551.524.36(548.1)

A statistical study of daily maximum temperatures at Madras during the summer months

T. R. SRINIVASAN and S. S. HASHIM

R-gional Meteorological Centre, Madras

(*Received 6 September 1965*)

ABSTRACT. Daily maximum temperature data of Madras for the months April, May and June for the period 1945-1964 have been analysed. The frequency of spells of days having the same type of maximum temperature tendencies appear to follow a random probability model $s_x = Kp^x$, K and p being the parameters determinable from the data, s_x representing the frequencies of spells of x days duration. It is also shown that low level wind field over Madras and Anantapur at 00Z can be utilised in predicting the day's maximum temperature. Maximum temperature forecast diagrams for May, the hottest month, have been constructed on the basis of graphical integration method; and utility of these diagrams discussed.

1. Introduction

A number of articles are available in the meteorological literature in recent years on objective methods of forecasting of various weather elements although only a few of these studies have shown significant improvement over conventional forecasting techniques. In the present note, an attempt has also been made to study the persistence of maximum temperature tendencies over the same station during April, May and June. An objective method of forecasting the maximum temperature is suggested for the month of May based on the prior knowledge of the wind field at 00 GMT over the lower levels of Madras (Lat. 13° 00′ N, Long. 80° 11 ′E) and Anantapur (Lat. 14° 41′N, Long. 77° 37′E). The orientation of Madras with reference to Anantapur is about 120°. This study is based on the 20 years (1945—64) daily maximum temperature record of Madras (Meenambakkam Observatory).

2. Maximum (day) temperature tendency

The daily maximum temperature data of the 20-year period have been analysed to study the distribution of spells of days with the maximum temperature having the same tendency (24-hour change), *i.e.*, either increasing (positive) or decreasing (negative). Table 2 represents frequencies of both positive and negative tendencies for various duration x in days. It is seen from the actual values given in Table 1 that a functional form of the type $s_x = Kp^x$ as suggested by Srinivasan (1956) in earlier similar study can be used to describe the above distribution. s_x and x represent the frequency and duration of spell in days respectively. The parametres K and p are given as —

$$p = \frac{T_1 - S}{T_1},\quad K = \frac{S}{T_1 - S}$$

$$\text{where, } S = \Sigma\, s_x = \frac{K_p}{1-p}$$

= Total number of sequences

$$T_1 = \Sigma x s_x = \frac{Kp}{(1-p)^2},$$ the first moment of the distribution.

The values of S, T_1, K and p for the distribution are given in Table 1.

It will be seen that the value of K for the decreasing tendency is larger than that of increasing tendency and the persistence coefficient is greater for increasing tendency indicating that the maximum temperature rise takes place gradually while the decrease of maximum temperature takes place much more rapidly. Table 1 also contains the computed frequencies. It is seen that the agreement between the actual and the computed value is satisfactory particularly in the case of rising tendency. Hence the model Kp^x provides a fairly satisfactory objective assessment of the probability of occurrence of any length of spell of rising or falling day temperatures.

In this connection it was also found necessary to confirm whether the sequence of the two types of tendencies are randomly distributed. Table 2 gives the contingency table in which the cell frequencies namely (1) Day with increasing day temperature followed by a day of further increase, (2) Day with increasing day temperature followed by a day of decrease, (3) Day with decreasing temperature followed by an increase and (4) Day with decreasing temperature followed by further decrease.

χ^2 test was applied to the data to find out the association between two types of tendencies. The value of χ^2 works out to be 2·01 which confirms the random distribution of the frequencies given in Table 2.

TABLE 1

Length of spell (days)	Increasing tendency			Decreasing tendency		
	Actual	Calculated		Actual	Calculated	
1	185	196·8	$S=433$	209	224·1	$S=433$
2	113	108·2	$T_1=957$	106	109·8	$T_1=843$
3	63	59·5	$K=357·8$	72	53·6	$K=457·8$
4	41	32·7	$p=0·55$	31	26·3	$p=0·49$
5	10	18·0		8	12·9	
6	10	9·9		7	6·3	
7	7	5·4				
8	2	3·0				
9	2	1·7				

TABLE 2

Tendency on the preceding day	Tendency on the following day		
	Increase	Decrease	Total
Increase	524	433	957
Decrease	433	410	843
Total	957	843	1800

3. An objective method of predicting the maximum temperature tendency at Madras in May

The city of Madras has relatively low daily maximum temperatures during the hot months April to June in view of its proximity to the sea. During this season, rise or fall of temperatures above or below the normal values occur on quite a number of occasions. The northward movement of sun shifts the thermal equator rendering May the hottest of the months. The occurrence of the significant rise or fall of maximum temperatures is considerably influenced by (*a*) the time of onset of the sea-breeze, (*b*) the advective transfer of hot continental air from Rayalaseema and its further heating by adiabatic processes. On a number of occasions during the month of May it has been noticed that the prevailing day time low level westerlies are sufficiently strong to arrest or delay the setting of the sea-breeze current. On such occasions one naturally expects that the day temperature will go on steadily rising during the day time in view of the absence of well defined sea-breeze. Hence the strength of the westerlies at Madras may naturally be selected as a parameter for the temperature forecast. Since the advective transfer of hot continental air from Rayalaseema also contributes to the rise in the day temperature at Madras the prevailing low level wind from a representative station (Anantapur) in the region was considered as another parameter.

Daily upper wind data of 2000, 3000 and 5000 ft a.s.l. for Madras and Anantapur for the month of May for the year 1958, 1964 were collected and used in this study. The daily values of winds of Madras and Anantapur were resolved into components along the orientation, Anantapur—Madras line. The range of those component values at 3000 and 5000 ft with the corresponding surface maximum temperature tendency at Madras is shown in Table 3. (The wind components at 2000 ft and the maximum temperature of Madras rather show indifference association and as such these are not included in the table).

The following are the salient features shown by Table 3—

(*a*) *3000 ft wind components*

It is seen that the chance of positive temperature tendency at Madras varies from 0·5 to 0·7 when wind component at this station ranges from —10 to +14 knots. The component towards Madras has been taken as positive. Outside this range, falling temperature tendency is more likely.

The chance of positive tendency at Madras is generally of the order 0·6 to 0·7 when the wind components are positive at Anatapur.

(*b*) *5000 ft wind components*

It is seen that the chance of a positive temperature tendency at Madras varies between 0·6 to 0·7 when the wind component varies from —5 to +9 knots at Madras. Outside this range the falling temperature tendency is having more chance. On the other hand, the chance of positive tendency varies between 0·5 to 0·8 when the wind components at Anantapur are in the range —10 to +21 knots.

Table 3 gives the association of the temperature tendency at Madras with the wind components at Madras and Anantapur. It is seen that the 3000 and 5000 ft winds give more or less similar satisfactory results. Therefore it was considered worthwhile to examine how far this association could be utilised for the prediction of maximum temperature.

TABLE 3

Wind components along the orientation, Anantapur-Madras

Range of wind components (knots)	3000 ft Madras Temperature tendency at Madras +	—	0	T	3000 ft Anantapur Temperature tendency at Madras +	—	0	T	5000 ft Madras Temperature tendency at Madras +	—	0	T	5000 ft Anantapur Temperature tendency at Madras +	—	0	T
⩾25	2 (29)	5 (71)	0 (0)	7	4 (67)	2 (33)	0 (0)	6	1 (25)	3 (75)	0 (0)	4	3 (43)	4 (57)	0 (1)	7
20 to 24	8 (42)	11 (58)	0	19	13 (57)	10 (43)	0 (0)	23	1 (20)	4 (80)	0 (0)	5	8 (50)	8 (50)	0 (0)	16
15 to 19	7 (39)	10 (55)	1 (6)	18	23 (52)	20 (46)	1 (2)	44	4 (44)	5 (56)	0 (0)	9	11 (50)	10 (45)	1 (5)	22
10 to 14	12 (60)	7 (35)	1 (5)	20	31 (63)	17 (35)	1 (2)	49	8 (35)	13 (56)	2 (9)	23	16 (46)	19 (54)	0 (0)	35
5 to 9	19 (68)	7 (25)	2 (7)	28	14 (44)	17 (53)	1 (3)	32	29 (73)	10 (25)	1 (2)	40	26 (79)	6 (18)	1 (3)	33
0 to 4	26 (62)	15 (36)	1 (2)	42	14 (67)	7 (33)	0	21	27 (62)	16 (36)	1 (2)	44	19 (50)	18 (47)	1 (3)	38
—5 to —1	22 (54)	17 (41)	2 (5)	41	7 (47)	6 (40)	2 (13)	15	29 (56)	21 (40)	2 (4)	52	18 (60)	9 (30)	3 (10)	30
—10 to —6	16 (52)	13 (42)	2 (6)	31	7 (47)	6 (40)	2 (13)	15	13 (45)	14 (48)	2 (3)	29	12 (63)	6 (32)	1 (5)	19
—15 to —11	2 (40)	3 (60)	0	5	5 (46)	4 (36)	2 (18)	11	2 (40)	2 (40)	1 (20)	5	2 (22)	7 (78)	0	9
⩽—16	2 (67)	1 (33)	0	3					2 (100)	0	0	2	2 (33)	2 (34)	2 (33)	6
Total	116	89	9	214	118	89	9	216	116	88	9	213	117	89	9	215

Figures in brackets indicate percentage frequencies

4. Maximum temperature forecast diagram for Madras

As already stated in the earlier part of this paper, the persistent behaviour of temperature condition (after effect) can also be chosen as an additional parameter for our problem. Therefore, the following three parameters have been considered to prepare the maximum temperature prediction diagram—

(1) Wind components at 00 GMT of date at Madras at 3000 ft along the direction Anantapur—Madras.

(2) Wind components at 00 GMT of date at 3000 ft at Anantapur along the same direction.

(3) The previous day's maximum temperature at Madras

Let T_x be the predictant,

$$T_x = f\ (T_x - 1,\ W_A,\ W_M)$$

where $T_x - 1$ refers to the previous day's maximum temperature and W the wind parameter at 00 GMT of date at the two stations respectively. Problems of this type are usually solved by fitting a multiple regression equation. Obviously the method will become laborious even when the relationship of the predictant with the predictors is assumed to be linear. Several authors notably Thompson, Brier, Beebe have approached such problems by graphical integration methods. The construction of the diagram is based on the approach of the authors mentioned above.

5. Brief description of the method of the construction of diagrams (Fig. 1)

The abscissa refers to the wind components over Madras and the ordinates those over Anantapur. Corresponding to certain values of the wind components of these stations, the maximum temperature realised on that day is plotted. Thus we get a scatter diagram showing the dispersal of maximum temperature corresponding to different wind component values. In this diagram we get a number of frequency distribution of maximum temperatures for the specified wind component interval. The mean value of the maximum temperatures found in this interval is calculated and plotted at the centre of the interval square. Similarly, mean temperature values were determined for all the various squares and plotted at their centres. Then isolines of these mean values were drawn at 1°C interval. Using the temperature values in Fig. 1 as the abscissa and the previous day's maximum temperature as the ordinate the final forecast diagram is constructed on the same lines as shown in Fig. 2.

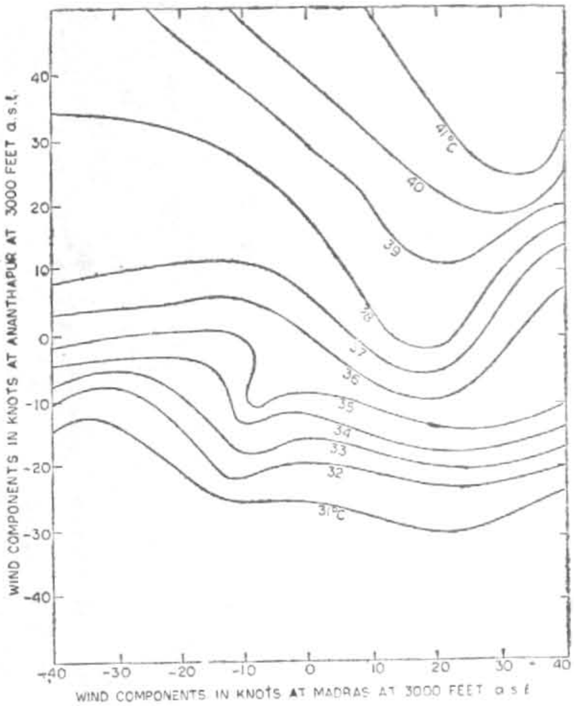

Fig. 1

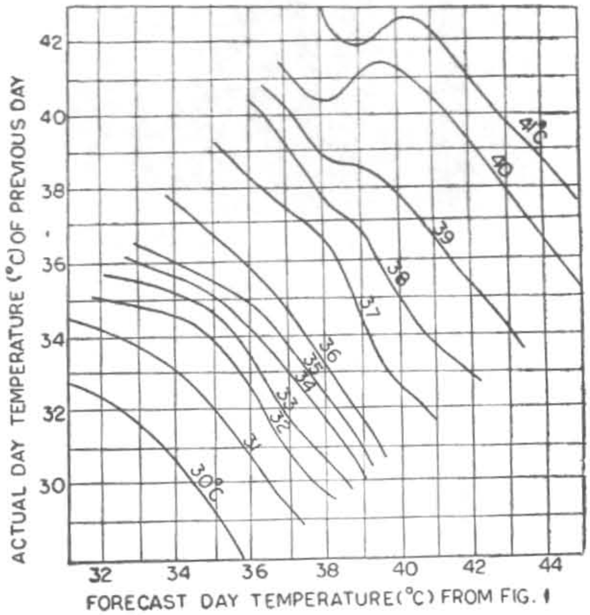

Fig. 2

6. Test results

The independent data for the month of May for years 1955, 1956, 1957 and 1965 were put to test with reference to these forecast diagrams. Table 4 gives the results of the test in which are given the absolute value of the error against the actual maximum temperature realised on the day for the different class intervals of 2°C.

It is seen that out of 115 days considered for testing the result, 78 per cent of the days had the maximum temperature between 34°C to 40°C. It is also seen that when the temperatures ranged between 34° to 36°C, 36° to 38°C and 38° to 40°C, the forecasts were correct within one degree centigrade on 62, 68 and 77 per cent of the occasions respectively. But it is noticed that when actual day temperatures are less than 34°C, the results are not so satisfactory. On a scrutiny of the test data it was seen that on markedly rainy days the temperatures are very much below the normal May values. In constructing the forecast diagrams we have not taken into account the precipitation parameter. Perhaps omission of this parameter might have contributed to the larger magnitudes of errors when actual temperatures are less than 35°C.

TABLE 4

Test data for May 1955, 1956, 1957 and 1965

Error distribution in degrees centigrade

Magnitude of error in absolute values

Actual temp. range	⩽ 1·0	1·1-2·0	>2·0	Total
30·1—32·0	1	0	1	2
32·1—34·0	1	0	7	8
34·1—36·0	16	4	6	26
36·1—38·0	28	9	5	42
38·1—40·0	17	5	0	22
40·1—42·0	6	5	2	13
>42·0		1	1	2
			Total	115

7. Acknowledgement

The authors desire to express their grateful thanks to Shri N. C. Rai Sircar, Director, Regional Meteorological Centre, Madras for his encouragement and guidance in the preparation of the paper. Their thanks are also due to Shri S. Jayaraman for various help and suggestions.

REFERENCES

Beebe, R. G. 1950 *Mon. Weath. Rev., Wash.*, **78**, pp. 59-68.

Brier, G. W. 1945 Predicting occurrence of winter time precipitation for Washington, D.C., U.S. Weath. Bur., Washington, D.C

Srinivasan, T. R. 1956 *Indian J. Met. Geophys.*, **10**, pp. 105-106.

Thompson, J. C. 1950 *Mon. Weath. Rev., Wash.*, **78**, pp. 113-124.