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CANADA

ONTARIO WEATHER CENTRE
CENTRE MÉTÉOROLOGIQUE DE L'ONTARIO

DEPARTMENT OF TRANSPORT
METEOROLOGICAL BRANCH

Technical Memoranda

ERRORS IN TEMPERATURE FORECASTS FOR THE ATLANTIC PROVINCES 14 NOVEMBER 1969 TO 31 JANUARY 1970

by

R.V. TYNER

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CANADA - DEPARTMENT OF TRANSPORT - METEOROLOGICAL BRANCH
315 Bloor Street, West,
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ERRORS IN TEMPERATURE FORECASTS FOR THE ATLANTIC PROVINCES 14 NOVEMBER 1969 to 31 JANUARY 1970

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ABSTRACT

An analysis of the errors appearing in the temperature forecasts provided by the Atlantic Weather Central and the Central Analysis Office for the Atlantic Provinces has been carried out for the period of 14 November 1969 to 31 January 1970.

ERREURS DANS LES PRÉVISIONS DE LA TEMPÉRATURE POUR LES PROVINCES DE L'ATLANTIQUE, DU 14 NOVEMBRE 1969 AU 31 JANVIER 1970

par

R. V. Tyner

RÉSUMÉ

L'auteur a fait l'analyse des erreurs dans les prévisions de la température fournies par le Bureau central de météorologie de l'Atlantique et par le Bureau central d'analyse pour les provinces de l'Atlantique couvrant la période du 14 novembre 1969 au 31 janvier 1970.

ERRORS IN TEMPERATURE FORECASTS FOR THE ATLANTIC PROVINCES 14 NOVEMBER 1969 TO 31 JANUARY 1970

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R. V. Tyner

(Manuscript received May 22, 1970)

Introduction

A verification study of the computer-produced extreme temperature forecasts for certain localities in the Atlantic Provinces was undertaken at the Halifax Atlantic Weather Central (AtWC) shortly after the Central Analysis Office (CAO) began issuing these forecasts. Minimum temperature forecasts for the morning following the day of issue, essentially a 24-hour forecast for the AtWC and an 18-hour forecast for the CAO, and the maximum temperature forecasts for the next day, approximately a 36-hour forecast for the AtWC and a 30-hour forecast for the CAO, were examined to determine the relative success of the two offices in temperature prediction.

The CAO provides computer-produced minimum and maximum temperature forecasts for Halifax and Sydney in Nova Scotia; Charlottetown in Prince Edward Island; Saint John, Moncton and Fredericton in New Brunswick; and Gander, Stephenville and St. John's in Newfoundland (1). Temperature guidance provided by the AtWC consists of forecasts of the range of minimum temperatures expected tonight in various parts of the Atlantic Provinces and of the highest maximum temperatures expected to be realized tomorrow in several regions of the Atlantic Provinces.

Procedure

In carrying out the analysis of forecast errors of the minimum temperature forecasts, the average error of the temperature forecasts provided by the CAO for the localities in a given province was compared with the average error of the range of minimum temperatures forecast by the AtWC. For the maximum temperature forecasts, the average error of the temperature forecasts provided by the CAO for the localities in a given province was compared with the forecast error obtained by comparing the highest observed temperature in that province with the forecast maximum for that region provided by the AtWC.

The forecasts provided by the two offices are not strictly comparable since it might be expected that forecast errors of the minimum temperature obtained by comparing a forecast temperature range with several observed minima would exceed the errors obtained from comparing the observed and forecast temperatures at two or three specific sites. Conversely, it might be expected that comparing a single forecast maximum temperature for a region with the highest reported temperature in that region would show a smaller error than the average error obtained from

comparing two or three observed maxima with their forecast counterparts. In other words, intuitively it would seem reasonable to expect that minimum temperature forecasts provided by the CAO would show a smaller error than those produced by the AtWC whereas the AtWC forecasts of maximum temperature might be expected to show a smaller error than the objective forecasts.

Temperature forecasts verified for the AtWC were those issued at 1211Z while the objective forecasts provided by the CAO are ordinarily available at the AtWC about three hours later. The CAO forecasts are thus based on more recent data, and it might be expected that this would lead to improved accuracy over the AtWC forecasts. On the other hand, the AtWC meteorologists should be able to apply their knowledge of local peculiarities to the advantage of their forecasts.

The choice of AtWC temperature forecasts issued at 1211Z and of the CAO forecasts available at 1530Z was made to ensure as great a degree of independence as possible in the two sets of forecasts. As a check on the independence of the forecasts, the absolute value of the difference between the CAO and AtWC forecasts for the same day was plotted for the 78 corresponding forecasts issued by both offices. The error differences for the first night's (N_1) minimum temperature forecasts for New Brunswick appear in Figure 1. Error difference distributions for the forecasts for the other Atlantic Provinces are very similar. From the figure it is apparent that few forecasts show a close correspondence and it would, therefore, seem reasonable to assume a considerable degree of independence between the two forecasts. It is probable that there is not complete independence since the 42-hour and 60-hour temperature forecasts issued the preceding day by the CAO are available to the AtWC meteorologists at the time of preparation of the 1211Z forecast.

Discussion

Average forecast errors for maximum and minimum temperatures, and the standard deviations of those errors, for the Atlantic Provinces are set out in Table 1. It is apparent that, with the exception of forecasts for Newfoundland and the Nova Scotian minima, where the temperature guidance provided by the AtWC was superior to the objective forecasts, the CAO product shows smaller errors than the AtWC temperature guidance. Frequency diagrams for the error distributions obtained in the analysis appear in Figures 2A, B, C, D, E, F, G and H, and bear out the contention that only the temperature forecasts for Newfoundland show any important difference between the forecasts provided by the AtWC and the numerically derived forecasts provided by the CAO. It is apparent from these figures that, with the exception of the N_1 forecasts for Nova Scotia and the N_1 and D_2 forecasts for Newfoundland, the frequency of small errors in the objective temperature forecasts is greater and the frequency of large errors less than in the temperature forecasts provided by the AtWC.

As a matter of interest, the absolute forecast errors in the temperature forecasts based on the AtWC guidance and issued by the Maritimes Weather Office for the cities of Halifax and Moncton were also examined. Average error of the forecast minimum temperatures was 4.8°F. for Halifax, 5.6°F. for Moncton; of the forecast maximum temperatures 4.7°F. for Halifax, 5.2°F. for Moncton.

The number of occasions when the forecast temperatures were lower than, higher than, or equal to the observed temperatures is set out in Table 2. As far as the AtWC forecasts are concerned, there appears to be no particular bias toward over-estimation or under-estimation of the observed temperature, while the objective forecasts show a definite tendency to under-estimate the observed temperature. In particular, considering the two events, forecasts lower than observed and forecasts higher than observed, it is apparent that the distribution of the AtWC forecasts obeys the (weak) law of large numbers for this binomial distribution, which would imply that in the case of the AtWC forecasts the distribution of high or low forecasts is dictated by chance.

The average forecast error and standard deviation of the error for the four numerical forecasts issued daily by the CAO are displayed in Table 3. In this table, N_1 is the first night's minimum temperature, D_2 the next day's maximum temperature, N_2 the second night's minimum temperature, and D_3 the maximum temperature for the third day from the date of issue of the forecast. The small increase in the average forecast error, and the small variation in the value of the standard deviation of the forecast error, are worth notice.

The usefulness of the temperature forecasts should not be judged solely on the average error of the forecasts. Of considerable importance as well, is the frequency of occurrence of large errors in the forecasts. In this study the frequencies of errors greater than 7.9°F., greater than 9.9°F., and greater than 14.9°F. were compiled. The frequency of occurrence of these large errors is set out in Table 4.

In the range of error between 8 and 10°F., both the objective forecasts and those provided by the AtWC showed approximately the same frequency of occurrence - 58 occurrences in the objective forecasts, 57 in the AtWC forecasts; while in the range of errors between 10 and 15°F. the number of occurrences was again very similar: 59 in the objective forecasts, 64 in the AtWC forecasts. The comparatively large number of forecast errors of 15°F. or more appearing in the AtWC forecasts was a matter of some surprise.

A plot was made of the day-to-day forecast errors of the two sets of forecasts which indicated that, with the exception of the Newfoundland forecasts, large forecast errors are of greater frequency in the AtWC forecasts, also the magnitude of the large forecast errors is in most cases largest in the AtWC forecasts. An example, the D_2 forecasts for Nova Scotia, is provided. (Figure 3).

If we examine the probability that a forecast showing $5^{o}F$. or less of error will be followed by a forecast with not more than 5^{o} of error, and use this probability as a rough measure of the reliability of the forecasts, it appears that, with the exception of Newfoundland forecasts, the objective forecasts are more likely to show more frequent runs of forecasts with this amount of error. Results of this analysis appear in Table 5.

The difference between the forecast temperatures and the long-term climatological mean minimum or maximum temperatures was also examined for the two sets of forecasts with the results summarized in Table 6. With the exception of the D_2 forecasts for Prince Edward Island, it would appear that the objective forecasts are more influenced by the mean temperature than are those of the AtWC. A plot of the absolute values of the differences of observed and forecast minimum temperatures from the mean minimum for the N_1 temperature forecasts for Prince Edward Island was made (Fig. 4), which shows that the objective forecasts follow the mean somewhat more closely than do those of the AtWC.

The average absolute forecast errors for those situations in which the observed minimum or maximum temperatures differed by $10^{o}F.$ or more from the climatological mean minimum or maximum temperatures were also examined, with the results being summarized in Table 7. For these unusual situations where it might have been expected that the AtWC forecasts would show a greater flexibility in adjusting to an extreme temperature situation and, thus, smaller forecast errors, the objective forecasts, with the exception of those for Newfoundland and the N_1 forecasts for Nova Scotia, showed a smaller average error than those provided by the AtWC.

Conclusions

Based on this study, it would appear that the numerically-produced temperature forecasts provide temperature guidance for the centres in the Maritime Provinces which is of equal or better quality than that provided by the AtWC. Only in Newfoundland was the AtWC guidance superior to that of the objective forecasts. In those situations where the observed temperature differed considerably from the mean, the forecast errors of the objective forecasts were less than those of the AtWC with the exception of the Newfoundland forecasts and the N_1 forecasts for Nova Scotia. Large forecast errors are somewhat more likely to occur in the AtWC forecasts than in the objective forecasts, while the probability of a good forecast following a preceding good forecast is somewhat less for the AtWC forecasts than for those produced by numerical means.

APPROVED,

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

Reference

1. DMB memorandum of 31 October 1969 on "Objective Temperature Forecasts from CAO".

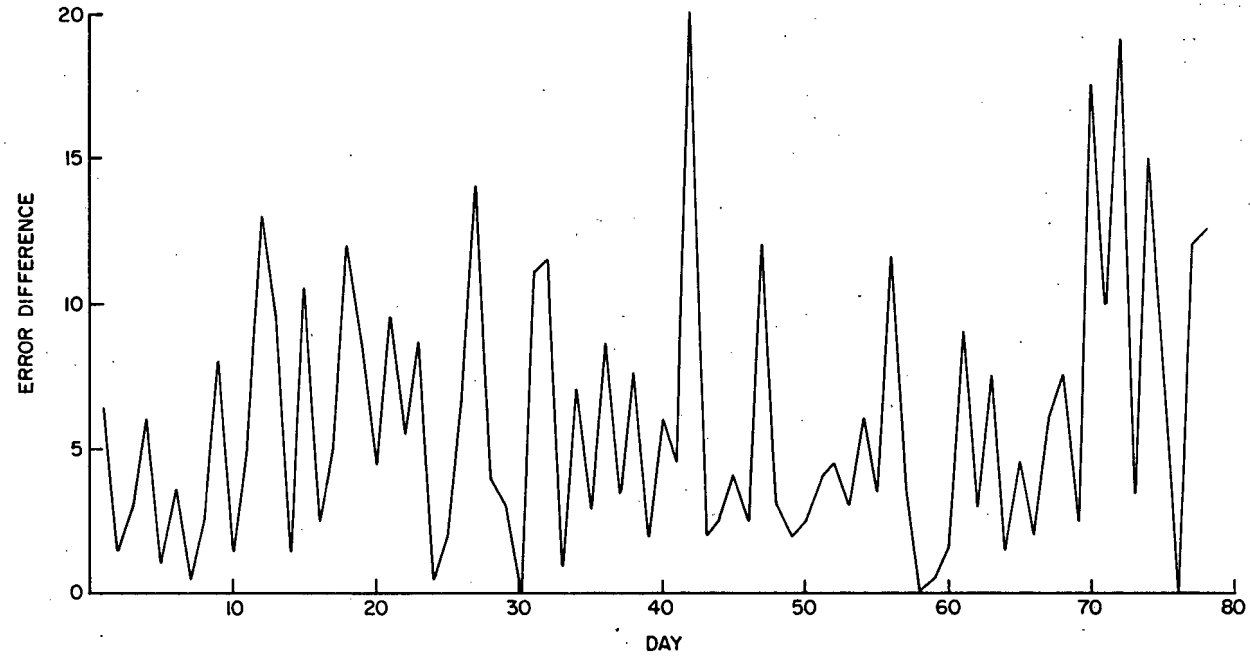

Figure 1.
Error Difference between AtWC and CAO Forecasts for First Night's Minimum (N_1) Temperature for New Brunswick

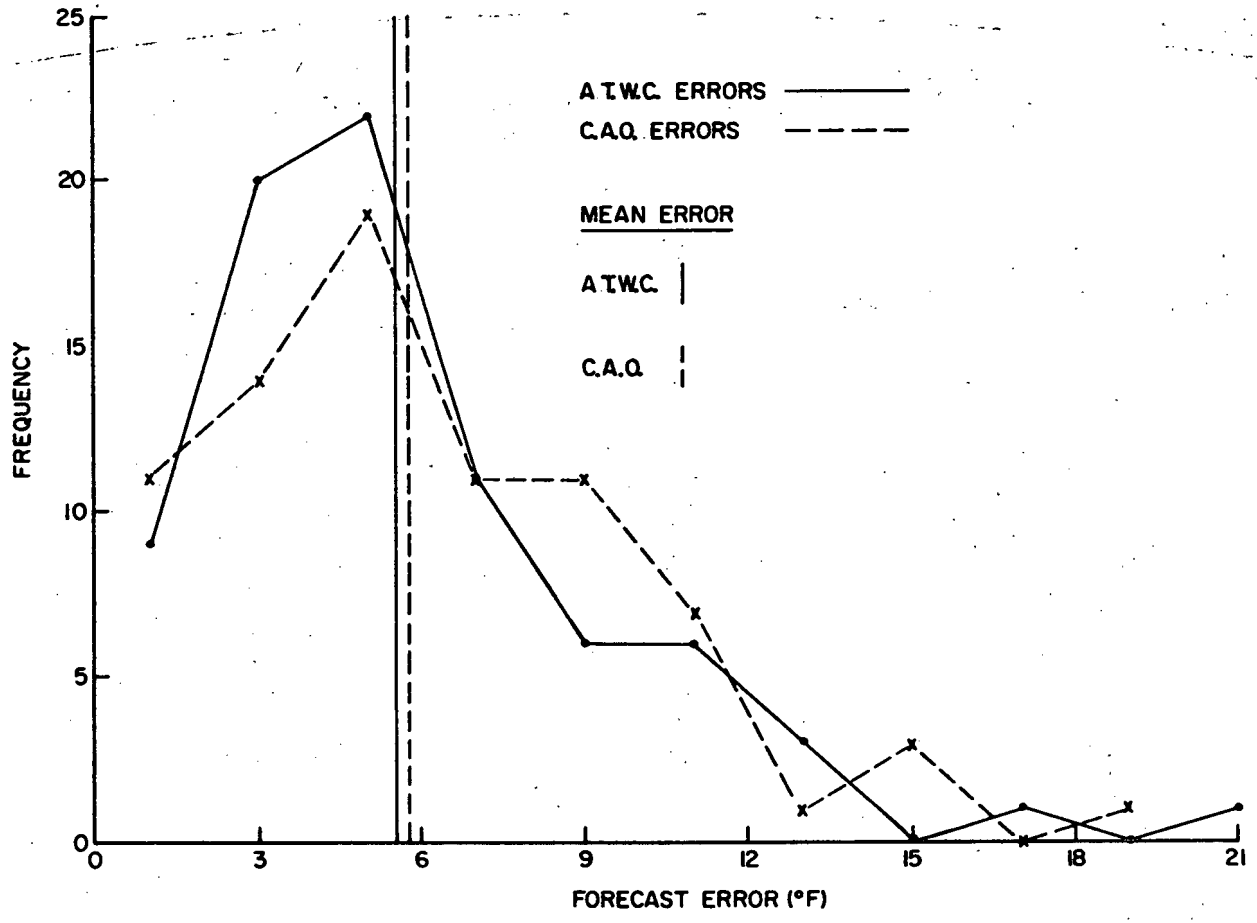

Figure 2A.
Error Distributions for N_1 Forecasts for Nova Scotia

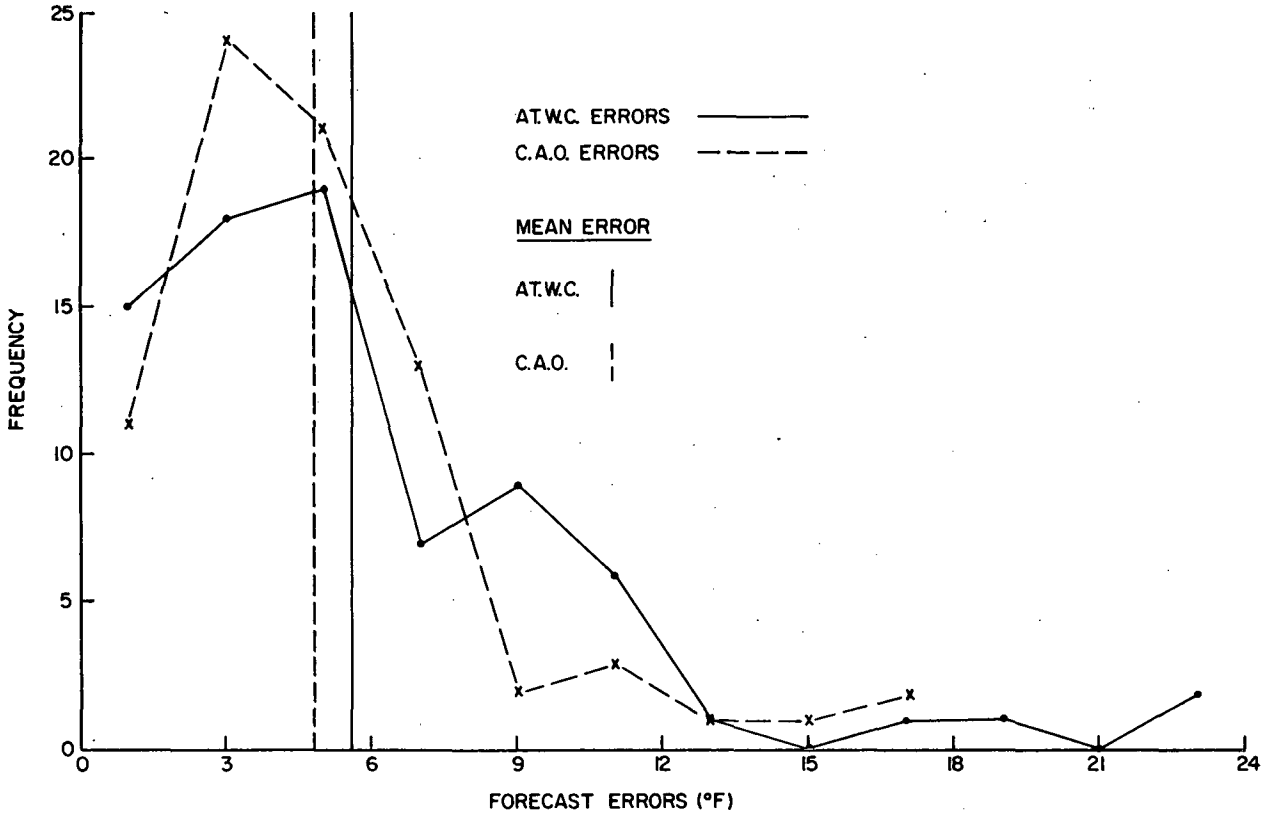

Figure 2B.
Error Distributions for D_2 Forecasts for Nova Scotia

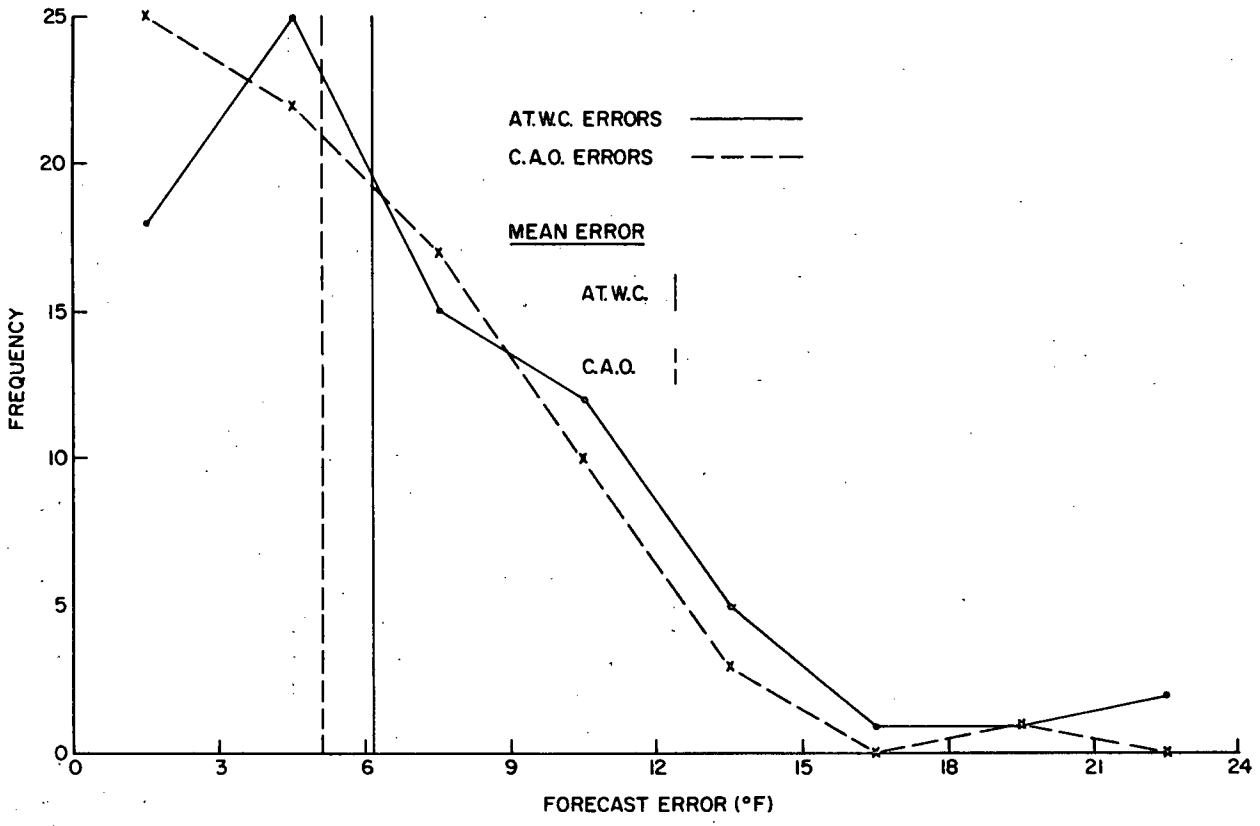

Figure 2C.
Error Distributions for N_1 Forecasts for Prince Edward Island

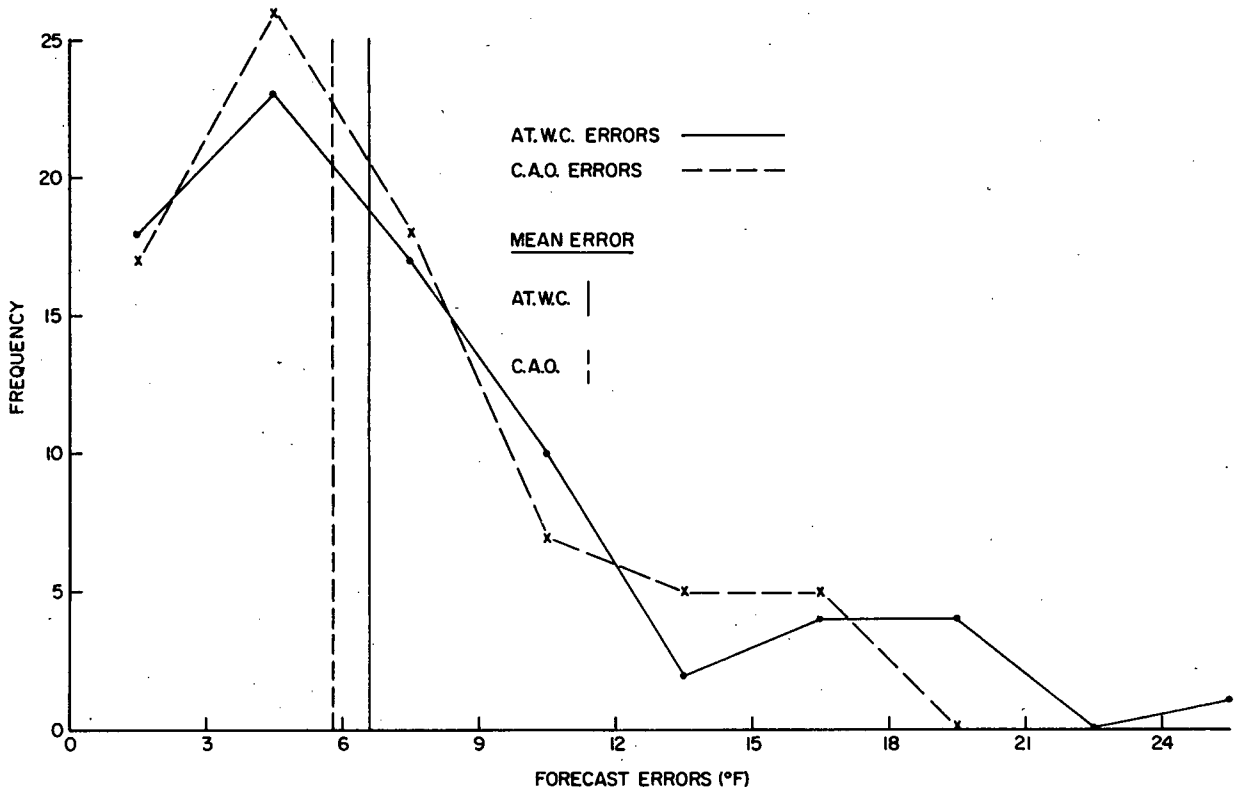

Figure 2D.
Error Distributions for D_2 Forecasts for Prince Edward Island

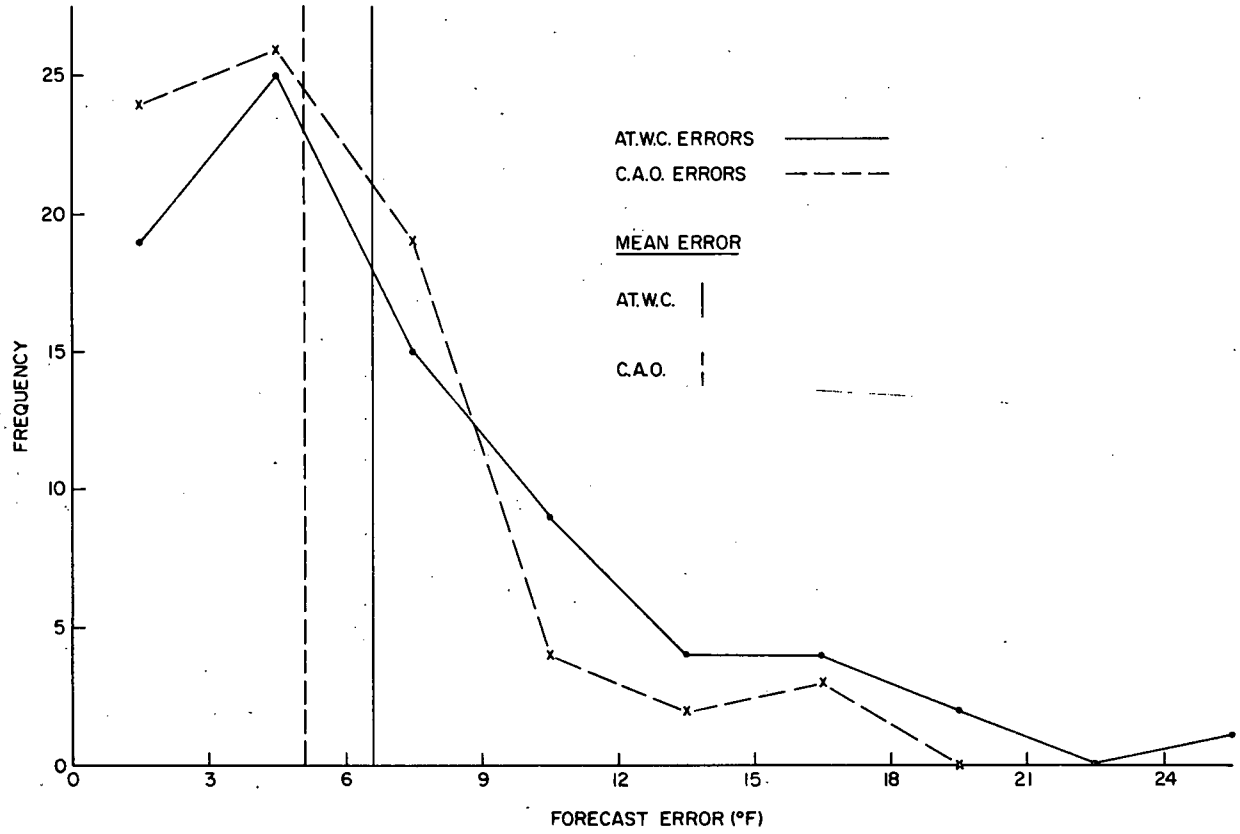

Figure 2E.
Error Distributions for N_1 Forecasts for New Brunswick

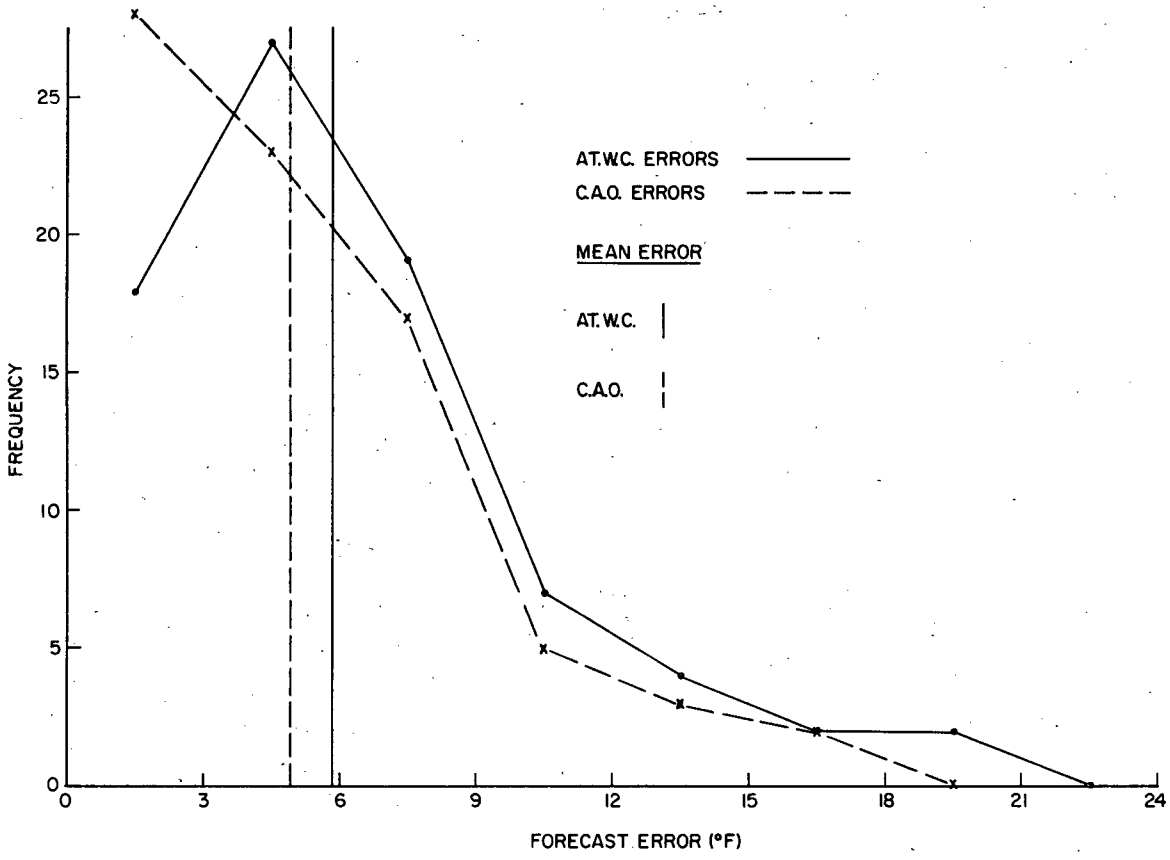

Figure 2F.
Error Distributions for D_2 Forecasts for New Brunswick

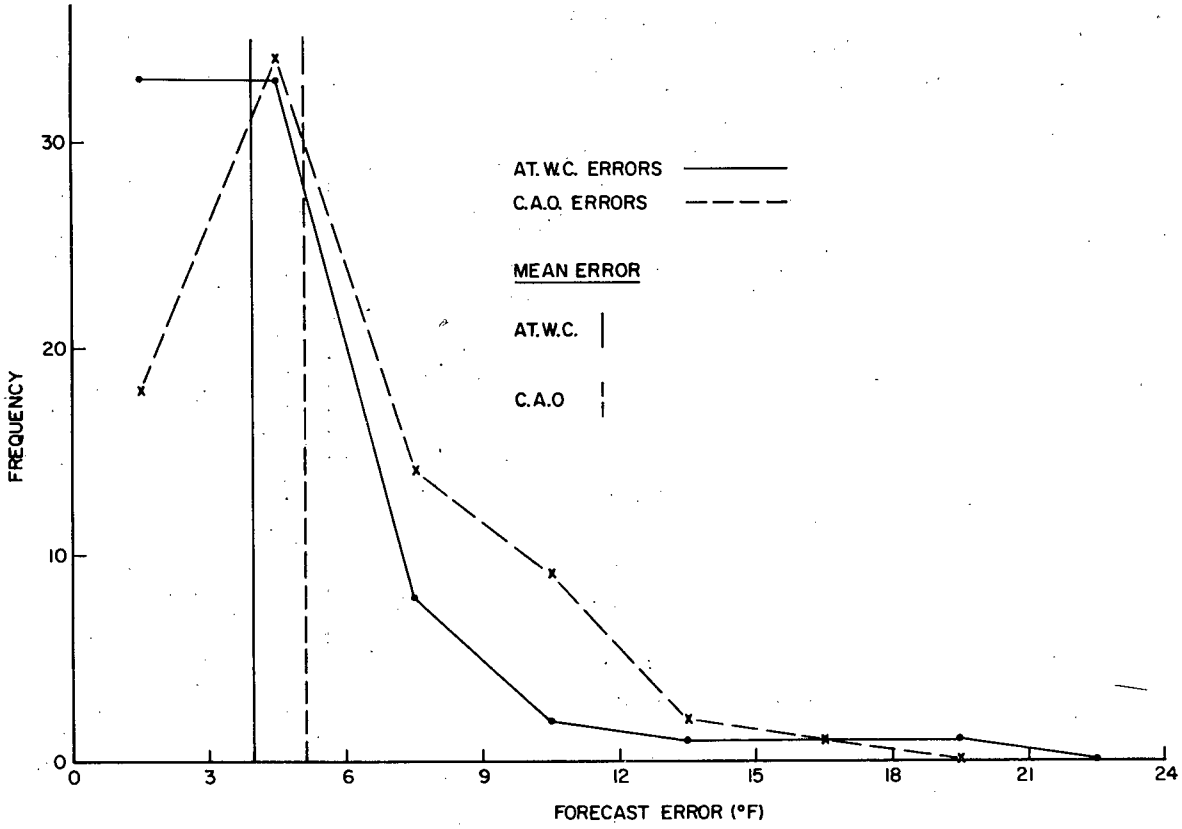

Figure 2G
Error Distributions for N_1 Forecasts for Newfoundland

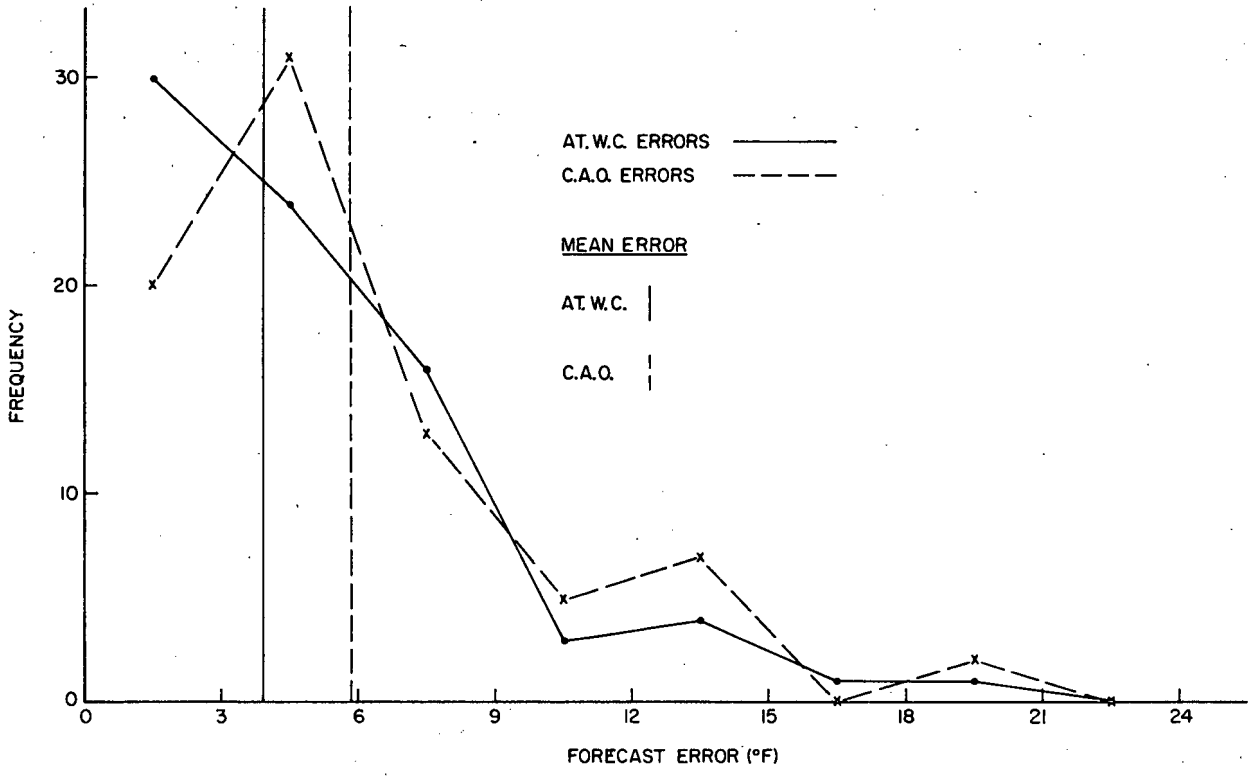

Figure 2H.
Error Distributions for D_2 Forecasts for Newfoundland

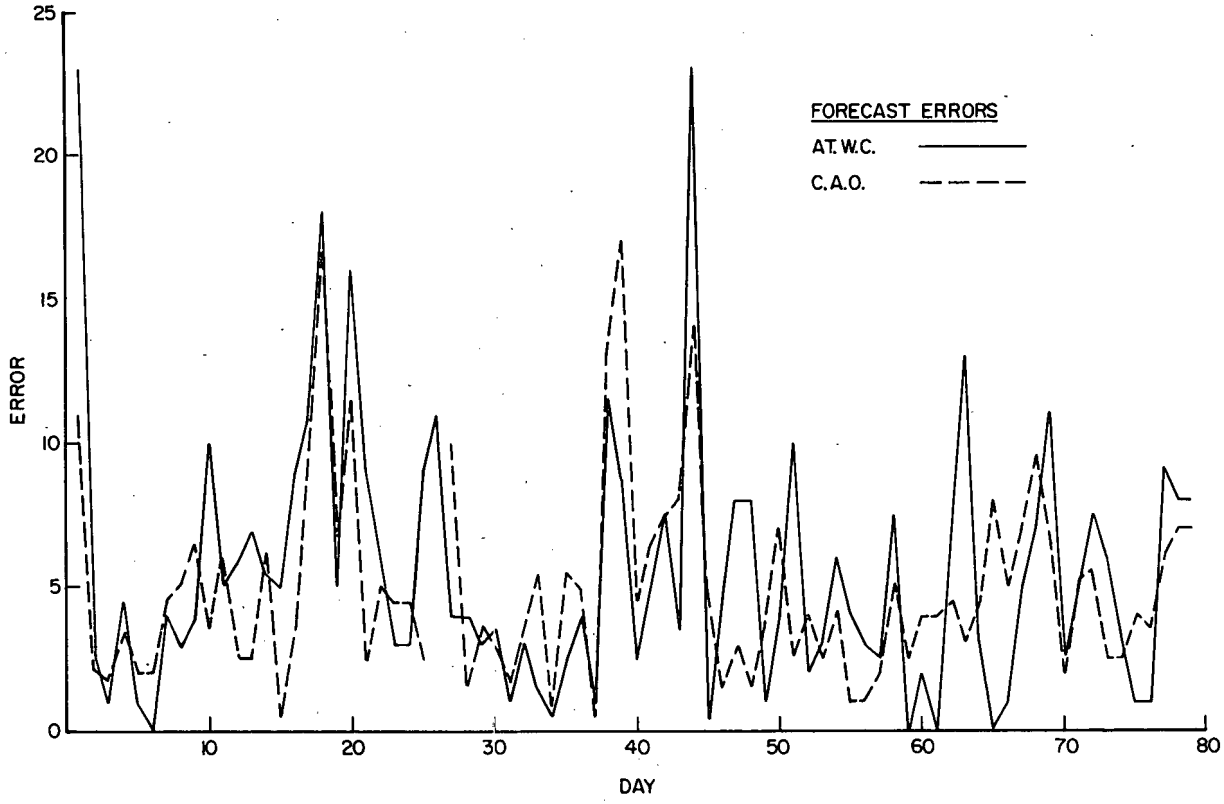

Figure 3.
AtWC and CAO Forecast Errors for the D_2 Forecasts for Nova Scotia

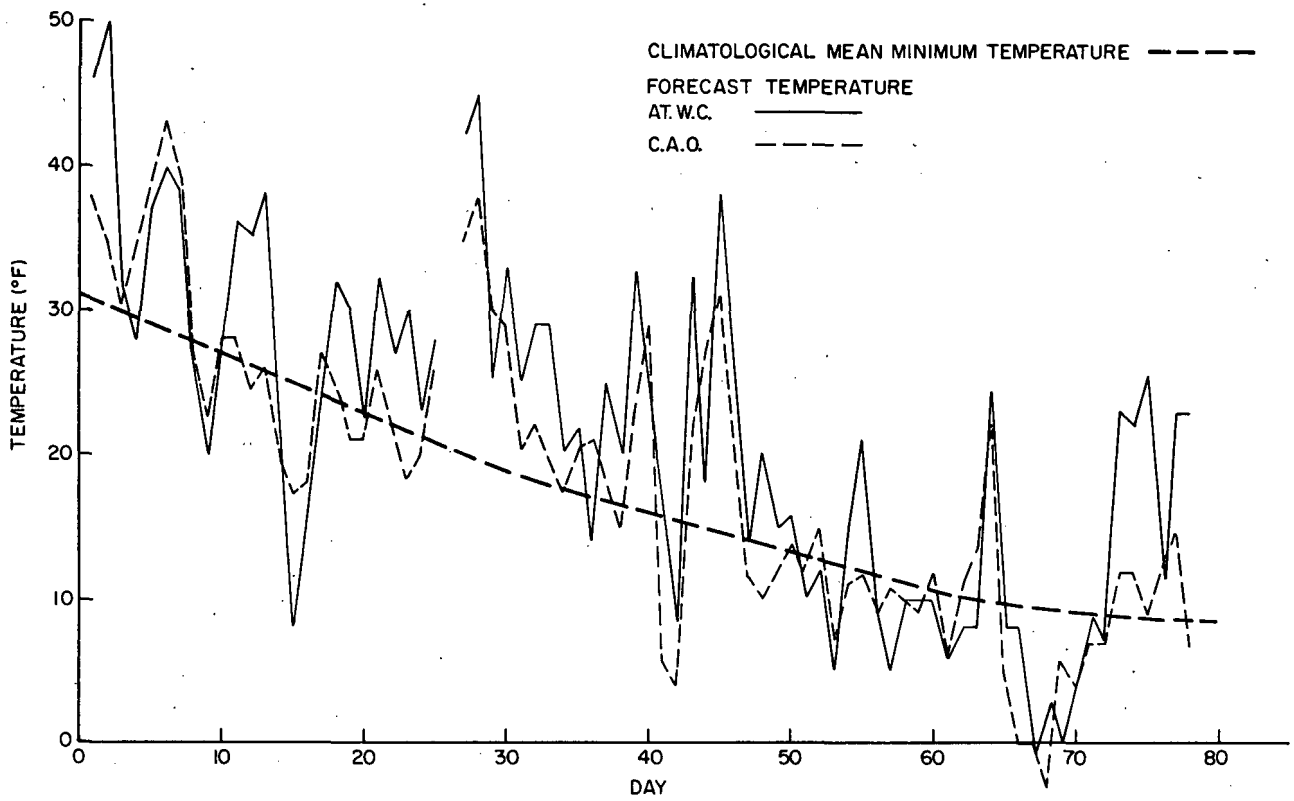

Figure 4.
Differences of Forecast Minimum (N_1) Temperature for Prince Edward Island from the Climatological Mean Minimum Temperature

Table 1.

TEMPERATURE FORECAST ERRORS

		Nova Scotia		Prince Edward Island		New Brunswick		Newfoundland	
		Min	Max	Min	Max	Min	Max	Min	Max
CAO	Average Error	5.8	4.8	5.1	5.8	5.1	4.9	5.1	5.8
	Standard Deviation	3.8	3.4	3.7	4.1	3.7	3.7	3.2	4.2
AtWC	Average Error	5.5	5.5	6.2	6.6	6.6	5.8	4.0	4.7
	Standard Deviation	3.8	4.6	4.7	5.4	4.9	4.3	3.2	3.7

Table 2.

		Forecasts Lower than Observed Temp		Forecasts Higher than Observed Temp		Forecasts Same as Observed Temp	
		CAO	At WC	CAO	AtWC	CAO	AtWC
Nova Scotia	Min	51	34	24	40	3	4
	Max	40	39	36	34	2	5
Prince Edward Island	Min	37	27	38	47	3	4
	Max	35	30	41	41	2	7
New Brunswick	Min	34	26	42	50	1	2
	Max	28	43	43	32	6	3
Newfoundland	Min	55	46	22	30	1	2
	Max	52	54	22	21	4	3
Totals		332	299	268	295	22	30

Table 3.

CAO TEMPERATURE FORECAST ERRORS

	Nova Scotia		Prince Edward Island		New Brunswick		Newfoundland	
	Average Error	Standard Deviation	Average Error	Standard Deviation	Average Error	Standard Deviation	Average Error	Standard Deviation
Forecast								
N_1(24 hr)	5.8	3.8	5.1	3.7	5.1	3.7	5.1	3.2
D_2(36 hr)	4.8	3.4	5.8	4.1	4.9	3.7	5.8	4.2
N_2(48 hr)	6.7	5.0	6.4	5.1	6.5	5.4	7.0	4.6
D_3(60 hr)	5.2	3.9	6.6	4.4	5.5	3.8	5.3	4.0

Table 4.

FREQUENCY OF LARGE FORECAST ERRORS

	Errors > 7.9°F.				Errors > 9.9°F.				Errors > 14.9°F.			
	CAO		AtWC		CAO		AtWC		CAO		AtWC	
Region	N_1	D_2	N_1	D_2	N_1	D_2	N_1	D_2	N_1	D_2	N_1	D_2
Nova Scotia	23	10	17	20	11	7	11	11	3	2	2	4
Prince Edward Island	20	18	25	24	9	14	17	17	1	5	4	9
New Brunswick	13	15	24	27	8	7	17	12	2	1	7	4
Newfoundland	15	20	5	13	8	12	5	8	1	2	2	2

Table 5.

PROBABILITY THAT A FORECAST WITH 5°F. OR LESS OF ERROR WILL BE FOLLOWED BY A FORECAST WITH NOT MORE THAN 5°F. OF ERROR

	N_1 (First Night's Minimum)		D_2 (Next Day's Maximum)	
Province	CAO Objective Forecasts	AtWC Forecasts	CAO Objective Forecasts	AtWC Forecasts
Nova Scotia	.295	.291	.474	.392
Prince Edward Island	.308	.291	.397	.304
New Brunswick	.346	.279	.333	.253
Newfoundland	.385	.506	.346	.443

Table 6.

DIFFERENCE BETWEEN FORECAST AND CLIMATOLOGICAL MEAN TEMPERATURES

Average of Absolute Difference from the Mean

	N_1 (First Night's Minimum)			D_2 (Next Day's Maximum)		
Province	Observed Minimum	CAO Objective Forecast	AtWC Forecast	Observed Maximum	CAO Objective Forecast	AtWC Forecast
Nova Scotia	7.5	5.6	6.4	6.1	4.8	5.4
Prince Edward Island	7.8	5.2	6.7	8.2	5.5	5.5
New Brunswick	8.0	6.0	7.6	7.7	5.4	6.9
Newfoundland	7.0	4.2	6.4	6.0	5.0	6.0

Table 7.

AVERAGE FORECAST ERRORS WHERE OBSERVED TEMPERATURES DIFFERED BY 10°F OR MORE FROM THE MEAN

	Average Difference of Observed Temperature from Mean		Average Forecast Error			
			N_1 (First Night's Minimum)		D_2 (Next Day's Maximum)	
	N_1	D_2	CAO Objective Forecast	AtWC Forecast	CAO Objective Forecast	AtWC Forecast
Nova Scotia	14.3	13.7	7.5	6.9	8.9	9.4
Prince Edward Island	13.6	14.4	7.5	9.0	6.6	9.7
New Brunswick	14.7	14.3	6.7	7.6	7.7	8.5
Newfoundland	15.0	13.5	8.0	4.0	10.3	7.0

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