

MAXIMUM TEMPERATURE PREDICTION FOR ADELAIDE

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(Manuscript received July 1965)

ABSTRACT

Maine's (1958) method of maximum temperature prediction for Adelaide was evaluated for six Januarys.

On the basis of the errors obtained, refinements to this method of prediction are proposed.

1. INTRODUCTION

Maine (1958) derived an objective technique of maximum temperature prediction for Adelaide in January which has now been an operational forecasting aid in the S.A. Regional Office for several years. The predictors used are the Adelaide Airport 3 a.m. wind at 2000 ft, the amount and type of 6 a.m. cloud at Adelaide, and the Adelaide 6 a.m. temperature. The prediction nomograms and detailed instructions for their use, are reproduced in Appendix I.

In the following investigation, Maine's method was applied straight-out (without subjective modification) to six months of independent data, and the error distribution investigated from several aspects, enumerated in detail in Section 2, with the aim of detecting and eliminating any systematic bias.

2. INVESTIGATION OF ERRORS

The independent data used were the months of January from 1952 to 1954 and 1959 to 1961 with "change" and "rain" days as defined by Maine excluded. The months from 1955 to 1958 were omitted as these were used as basic data in the derivation of Maine's method.

One of the predictors used in Maine's method is the 2000 ft wind at Adelaide at 3 a.m. (0300 C.S.T.). When this 2000 ft wind is considered to be unrepresentative of the low-level wind flow, it has been suggested by Maine (1958) that the geostrophic wind obtained from the mean sea level isobars be used instead.

Inevitably, some subjectivity will occasionally be necessary in deciding whether the 2000 ft wind is "representative". In order to make the decision of what wind factor to use objective, and to reduce the subjectivity purely to that involved in drawing the isobars, the following procedure was adopted in this investigation. Two estimates of the maximum temperature were made for each day, using as a predictor (a) the observed 2000 ft wind and (b) the geostrophic wind using M.S.L. isobars, with the exception that when the difference in speed between the 2000 ft wind and the geostrophic wind was ≤ 5 knots, and in direction $\leq 20^\circ$, the observed 2000 ft wind was used for both (a) and (b). These tolerances were considered to be appropriate allowances for the subjectivity of the M.S.L. isobars. The procedure resulted in the 2000 ft wind being used for both (a) and (b) on slightly over 50 per cent of occasions. The distributions of errors obtained by each method were compared (Table 1).

The overall bias (mean algebraic error) was found to be significantly different from zero (below the 1% level of "t") for both the "2000 ft wind" and the geostrophic wind forecasts. The overall error variances using each method were not significantly different from each other ("variance ratio" or "F" test), and the two biases not significantly different from each other ("t" test).

TABLE 1

Comparative Performances of the Adelaide 3 a.m. 2000 ft wind and the 3 a.m. Geostrophic Wind as Predictors of Maximum Temperature.

(Based on months of January 1952 to 1954, 1959 to 1961)

	Forecasts using 2000 ft winds		Forecasts using geostrophic wind	
Mean modulus of errors	4.7	$^{\circ}\text{F}$	4.2	$^{\circ}\text{F}$
Bias	+1.8	$^{\circ}\text{F}$	+1.1	$^{\circ}\text{F}$
Variance of errors	32.5	$(^{\circ}\text{F})^2$	26.7	$(^{\circ}\text{F})^2$
Number of days used	152		155	

Errors of over 6°F were next examined in more detail, to determine whether the larger errors for either predictor tended to occur more frequently in any particular temperature range or wind direction (Tables 2A and 2B). Table 2A presents the distribution of errors with respect to observed maximum temperature.

The larger positive errors (over-estimates) of the "2000 ft wind" forecasts tended to be associated with observed maxima below 85, and the larger under-estimates with observed maxima above 85 (levels of significance of χ^2 below 1% and 5% respectively). The distribution of the larger errors using the "geostrophic wind" forecasts proved uninformative.

Table 2B presents the errors greater than 6°F with regard to wind direction.

No significant separation of the larger errors with regard to wind direction was obtained for the "2000 ft wind" forecasts. With the "geostrophic wind" forecasts, however, there was clearly a disproportionate number of large overestimates in the northerly sector (below 0.1% level of χ^2). This result suggested that the overall significant positive bias (see above) of the "geostrophic" forecasts might be due largely to overestimates in the northerly sector. It was therefore decided to re-examine all errors with respect to wind direction.

TABLE 2A Distribution of Errors over 6°F with respect to Observed Maximum temperature

Observed Maximum Temperature $^{\circ}\text{F}$	Forecasts using 2000 ft winds							Forecasts using geostrophic wind						
	<76	76- 80	81- 85	86- 90	91- 95	96- 100	>100	<76	76- 80	81- 85	86- 90	91- 95	96- 100	>100
Positive Errors over 6°F	8	11	6	3	1	0	0	5	9	0	3	2	5	3
Negative Errors over 6°F	1	0	2	0	2	4	3	2	1	2	0	2	3	2
Total Days in Range	35	30	22	13	19	19	14	36	31	22	13	19	19	15

TABLE 2B Distribution of Errors over 6°F with respect to Wind Direction
(January 1952 to 1954, 1959 to 1961)

Direction of isobars }→	Forecasts using 2000 ft winds				Forecasts using geostrophic wind			
	$310^{\circ}-050^{\circ}$	$060^{\circ}-140^{\circ}$	$150^{\circ}-300^{\circ}$	Calm	$310^{\circ}-050^{\circ}$	$060^{\circ}-140^{\circ}$	$150^{\circ}-300^{\circ}$	Calm
Positive errors over 6°F	3	12	13	1	12	6	8	1
Negative errors over 6°F	1	8	3	0	0	7	5	0
Total days in Range	26	64	61	1	27	65	62	1

In view of the results obtained from Tables 2A and 2B, it was decided to examine the error distribution with respect to wind direction for all days, not just those with errors over 6°F (Table 3).

For the "2000 ft wind" forecasts, the bias was found to be significantly different from zero in the $310^{\circ}-050^{\circ}$ and the $150^{\circ}-300^{\circ}$ sectors (below 5% level of "t") and probably significant in the $060^{\circ}-140^{\circ}$ sector (between 5% and 10% levels of "t"). In other words, the overall positive bias for the 2000 ft wind forecasts could not be attributed to errors associated with any particular sector.

Also, for the "2000 ft wind" forecasts, the variance of the errors was significantly lower in the $310^{\circ}-050^{\circ}$ sector than for other directions (below the 5% level of "F"). The 2000 ft wind might therefore be expected (after removing bias) to be a better predictor in this sector than in other sectors.

For the "geostrophic" forecasts, as suggested earlier in this section, the bias was significantly different from zero only in the northerly sector. The variances of the errors in the three sectors were not significantly different from each other.

The variance of the errors of the "geostrophic" forecasts was lower than that of the "2000 ft wind" forecasts (at a significance level of "F" between 1.0 and 5%) in both the $060^{\circ}-140^{\circ}$ and $150^{\circ}-300^{\circ}$ sectors. In the northerly sector, the variances were not significantly different. In other words, the greater mean absolute error occurring with "geostrophic" forecasts in this sector was due largely to the greater bias, and after removing bias from both predictors, there was little reason to suppose that one would be any better than the other.

TABLE 3 Comparative Performance (over all days) with respect to Direction of 2000 ft and geostrophic winds
(January 1952 to 1954, 1959 to 1961)

Direction of Isobars	Forecasts using 2000 ft. winds				Forecasts using geostrophic wind			
	No. of Days	Mean Modulus of error ($^{\circ}\text{F}$)	Bias ($^{\circ}\text{F}$)	Variance of errors ($^{\circ}\text{F}$) ²	No. of Days	Mean Modulus of error ($^{\circ}\text{F}$)	Bias ($^{\circ}\text{F}$)	Variance of errors ($^{\circ}\text{F}$) ²
$310^{\circ}-050^{\circ}$	27	3.8	+2.0	18.2	28	5.3	+4.2	22.9
$060^{\circ}-140^{\circ}$	63	5.1	+1.4	38.5	64	4.2	+0.1	26.1
$150^{\circ}-300^{\circ}$	61	4.5	+2.0	31.0	62	3.6	+0.5	22.1

The synoptic situations on those days when both predictors were associated with errors of over 6°F were examined in order to determine any other factor associated with the larger errors. (Table 4).

On 25 days, both predictors produced an error of over 6°F. Apart from the associations with observed temperature range and the direction of the airstream as discussed earlier in this section, other systematic factors were sometimes in evidence. These are shown in Table 4.

TABLE 4 Factors (other than airstream direction and temperature range) associated with simultaneous errors of over 6°F by both predictors.
(January 1952 to 1954, 1959 to 1961)

Factors in Operation	Times Occurring
Abnormal development of the low-level airstream	12
Unrepresentative 6 a.m. cloud	4
Abnormal vertical mixing	2
No single factor	7
TOTAL	25

Abnormal development in the speed and direction of the low level airstream was by far the most frequently occurring factor associated with large errors. A southeasterly gradient at 3 a.m., veering southerly instead of the "usual" backing easterly, would be a case in point, and a light easterly gradient at 3 a.m. changing to a fresh northerly by 9 a.m. would be another. In practice, abnormal development of this type is often detected from the surface pressure tendencies at 3 a.m., and the estimate of maximum temperature subjectively tempered.

All four cases of unrepresentative 6 a.m. cloud amount involved middle and high cloud either rapidly increasing or decreasing after 6 a.m. In three of the four cases this was subjectively indicated by the 3 a.m. analyses.

In both instances of abnormal vertical mixing, a shallow change had passed through Adelaide one or two days previously, but establishment of a dry adiabatic lapse rate in the first few thousand feet allowed mixing with the "old" warmer air.

The three factors discussed above may be regarded as special cases of what Maine (1959) has described as departures of stream conditions from the "average". This aspect is discussed further in Section 4.

3. ATTEMPTS AT REFINEMENT

The discussion in the previous section suggests the following refinement, A, in the application of Maine's method. The "geostrophic" wind is used as the predictor in all cases where it differs from the 3 a.m. 2000 ft wind by more than 5 knots or 20 degrees. This predictor is applied to a "wind" nomogram revised so as to remove the four degree bias in the 310° to 050° sector.

An alternative refinement, B, is to use the 2000 ft wind in the 310° to 050° sector and adjust the "wind" nomogram for a two degree bias in this sector, while still using the "geostrophic" wind in other sectors. However, as indicated in Section 2, there is little reason to supposed this would produce any smaller spread of errors than the first suggestion, which has the merit of simplicity as it uses the "geostrophic" wind in all sectors.

Refinements A and B were tested on four years of January data from 1962 to 1965, and the results compared with those obtained by straight-out application to the same data of the 2000 ft wind and "geostrophic" wind. This comparison is made in Table 5.

Some reduction in the bias (over all sectors) was achieved with both refinements, but a significant bias of $+1.4^{\circ}\text{F}$ remained (below 5% level of "t"). There were two reasons for this. Firstly, the refinements did not completely remove the bias in the northerly sector (see right hand half of Table 5). Also, over the four months of test data, in the 060° to 140° sector, a positive bias of $+1.7^{\circ}\text{F}$ (significant below 5% level of "t") was present in the geostrophic wind forecasts and contributed to the overall positive bias. No such positive bias in the geostrophic wind forecasts had been apparent in the 060° to 140° sector in the six months previously investigated.

TABLE 5 Comparative performances of refinements A and B, Adelaide 3 a.m. 2000. ft winds and 3 a.m. geostrophic wind as predictors of maximum temperatures (January 1962 to 1965)

	ALL SECTOR				310° - 050° SECTOR			
	Refine- ment B	Refine- ment A	Using 2000 ft Winds	Using Geos. Wind	Refine- ment B	Refine- ment A	Using 2000 ft Wind	Using Geos. Wind
Mean Modulus of error	3.2	3.3	3.7	3.6	3.4	3.7	4.6	5.7
Bias	+1.4	+1.4	+1.8	+1.9	+1.5	+1.4	+3.5	+5.4
Variance of errors	13.9	14.1	17.7	17.0	14.8	16.1	14.8	16.1
Number of days used	104	104	103	104	15	15	15	15

Some reduction in variance was also achieved by both refinements, although, in view of the sample size, this reduction was only on the borderline of statistical significance (near 10% level of "F").

Over the four test months, it was noticed that the error variances obtained by straight-out application (i. e. without removing bias) of either the 2000 ft wind or the geostrophic wind were significantly lower than the corresponding figures for the six months previously investigated (below 1% level of "F"). This aspect is discussed more fully in the Section 4.

In an attempt at further refinement it seemed logical to pool the results of the four-month and six-month sample, in order to obtain another estimate of the northerly sector bias which it was sought to eliminate. For the resultant ten-month sample, the bias using the 2000 ft wind in the northerly sector was $+2.5^{\circ}\text{F}$, and using the geostrophic wind $+4.6^{\circ}\text{F}$ (compared with $+2.0^{\circ}\text{F}$ and $+4.2^{\circ}\text{F}$ using the six-month sample).

Pooling the two samples in the 060° to 140° sector, a bias of $+0.9^{\circ}\text{F}$ resulted for the 10-month sample, using the geostrophic wind (corresponding to a significance level of "t" between 5% and 10%), and in the 150° to 300° sector the resultant ten-month bias using the geostrophic wind was non-significant. It was decided that the new figures were not sufficiently different from the original ones to warrant altering refinements A or B.

4. DEPARTURE OF MONTHLY CONDITIONS FROM "AVERAGE"

Maine (1959) has suggested that the error in the objectively predicted maximum in any particular situation is a function of the departure from the "average" of the stream development associated with the initial conditions of wind, temperature, etc. It follows that a large number of abnormal stream developments during a specific month will increase the monthly error variance.

The "average" stream development mentioned previously was estimated by the basic January data used by Maine in the original derivation of the objective aid, namely 1955-1958.

An explanation of the lower error variances (obtained by straight-out application of Maine's method) in the four-month sample (1962-1965) compared with the six-month sample (1952-1954 and 1959-1961), would be that stream developments in the four-month sample approximated more closely to those in 1955-1958 than did stream developments in the six-month sample.

In the light of this suggestion, the following statistics are interesting:

Mean maximum temperature for months of January 1955 to 1958 (data used in derivation of Maine's method)	=	82.2 ^o F
Mean for January 1952 to 1954, 1959 to 1961	=	85.2 ^o F
Mean for January 1962 to 1965	=	81.5 ^o F

Subjectively, these figures seem to support the suggested explanation for the lower variances in the four-month sample compared with the six-month sample, but in themselves they are by no means conclusive. Abnormal stream developments would often have compensating effects on the mean maximum temperature. Also, an above-average mean maximum over a period could, for example, be due largely to a high frequency of northerly airstreams rather than to a systematic abnormality in stream developments.

Nevertheless (again subjectively) it seems plausible that months which are much warmer or cooler than average are more likely to be characterized by abnormal stream developments than are other months.

The foregoing discussion in this section does not alter the fact that straight-out application of Maine's method (using either the 2000 ft wind or the geostrophic wind) produced a significant positive bias in the northerly sector in "warm" and "cool" months alike. It is therefore logical to attempt to remove this bias, using refinements such as suggested in Section 3, thereby using an improved estimate of the "average" stream development associated with initial wind directions in the northerly sector.

5. CONCLUSIONS

- (1) Comparison of the Adelaide 3 a.m. 2000 ft wind and the geostrophic wind at the same time indicates that, when the two differ by more than 5 knots or 20 degrees, it is preferable to use the latter as a predictor in Maine's formula, and
- (2) when the direction of the isobars is between 310 and 050 degrees, the original prediction nomograms should be refined (Refinement A) so as to correct for positive bias.
- (3) Since the error in the objectively predicted maximum depends upon the departure of the stream development from the "average" associated with the initial conditions, subjective modification seems logical when "abnormal" stream development is indicated.

ACKNOWLEDGMENT

I wish to thank Mr. R. Maine, Central Office, Melbourne, for his constructive comments and suggestions.

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APPENDIX 1

MAXIMUM TEMPERATURE PREDICTION FOR ADELAIDE

The percentage reduction of insolation is obtained from Fig. 1a using Adelaide 6 a.m. cloud amount and type.

Fig. 1b is then used to obtain first estimate of range R' .

Correction D_1 is obtained from Fig. 1c using the Adelaide 6 a.m. temperature ($T_{6 \text{ a.m.}}$).

Correction D_2 is obtained from Fig. 1d using the Adelaide Airport 3 a.m. 2000 ft wind.

$$\text{Predicted maximum} = T_{6 \text{ a.m.}} + R' + D_1 + D_2.$$

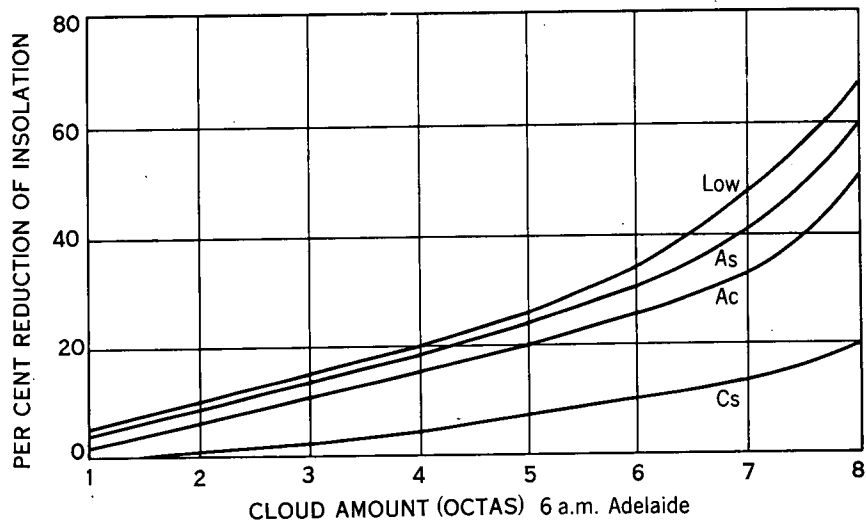


Fig. 1(a) Relation between cloud amount and per cent reduction of clear day average total insolation.

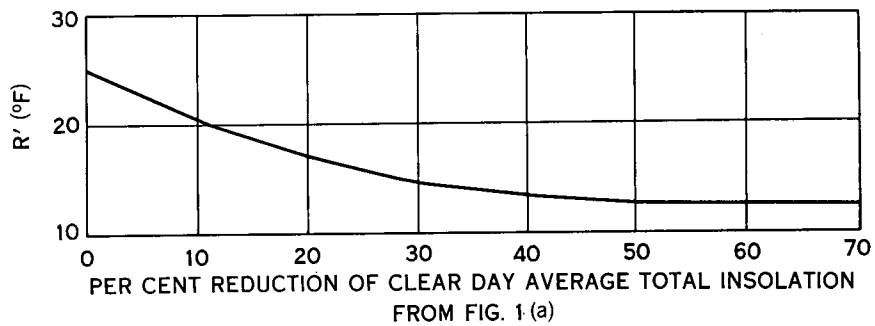


Fig. 1(b) Relation between R' (first estimate of range) and per cent reduction of clear day average insolation.

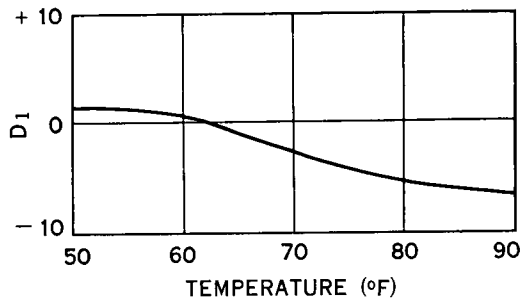


Fig. 1(c) Relation between correction D₁ and temperature 6 a.m. Adelaide.

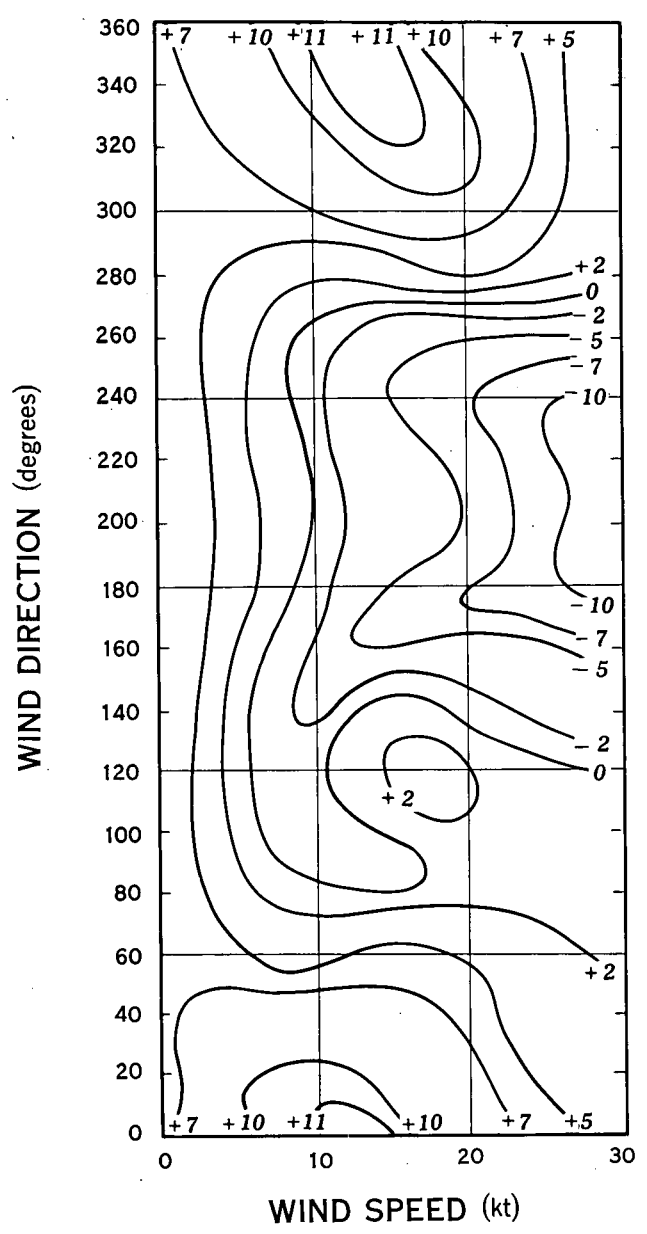


Fig. 1 (d) Curves of correction D_2 as related to 2000 ft wind at 3 a.m. Adelaide Airport.