A Trend in the Skill of Australian Temperature Forecasts

H. Stern, Regional Office, Bureau of Meteorology, Melbourne

Introduction

Stern (1980) analysed verification data for late afternoon forecasts of the next day's maximum and minimum temperatures. These data were for predictions issued to the general public of the six Australian State capitals, namely Hobart, Melbourne, Adelaide, Sydney, Perth and Brisbane (Figure 1), over the period 1964 to 1979, inclusive. He concluded that the skill displayed by these estimates increased, on the average, over this period. This paper updates this conclusion by performing a similar analysis on data over the period 1964 to 1984, inclusive.

Analysis of data

The temperature data are summarized in Figure 2, which depicts year-to-year fluctuations in the annual root mean square (rms) error of all temperature forecasts (maximum and minimum) at the six capitals. Figure 2 suggests that there was an increase in the accuracy of temperature forecasts over the period under consideration. To illustrate — only two of the rms errors for the latter eleven years were above the mean annual rms error for the entire period (2.18°C).

Forecast accuracy is a function of both forecast skill and forecast difficulty. Hence, year-to-year fluctuations and long-term trends in the accuracy of temperature predictions may be entirely due to corresponding fluctuations in the level of difficulty associated with forecasting that element. An analysis of the relationship between change in forecast accuracy (ΔA), from one year to the next, and change in forecast difficulty (ΔD), from one year to the next, was then made in order to test the validity of this proposition. The relationship was assumed to be linear and of the form:

$$\Delta A = C_0 + C_1 \Delta D \qquad (1)$$

where C_0 and C_1 are constants.

Gregg (1969) notes that temperature forecast errors increase with increasing temperature variability. For each of the 20 pairs of consecutive years from 1964–1965 (to 1983–1984), ΔD was set equal to the inter-annual change in the rms (°C) inter-diurnal change of all temperatures (maximum and minimum) at the six capitals. Similarly, ΔA was set equal to the inter-annual change in the rms (°C) error of all temperature forecasts. If we use these data, the constants C_0 and C_1 are found by regression analysis to be -0.0101 and 0.3675, respectively. The correlation coefficient r_1 was found to be 0.8569. The t distribution was then used to show by means of a two-tail test (Yamane, 1973) that r_1 is significant at well below the 0.01% level, that is, the probability of the absolute value of r_1 being as large as, or larger than, 0.8569 by chance, is well below 0.0001.

Stern (1980) used a slightly different approach to test the relationship between forecast skill and forecast difficulty. An analysis of the relationship between forecast accuracy, A, and forecast difficulty, D, was made, the form of this relationship being $A = C_0 + C_1 D$ where A was set equal to the annual rms error and D was set equal to the annual rms inter-diurnal change in temperature. The approach used in the present paper is considered preferable for, if a trend is indeed taking place in A, then the

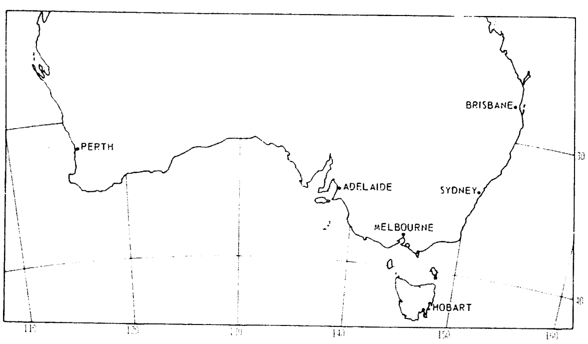

Figure 1 *Location of the six Australian State capitals whose temperature prediction data were analysed*

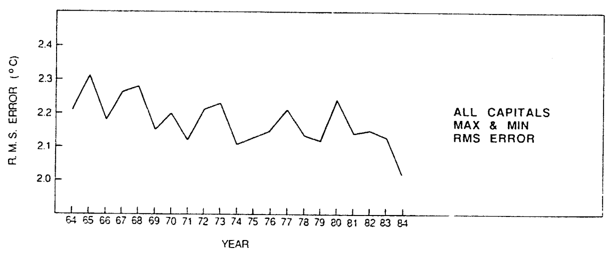

Figure 2 *Year-to-year fluctuations in the rms error (°C) of all temperature forecasts (maximum and minimum) at the six Australian State capitals over the period 1964 to 1984, inclusive*

relationship between A and D is weakened. Support for this proposition is given by the much lower correlation coefficient between A and D, 0.3686, than that between ΔA and ΔD.

Equation 1 was then solved for each of the 20 pairs of consecutive years from 1964–1965, the observed ΔDs being used to obtain expected values of ΔA and, hence, expected values of rms error subsequent to 1964. Year-to-year fluctuations in the parameter expected rms error minus observed rms error may be considered, at least in part, to be a consequence of corresponding fluctuations in predictive skill. The rms error data were 'normalized' to that of 1964 by subtracting, for each year following 1964, the parameter from the 1964 rms error. These normalized data are presented in Figure 3, and emphasize most strongly the marked increase in forecast skill that has taken place. To illustrate — from 1977 every normalized annual rms error was less than any recorded prior to 1977.

The significance of this apparent increase in forecast skill was then tested by analysing the relationship between forecast skill (S), represented by the normalized rms error, and time (T), represented by (year -1963) where:

$$S = C_2 + C_3 T \qquad (2)$$

where C_2 and C_3 are constants. If we use these data, the constants C_2 and C_3 are found by regression analysis to be 2.2655 and -0.0103, respectively. The correlation coefficient r_2 was found to be -0.8759. The t distribution was then used to show by means of a two-tail test that r_2 is significant at well below the 0.01% level.

In order to ascertain the specific contributions to this increase in the skill of temperature forecasting, the above analysis was performed on data for each of the twelve temperature forecasts under consideration (Hobart maximum, Hobart minimum, Melbourne maximum, etc.). Values of r_1 and r_2, and their associated levels of significance, are presented in Tables 1 and 2, respectively.

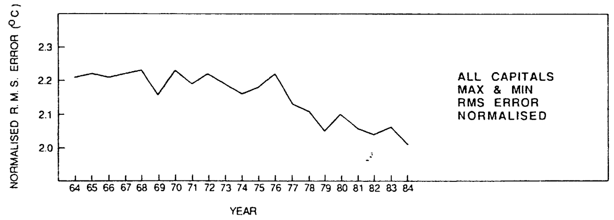

Figure 3 *Year-to-year fluctuations in the skill, represented by the normalized rms error (°C), of all temperature forecasts (maximum and minimum) at the six Australian State capitals over the period 1964 to 1984, inclusive*

The r_1 values are positive in all cases, and significant in most cases, so providing supporting evidence for the approach used to normalize the rms error data. The normalized data for each of the six maximum temperature forecasts are presented in Figure 4 and the normalized data for each of the six minimum temperature forecasts are presented in Figure 5.

The maximum temperature r_2 values are negative in all cases, and significant in all cases, so suggesting that maximum temperature forecast skill is increasing for all capitals. With regard to minimum temperature, the r_2 values suggest that forecast skill is significantly increasing only for Melbourne and

Table 1 Values of r_1 correlation coefficient and their associated levels of significance (significance levels are only given where they are 5% or less)

City	r_1	Significance
		(%)
All	0.8569	≪0.01
Hobart maximum	0.6752	0.1
Hobart minimum	0.6936	0.1
Melbourne maximum	0.7013	0.1
Melbourne minimum	0.4887	2
Adelaide maximum	0.4709	2
Adelaide minimum	0.6018	1
Sydney maximum	0.5503	1
Sydney minimum	0.2265	—
Perth maximum	0.2465	—
Perth minimum	0.7251	0.01
Brisbane maximum	0.8054	0.01
Brisbane minimum	0.7586	0.01

Table 2 Values of r_2 correlation coefficient and their associated levels of significance (significance levels are only given where they are 5% or less)

City	r_2	Significance
		(%)
All	−0.8759	≪0.01
Hobart maximum	−0.7727	0.01
Hobart minimum	−0.0208	—
Melbourne maximum	−0.5759	1
Melbourne minimum	−0.4982	2
Adelaide maximum	−0.4692	4
Adelaide minimum	−0.4032	5
Sydney maximum	−0.4446	3
Sydney minimum	−0.0320	—
Perth maximum	−0.4600	3
Perth minimum	−0.7976	0.01
Brisbane maximum	−0.3904	5
Brisbane minimum	−0.4095	5

Perth and that, for Brisbane, forecast skill is significantly decreasing.

Discussion

Stern (1980) explained the trend towards increasing skill that he noted, in terms of the advent of: (a) satellite cloud imagery, (b) numerical predictions of atmospheric flow, (c) buoy data, and (d) local objective forecasting aids. The addition of verification data over the 1980–1984 period supports these conclusions. Firstly, the most significant improvement in maximum temperature forecasting occurred at the two more southerly locations, Hobart and Melbourne, where (a) and (b) would be expected to play a major role in the prediction of fronts. Secondly, the notable performances in maximum temperature forecasting at Hobart, Melbourne and Perth in 1979 (Figure 4) may be explained in terms of the numerous buoys deployed during that year as part of the First Garp Global Experiment. Finally, in the earlier paper, Stern (1980) explained Perth's performance in minimum temperature prediction in terms of an objective forecasting aid and Figure 5 suggests that the increased skill levels are being maintained.

There are features depicted on Figures 3, 4 and 5 that are difficult to explain, for example:

(a) the lack of increase in skill between 1964 and 1976 (Figure 3);
(b) the apparent decrease in skill at predicting Melbourne's maximum temperature, between 1964 and 1971 (Figure 4);
(c) the apparent decrease in skill at predicting Brisbane's minimum temperature (Figure 4) supported by its r_2 value.

In the absence of any sound explanations being forthcoming, one can only speculate about the causes.

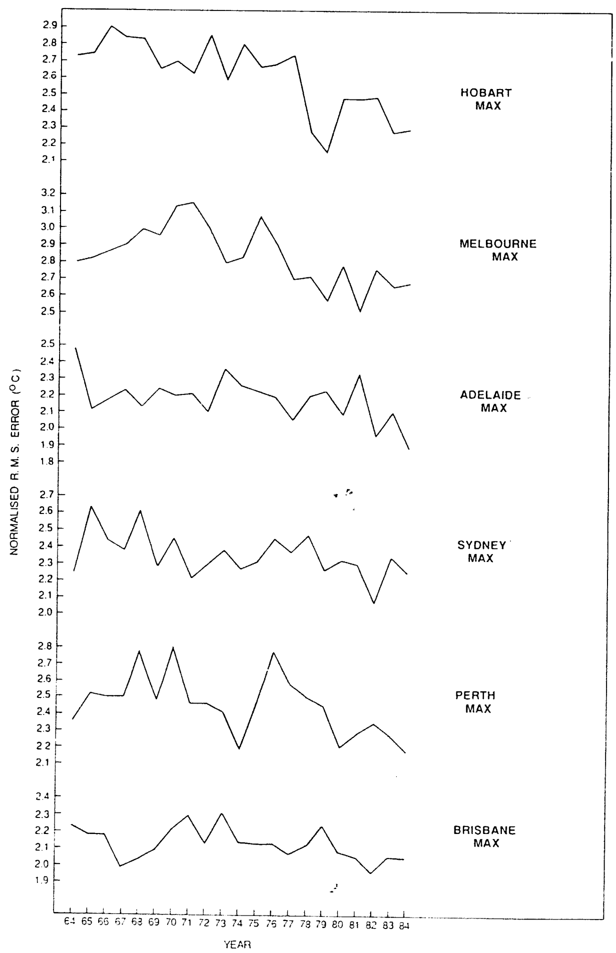

Figure 4 *Year-to-year fluctuations in the skill, represented by the normalized rms error (°C), of maximum temperature forecasts at each of the six Australian State capitals over the period 1964 to 1984, inclusive*

Conclusion

It has been shown that the trend towards increasing skill by late afternoon predictions of the next day's maximum and minimum temperatures at the six Australian State capitals, identified by Stern's (1980)

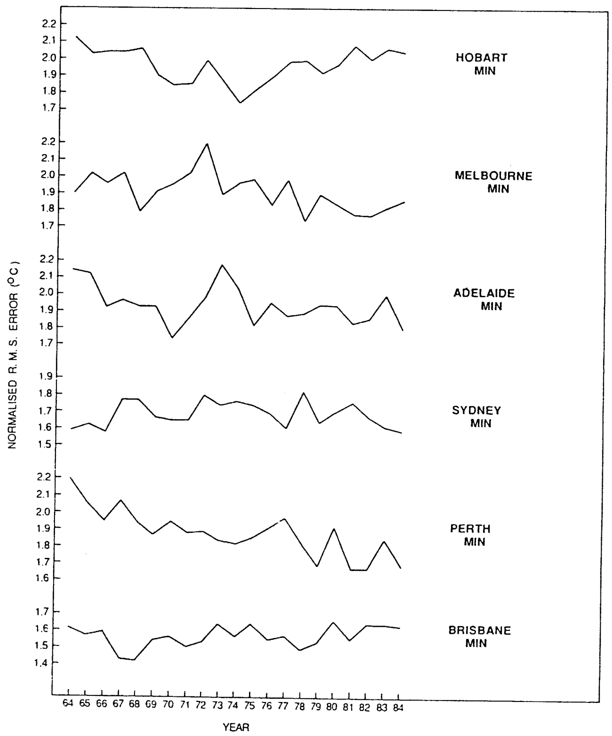

Figure 5 *Year-to-year fluctuations in the skill, represented by the normalized rms error (°C), of minimum temperature forecasts at each of the six Australian State capitals over the period 1964 to 1984, inclusive*

analysis of 1964–1979 verification data, is confirmed by a similar analysis on a data set including data from the past five years, namely 1964–1984.

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References

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