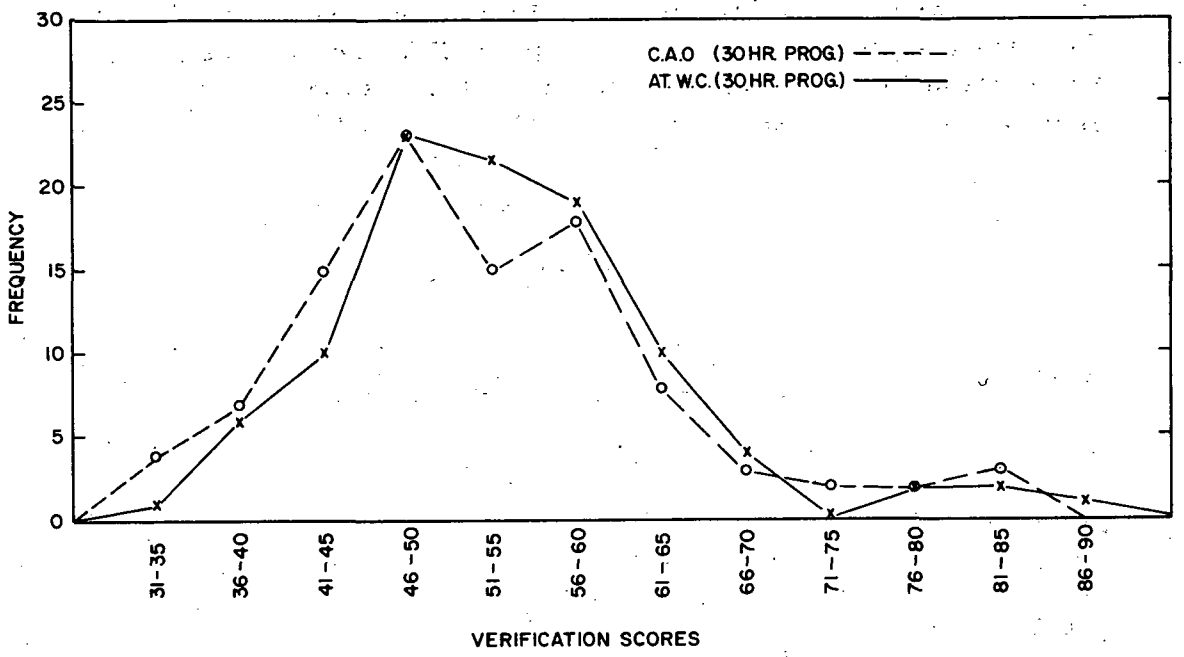

Figure 1A
Frequency Distributions

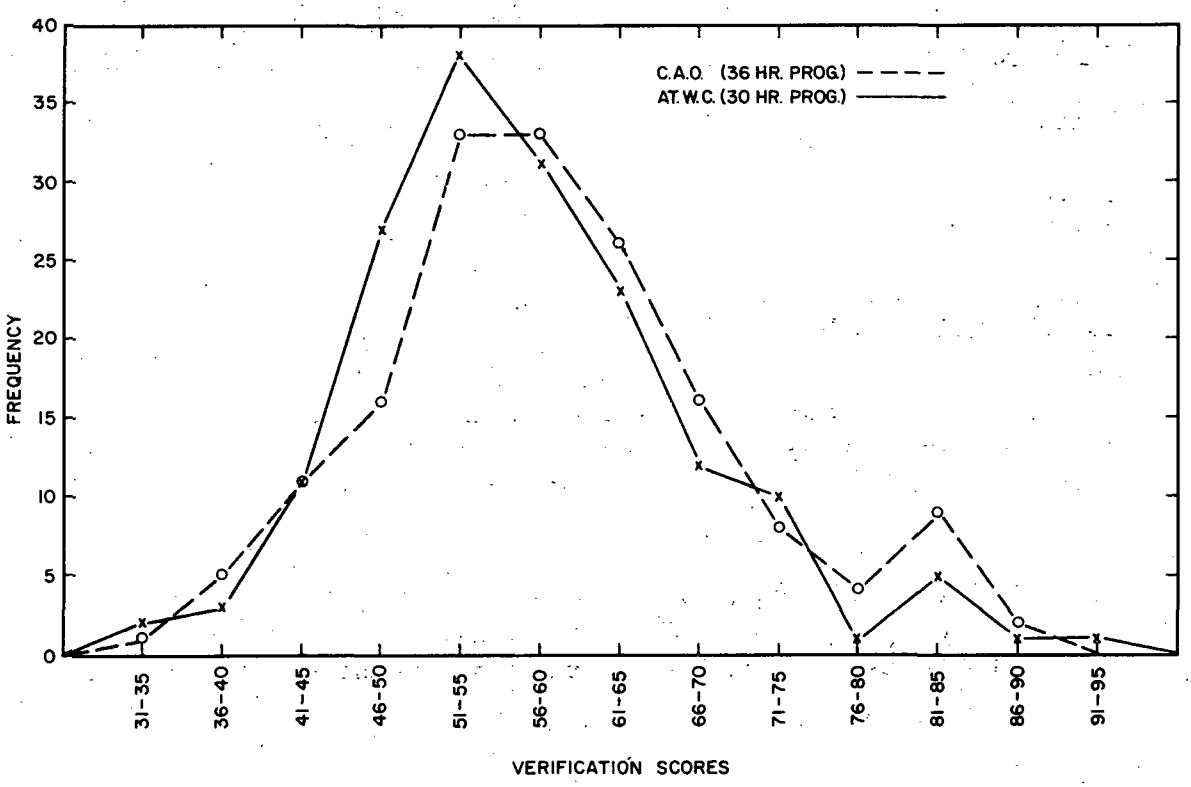

Figure 1B
Frequency Distributions

At. W. C. prognostics which were compared with them are approximately normal, we may assume that the central limit theorem applies and, for these comparatively large samples, that the values of the sample standard deviations approximate the true standard deviations. We then test for significance of differences between the means using the "t" statistic (3). For the comparison of the 30-hour CAO prognostics with the 30-hour At. W. C. prognostics the value of "t" = 1.49, i.e., less than $t_{.05,\infty}$; hence, it must be concluded that there is no significant difference between the means at the 5% confidence level.

For the comparison of the 36-hour CAO prognostics with the 30-hour At. W. C. prognostics, the value of "t" = 1.6., i.e., also less than $t_{.05,\infty}$, indicating no significant difference between the means at the 5% confidence level.

CORRELATION

Correlation coefficients for the comparison of scores for the CAO 30-hour prognostics with the At. W. C. 30-hour prognostics, and for the comparison of the 36-hour CAO prognostics with the 30-hour At. W. C. prognostics were determined, with the coefficient obtained in the usual manner (1). In the first comparison r = +.57; in the second r = +.7. These are both much above the value of the coefficients at a significance level of 5% for uncorrelated populations of the same size (4).

Least squares regression equations for these approximately normal distributions were obtained using the expression:

$$y = m_2 + \frac{r\,\sigma_2}{\sigma_1}(x - m_1) \qquad (5)$$

where $m_2 = \bar{y}$, $m_1 = \bar{x}$, $\sigma_2 = \sigma_y$, $\sigma_1 = \sigma_x$,

r = correlation coefficient.

For the comparison of the 30-hour CAO with 30-hour At. W. C. prognostics, the regression equations thus obtained with

$m_2 = 53.3$ $\quad \sigma_2 = 10.1$

$m_1 = 52.1$ $\quad \sigma_1 = 11.0$

$r = .57$

are

$$\begin{cases} y = 26.2 + .52x \\ x = 19.1 + .62y. \end{cases}$$

For the comparison of the 36-hour CAO with the 30-hour At. W. C. prognostics, with

$$m_2 = 56.7 \qquad \sigma_2 = 10.7$$

$$m_1 = 58.6 \qquad \sigma_1 = 10.9$$

$$r = .7$$

the regression equations are

$$\begin{cases} y = 16.3 + .69x \\ x = 28.4 + .7y. \end{cases}$$

Regression lines for these equations are shown in Fig. 2.

ANALYSIS OF THE INDIVIDUAL SCORES

An examination of the paired verification scores of the At. W. C. prognostics and the 30-hour and 36-hour CAO prognostics and the 36-hour PE prognostics was carried out to determine the number of occasions when one prognostic scored 5 or more, and 10 or more, points better than the other. The results of this examination appear in Table 2.

Table 2.

Prognostics	No. of Examples	No. of Prognostics Scoring 5 or More Points above the Other	No. of Prognostics Scoring 10 or More Points above the Other
CAO 30-hr.	100	31	18
At. W. C. 30-hr.	100	26	11
CAO 36-hr.	164	34	19
At. W. C. 30-hr.	164	57	26
PE 36-hr.	41	13	9
At. W. C. 30-hr	41	12	4

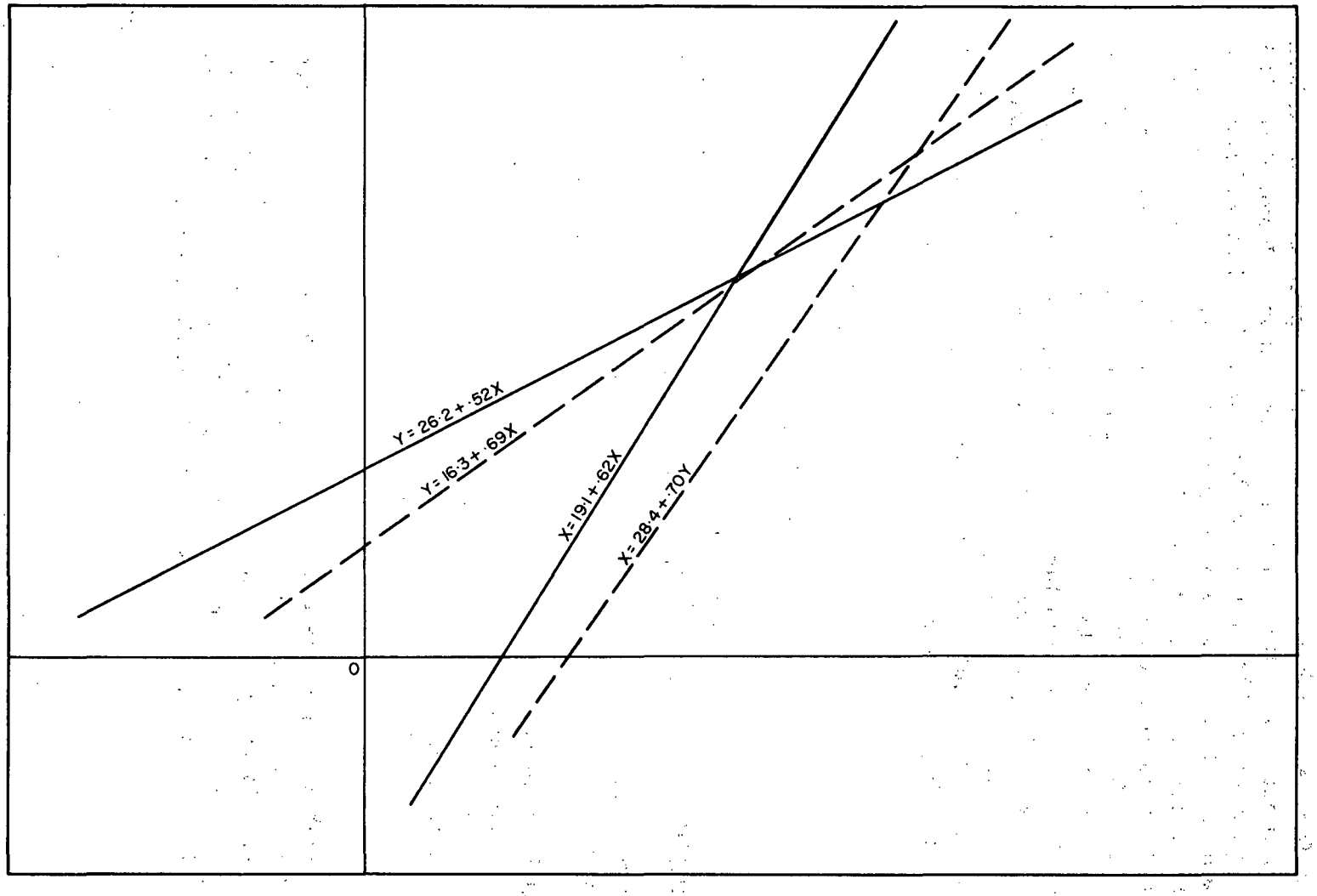

Figure 2
Regression Lines: C.A.O. and At.W.C. Verification Scores

36-HOUR DEEPENING OF SURFACE LOWS

On each At. W. C. 30-hour prognostic chart, predicted 36-hour locations and depths of pressure centres are indicated. The forecast 36-hour changes in central pressures of surface lows appearing in the verification area from 1 November 1968 to 28 February 1969 were compared with the observed pressure changes of those lows. Forecast charts prepared by the At. W. C. were verified against the At. W. C. surface analyses; forecast charts prepared by the CAO were verified against the CAO analyses. In this comparison, 271 examples of lows appeared on the charts prepared by the CAO, 273 on the charts prepared by the At. W. C. Values of the mean of the absolute error, standard deviation of the distribution of the absolute error, and standard error of the mean for 36-hour forecast deepening are set out in Table 3. Distributions of the absolute forecast errors of the 36-hour deepening appear in Figure 3.

Table 3.

Statistic	Deepening Error in CAO 36-hr Forecast	Deepening Error in At. W. C. 36-hr Forecast
Mean of Absolute Error	8.0	9.0
Standard Deviation of the Distribution	6.9	7.6
Standard Error of the Mean	.42	.46

36-hour forecasts of deepening in error by 12 mb. or more numbered 67 for the prognostics prepared by the CAO, 76 for the prognostics prepared by the At. W. C. Forecasts of 36-hour deepening of lows which were in error by 24 mb. or more numbered 8 in the CAO prognostics, 18 in the At. W. C. prognostics.

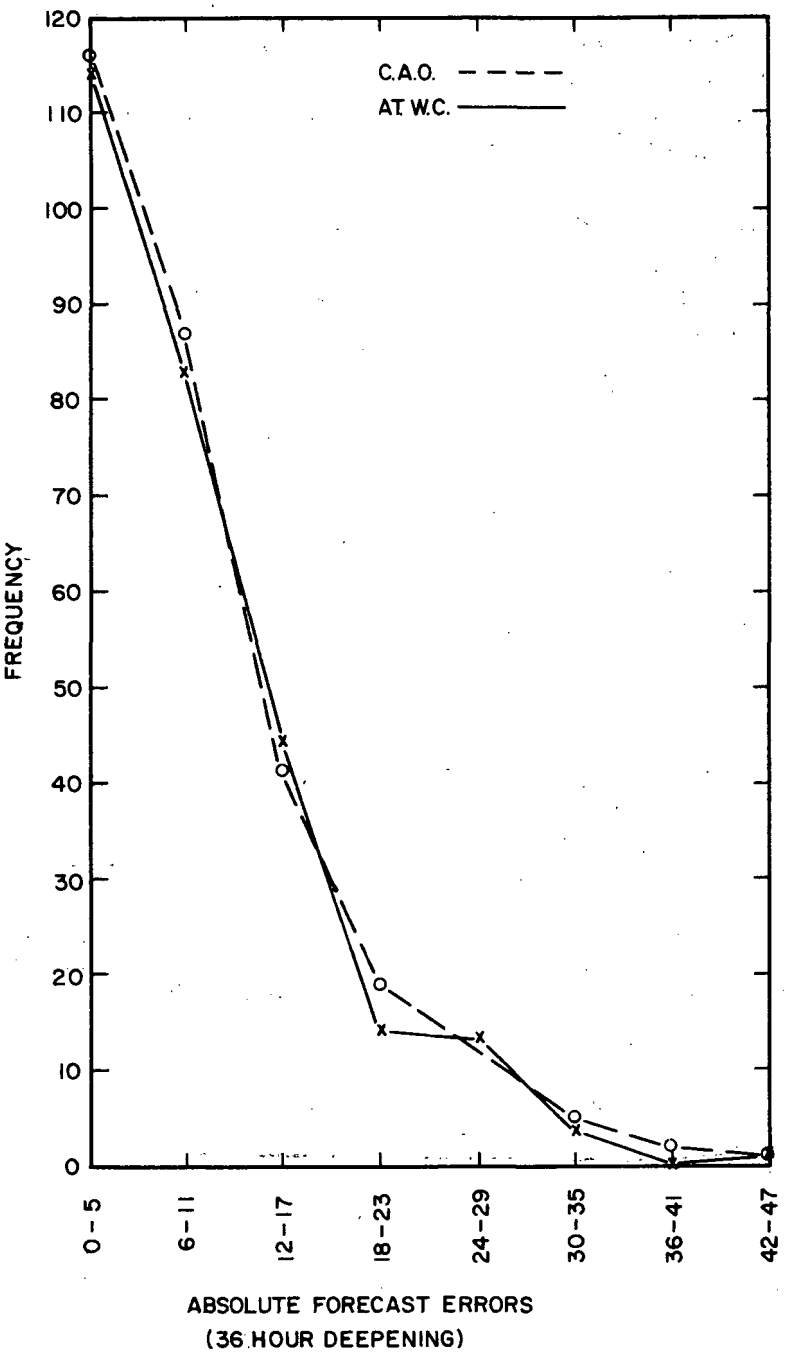

Figure 3
Frequency Distributions

With the CAO 36-hour prognostics there were 12 occasions when filling was forecast and deepening occurred with a resulting forecast-deepening error of 16 mbs. or more, and with the At. W. C. 36-hour prognostics also 12 such occasions.

For those occasions where deepening was forecast, but where the observed deepening was 12 mbs. or more greater than that forecast, 27 examples appeared in the CAO prognostics, 36 examples in the At. W. C. prognostics.

The prognostic charts were examined to determine the success of the forecasts in predicting lows which were actually observed in the forecast area. The results of this examination are set out in Table 4.

Table 4.

	Lows Observed		Lows Not Observed	
	CAO	At. W. C.	CAO	At. W. C.
Lows Forecast	271	273	33	43
Lows Not Forecast	115	148		

The discrepancy in the total number of lows observed appearing in the CAO and At. W. C. columns in the table arises from the use of the CAO analyses to verify the CAO prognostics, and of the At. W. C. analyses to verify the At. W. C. prognostics.

ERRORS IN FORECAST DEPTH AND DISPLACEMENT OF SURFACE LOWS

The forecast depths of all lows appearing on the 30-hour At. W. C. prognostics and on the 36-hour CAO prognostics were compared with the observed depths of those centres on the verifying surface analyses. An error was considered as negative if the forecast pressure was lower than that observed, positive if the forecast pressure was higher.

The mean of the absolute errors in depth, mean depth error taking regard to sign, and standard deviation of the signed error distribution for the forecast centres of lows appearing in the forecast area on the At. W. C. and CAO prognostics, are set out in Table 5.

Table 5.

Depth Errors in Forecasts of Lows

Statistic	CAO (36-hr prog)	At. W. C. (30-hr prog)
Mean of Absolute Errors	7.6 mb.	8.0 mb.
Mean of Signed Errors	1.5 mb.	1.5 mb.
Standard Deviation of Signed Error Distribution	9.5	10.1

Range of signed errors was from -22 mb. to +34 mb. for the CAO forecasts: from -21 mb. to +33 mb. for the At. W. C. forecasts.

Distribution curves for the absolute errors of the CAO and At. W. C. forecasts are shown in Figure 4.

Location errors in the forecasts of lows appearing in the forecast area were measured in terms of a direction error measured in degrees of arc; displacement errors were measured in degrees of latitude and were measured in terms of degrees of arc and degrees of latitude from the observed position of the low. The vector sum, vector mean, scalar mean and standard vector deviation for the error vectors thus obtained are shown in Table 6. In the table, α is the direction error.

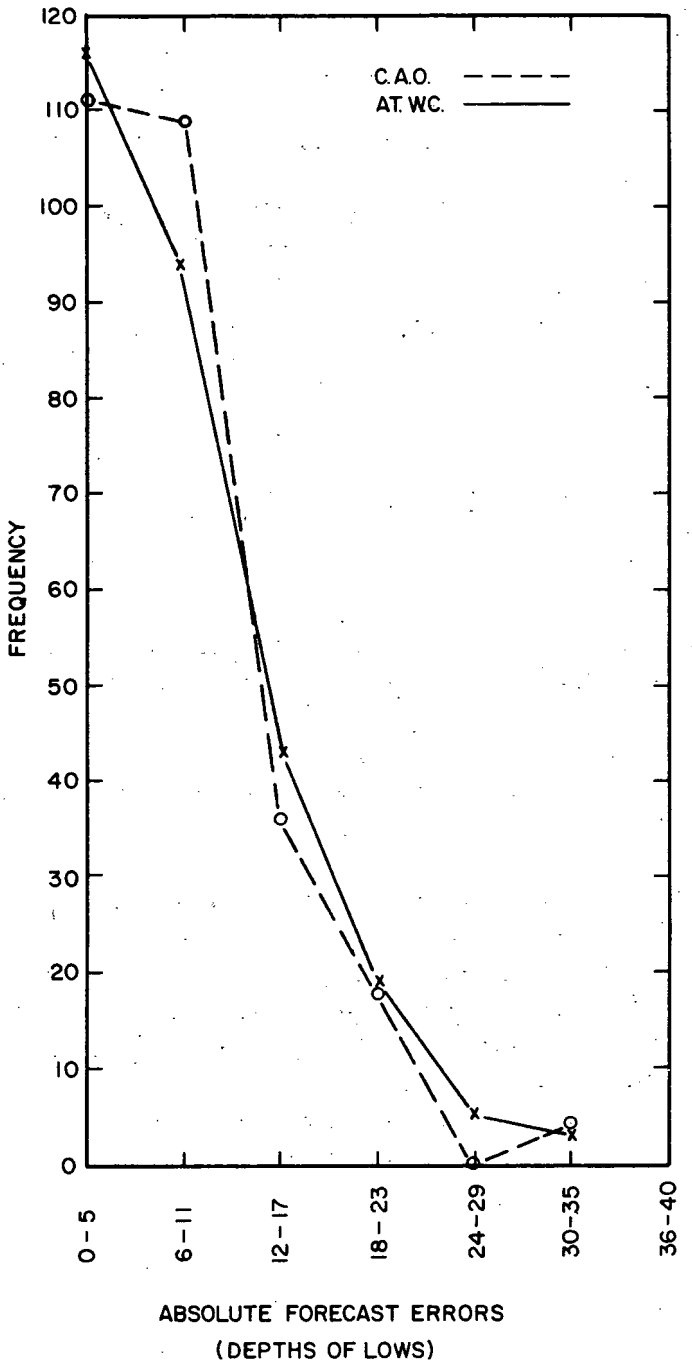

Figure 4
Frequency Distributions

Table 6.

	Error Vectors in Forecasts of Location of Lows	
	CAO (36-hr prog)	At. W. C. (30-hr prog)
Vector Sum	+ 87.2 degs. lat. $\alpha = 37^{o}\ 50'$	160.5 degs. lat., $\alpha = 19^{o}\ 52'$
Vector Mean	.31 degs. lat. $\alpha = 37^{o}\ 50'$	.57 degs, lat., $\alpha = 19^{o}\ 52'$
Scalar Mean	4.0 degs. lat.	3.75 degs. lat
Standard Vector Deviation	5.3	5.0

FORECASTS OF FORMATION OF NEW LOWS

During the period 1 November 1968 to 28 February 1969 there were 69 occurrences of formation of new lows in the area being verified which appeared on the CAO analyses, and 74 occurrences of formation of new lows which appeared on the At. W. C. analyses. Of the 69 occurrences shown on the CAO analyses, 13 were forecast by the CAO or a little less than 20% of the observed formations of new lows. Of the 74 occurrences shown on the At. W. C. analyses, 10 were forecast by the At. W. C., or 13.5% of the observed formations of new lows. The results of this examination are set out in Table 7.

Table 7.

	New Lows Observed		New Lows Not Observed	
	CAO	At. W. C.	CAO	At. W. C.
New lows Forecast	13	10	16	17
New Lows Not Forecast	53	64		

Mean displacement error (degrees of latitude) and depth forecast errors for these new lows which were successfully forecast follow:

	CAO	At. W. C.
Mean displacement error	5.4 degs. lat.	6.8 degs. lat.
Mean depth error	8 mb.	4.6 mb.

3. CONCLUSIONS

The evaluation of the pressure gradients shows that little significant improvement is contributed by the At. W. C. to the CAO 36-hour prognostics. The magnitude of the positive correlation coefficient (+.7) obtained from the paired scores of the At. W. C. 30-hour prognostics and CAO 36-hour prognostics shows a considerable dependence of the At. W. C. on the CAO prognostics.

Although the sample used for comparison of the At. W. C. 30-hour surface isobaric prognostics with the CAO 42-hour surface isobaric prognostics is admittedly small (40 examples), it would seem reasonable to conclude that the At. W. C. 30-hour prognostics contribute a significant improvement in accuracy to the CAO 42-hour prognostics.

The At. W. C. appears to be no more successful than the CAO in forecasting 36-hour deepening of surface lows, and is more likely to show a large error in forecast deepening than is the CAO.

In forecasts of position and depth of surface lows, there is little to choose between the At. W. C. 30-hour prognostic isobaric surface chart and the CAO 36-hour prognostic isobaric surface chart. Neither office is particularly successful in predicting the formation of new lows, the At. W. C. being somewhat less successful in this respect than the CAO.

The At. W. C. 30-hour surface isobaric prognostic charts show only a slight improvement over the accuracy shown by CAO 36-hour surface isobaric prognostic charts.

4. ACKNOWLEDGEMENTS

The author wishes to acknowledge the assistance of the Operations Technicians at the At. W. C. who worked out most of the verification scores for this project.

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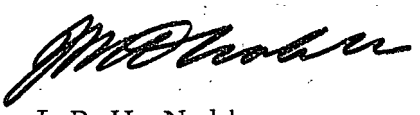

J. R. H. Noble,
Director,
Meteorological Branch.

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