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Relationship of mean temperatures with screen temperatures

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सार — इस शोध पत्र में रिकार्ड किए गए अधिकतम तथा न्यूनतम तापमानों में से दैनिक माध्य तापमानों तथा कृषि मौसम वैज्ञानिक वेधशाला में स्वचालित मौसम केन्द्र द्वारा रिकार्ड किए गए तापमानों में से लिए गए तापमानों में विभिन्नता के अध्ययन का प्रयास किया गया है।

दैनिक अधिकतम तथा न्यूनतम तापमानों के रिकार्ड से प्राप्त माध्य तापमान सितम्बर से मई के दौरान स्वचालित मौसम केन्द्र द्वारा इसी अवधि में घंटेवार रिकार्ड किए गए तापमानों की तुलना में - 1.5 से 1.5 ° से. के बीच प्रबल तथा घटते-बढ़ते पाए गए हैं। तथापि मई से सितम्बर के दौरान ये दैनिक माध्य तापमान स्वचालित मौसम केन्द्र से प्राप्त माध्य तापमानों की तुलना में अधिक पाए गए हैं। घंटेवार तापमानों के आकलन के लिए स्वचालित मौसम केन्द्र के रिकार्ड से विभिन्न सहसंबंध निकाले गए तथा विलियम और लोगन (1981) नामक मॉडल की तरह एक मॉडल विकसित किया गया। इस प्रकार से आकलित घंटेवार तापमान तथा दैनिक तापमान स्वचालित मौसम केन्द्र द्वारा इसी प्रकार प्राप्त किए गए वास्तविक घंटेवार तथा दैनिक तापमानों के सही ढंग से अनुरूप पाए गए हैं।

इसलिए, इस मॉडल का प्रयोग करते हुए अधिकतम तथा न्यूनतम तापमानों के रिकार्ड से सही दैनिक माध्य तापमान का आकलन किया जा सकता है।

ABSTRACT. An attempt has been made to study the variation in daily mean temperatures obtained from maximum and minimum temperatures and that obtained from hourly temperatures recorded by the automatic weather station at the Agrometeorological Observatory, Anand (Gujarat).

The mean temperatures obtained from the records of daily maximum and minimum temperatures were higher and fluctuated from -1.5 to 1.5°C during the months of September to May as compared to the respective values obtained from hourly temperatures recorded by the automatic weather station. However, during May to September, these daily mean temperatures were found to be higher than mean temperatures obtained from the automatic weather station. Different coefficients were deduced from the records of the automatic weather station to estimate the hourly temperatures and a model was developed similar to that of William and Logan (1981). The hourly temperatures and the daily mean temperatures so estimated were in good agreement with the respective actual hourly and daily temperatures record by the automatic weather station.

Therefore, by using this model one could estimate the true daily mean temperature from the records of maximum and minimum temperatures.

Key words — Temperature. Daily mean temperature, Diurnal range of mean temperature.

1. Introduction

Air temperature exerts a marked influence on plant growth and development. Temperature has direct effect on the rate of biochemical reaction and thereby also on the rate of growth of plants. The diurnal and seasonal temperature patterns affect the structure of indigenous vegetation. These also influence to a considerable degree, the species of field crops which can be grown in a given region. The duration of a particular stage of growth of crop was directly related to the temperature and that this duration for particular species could be predicted using the sum of daily mean air temperatures (Wang 1960). This procedure for normalizing the growth time with means of maximum and minimum temperatures to predict the plant development rate has been in use widely now-a-days in crop-weather modelling. Several synonymous terms have been used to describe the

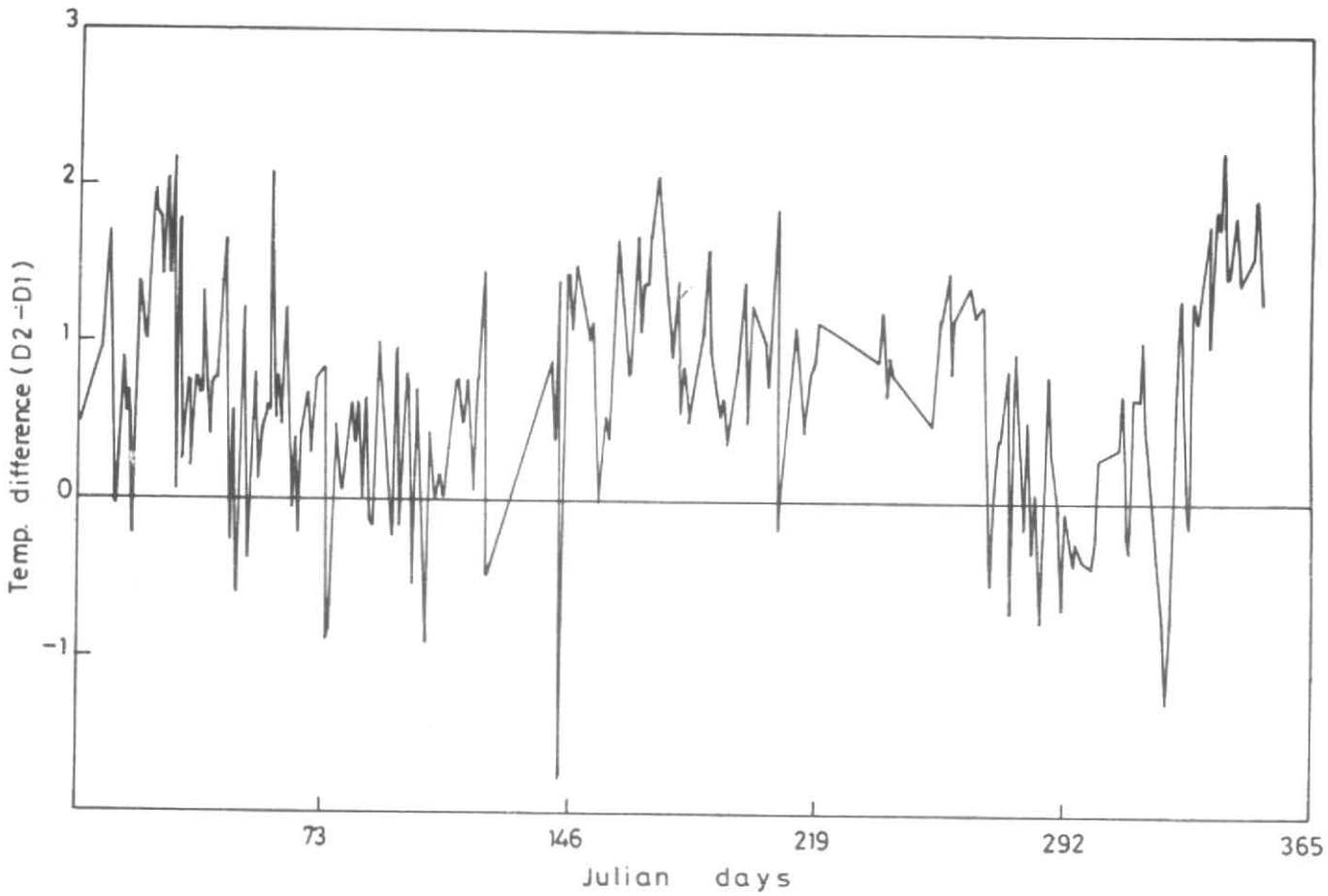

Fig.1. The difference of daily mean temperature calculated from maximum and minimum temperature (D2) and mean temperature calculated from hourly records (D1)

process of summation of temperatures to predict the plant growth duration (Nuttonson 1955). These terms have been included in Soybean Development Unit (Brown and Champman 1961), Ontario corn heat unit (Brown 1975) and Biometeorological time scale (Robertson 1968). In this procedure there are some sources of uncertainties.

Most of the maximum and minimum temperatures are recorded by liquid-in-glass thermometers exposed in the Stevenson screen (Epperson and Dale 1983). These observations are made only once a day by using separate thermometers for measuring maximum or minimum temperatures. The major discrepancy will occur when a cold or warm air mass moves into the area near the beginning or end of the daily temperature record. Three years of maize growing season in East Lansing, demonstrated that there were, between the years and within the year, differences between the mean temperature calculated using the maximum and minimum temperature values and the mean temperature obtained by averaging the values of temperatures recorded every minute. The total of differences amounted to 25 to 100 ° cd^{-1} (Ritchie and Nesmith 1991). In view of the fact an analysis was carried out to obtain with the help of a developed model (William and Logan 1981) true daily mean temperatures from the manually recorded maximum and minimum temperatures for predicting diurnal changes in air temperatures.

2. Data collection

The mean hourly temperatures recorded in the automatic weather station (Campbell USA) installed at the Agrometeorological Observatory of the Department of Agricultural Meteorology, B.A. College of Agriculture, Gujarat Agricultural University, Anand Campus, Anand (22.33° N, 72.55° E, msl 45 m) for the year 1992 were used to derive the constant in the temperature functional equation (William and Logan 1981). Manually recorded maximum and minimum temperature in the agrometeorological observatory were also used for the same period.

3. Model description

The mathematical descriptions of day time and night time temperatures recorded by William and Logan (1981) were used to estimate temperatures at specified hours. The relationships are reproduced here.

3.1. *Model for daytime temperature*

To find out the daytime temperature at a specified hour (*T*hr)d, the sine function used is given below:

$$(T\text{hr})d = (Tx\text{-}TN) \sin [3.14m/(Y+2a)] + TN \quad (1)$$

Where Y is day length in hour, $(T\text{hr})d$ is the temperature at the specified hour (hr) in a day and Tx and TN are the maximum and minimum temperatures of the specified julian day respectively. The parameter 'm' is the number of hours between the time of occurrence of minimum temperature and the time of sunset while 'a' is the lag coefficient for the maximum temperature.

Calculation of m and Y is shown in the Appendix.

3.2. *Model for night time temperature at the specified hour*

To find out the night time temperature at a specified hour $(T\text{hr})n$ the exponential function used is given as follows:

$$(T\text{hr})n = (TN) + (Ts\text{-}TN) \exp(-bn/Z) \quad (2)$$

Where, Ts is the temperature at the time of the sunset which is calculated from the Eqn.(1), TN is the minimum temperature of the specified julian day and b is the night temperature co-efficient.

Calculation of the variable 'n', *i.e.*, the number of hours after sunset to the time of the minimum temperature and night length z are shown in Appendix where n and z are functions of the time of the day. A sample computation also was presented in the Appendix.

3.3. *Parameter estimation*

All the calculations have been made by taking local mean time wherever the time is required. The lag coefficient 'a' for the maximum temperature is given by,

$$a = tix - 12.00 \quad (3)$$

Where *tix* is the time of occurrence of the maximum temperature. Similarly the lag coefficient 'b' for the night time temperature is obtained from the following formula,

$$b = \ln[(Ts\text{-}TN)/(Ti\text{-}TN)]z/n \quad (4)$$

provided $Ti\text{-}TN > 0$ and $Ti\text{-}Tx$ should not be large.

Where, Ts is the temperature at the time of sunset. TN is the minimum temperature of the specified julian day and Ti is the temperature at the specified hour. Likewise the lag coefficient 'c' for minimum temperature is given by,

$c = tin - tsR$, where *tin* is the time of occurrence of minimum temperature and *tsR* is the time of sunrise. Only the values obtained from records of automatic weather station were used to determine the co-efficients a, b and c.

The average estimated parameter values of 365 days for a, b and c so obtained were 2.69, 1.423 and -1.785 respectively at the height 1.25 m.

4. Results and discussion

The temperature data observed at the agrometeorological observatory as well as the data recorded by the automatic weather station for the year 1992 were used to estimate the hourly temperature by the model and different coefficients required to estimate it were worked out. The details of the results are presented below.

4.1. *Variation of temperatures*

The daily differences between mean temperatures obtained from maximum and minimum temperatures recorded manually from liquid-in-glass thermometers in the observatory (D2 method) and that obtained from the automatic weather station recorded at every hour (D1 method) are depicted in Fig.1. Three distinct periods of characteristic variation, *viz.*, (*i*) 5 December to 26 May (340 to 147 *j* day), (*ii*) 27 May to 22 September (148 to 266 *j* day) and (*iii*) 23 September to 4 December (267 to 339 *j* day) were noticed.

During the first period, the mean temperatures obtained by D2 method [*i.e.*, (max. + min.) / 2] were higher than those obtained by D1 method (*i.e.*, the temperatures recorded every hour by the automatic weather station), for most of the days except a few. These differences ranged from -1 to 2°C. In the second period, D2 > D1, for almost all the days. In contrast to these in the third period D1 > D2 except for a few days. The daily differences of mean temperatures during the first period (5 December to 26 May) were in the decreasing order and D2 was higher in the beginning.

After 32nd julian day, the differences were less as compared to the previous days. This type of variation may be due to the addition or removal of the energy by advection. Similar differences were also observed by Schaal and Dale (1977).

Biases in the manual measurement of temperature were also found to average about 0.5 to 1.5° cd^{-1} by Epperson and Dale (1983). In the present study also the differences of these types amounted on an average, to 1-2° cd^{-1}. This indicated that the mean temperature obtained from the maxi-

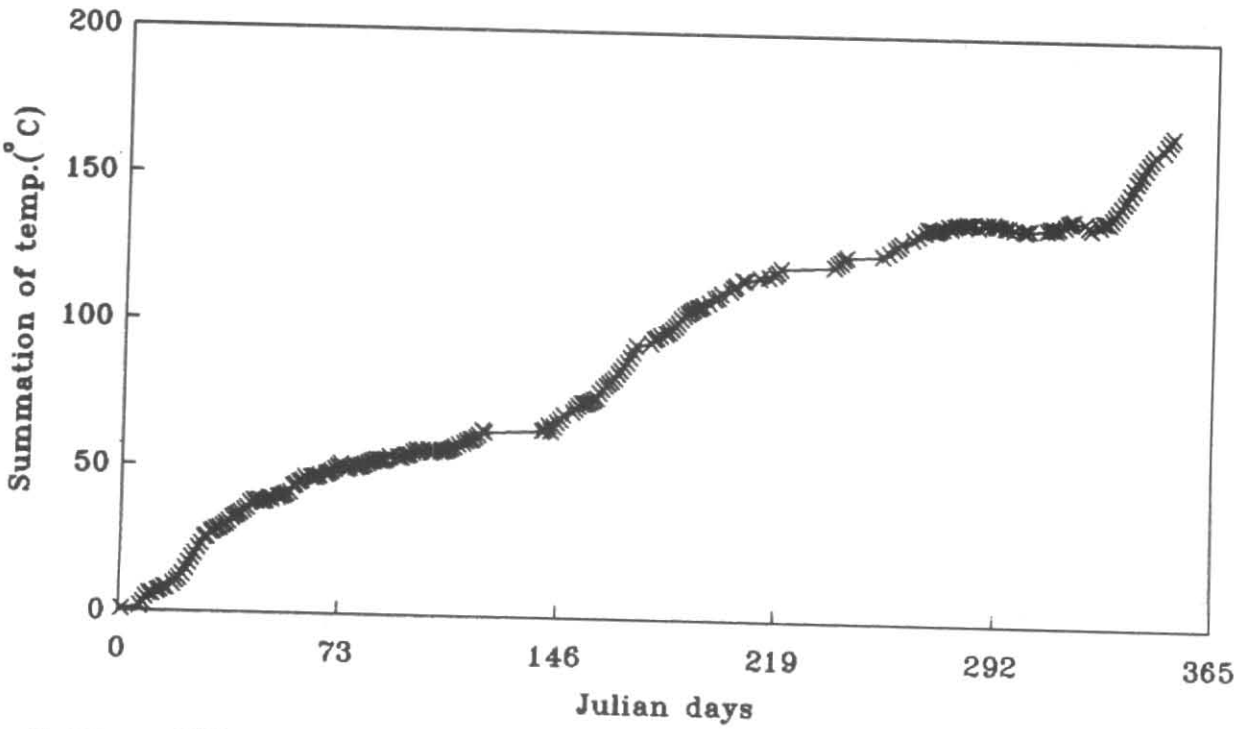

Fig.2. The sum of differences calculated from mean temperature from daily maximum and minimum and daily mean temperature calculated from hourly records

mum and minimum values were higher than the mean daily temperatures obtained from hourly values of the day.

The algebraic summation of the differences for 350 days is depicted in Fig.2. It indicated that the cumulative differences were in the increasing order, *i.e.*, D2>D1 for most of the days and the total summations came out to nearly 170°C. This error would associate itself in the calculation of the thermal time for growth and development of plant that would be used in the crop weather model.

4.2. *Estimation of hourly temperatures*

Eqns.(1) & (2) were used to obtain hourly temperatures for specific hours during the days and night. The hourly mean temperatures and the time of occurrence of maximum and minimum temperatures of 345 days recorded by the automatic weather station were used to estimate the lag coefficients '*a*', '*b*' and '*c*'. The computer program in Fortran language was developed for the estimation of the coefficients. The average values of all the respective coefficients were used to estimate the hourly temperatures, which were then compared with the actual values as recorded by the automatic weather station (The details of the mathematical calculation have been presented in Appendix). The difference between the daily mean of hourly temperatures as recorded by the automatic weather station and as predicted by the model were found to be statistically insignificant when tested by Student's 't' and Chi-square tests.

The comparison of hourly temperatures recorded by the automatic weather station with the predicted values for 13, 158 and 268 julian day is graphically shown in Fig.3. It showed that except for the period 0500 to 1400 hr the predicted values were consistent with the values of the automatic weather station. However, when hourly mean temperatures were used to obtain the daily means, these differences were negligible.

The estimated temperatures between 0500 to 1400 h are higher due to the facts that soil surface acts as a sink for the energy during these period which causes lag of time to attain the temperatures whereas estimated values are based on mathematical relation and do not take into account such a factor.

The predicted hourly temperatures were used to obtain the daily mean temperatures which were compared with actual mean temperatures calculated from recorded hourly temperatures by the automatic weather station. The comparison is graphically shown in Fig.4. The differences between these two mean temperatures on daily basis were almost less than 1.5°C. Thus, it indicated that simulated daily mean temperatures were comparable with those obtained from the observed data and their respective differences were insignificant when tested by Student's 't' and

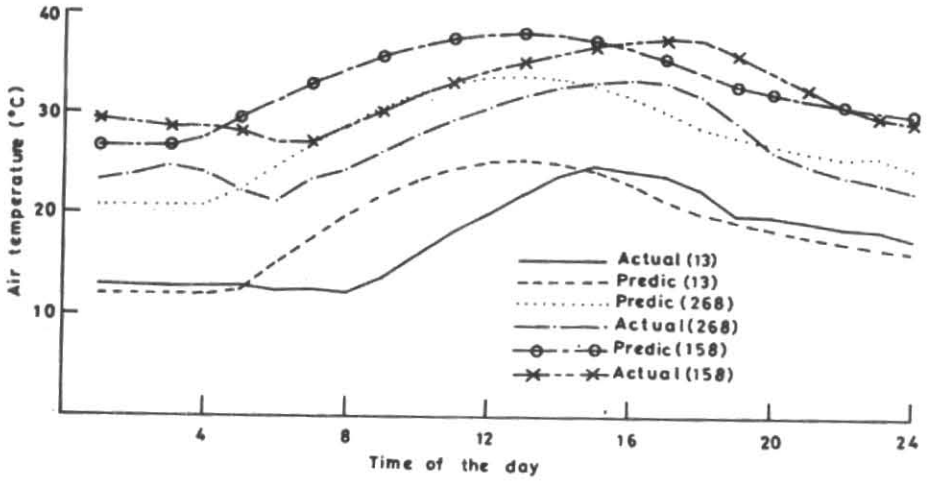

Fig.3. Actual and estimated air temperature for selected days

Chi-square tests. Similar result was also reported by William and Logan (1981).

5. Conclusion

Understanding of the temperature response of crop growth and development is important in building crop-weather model. The thermal time concept is useful but leads to an error with the use of only maximum and minimum temperatures. The daily mean temperatures obtained from maximum and minimum temperatures (D2) were found to be higher than those obtained from hourly records of automatic weather station (D1). This would lead to an error in the thermal time calculation. So functional model of the type suggested by William and Logan (1981) could be used to obtain the hourly temperatures and thereby daily mean temperatures with more precision in working out the thermal time.

The input data required to estimate the hourly temperatures by the model are maximum and minimum temperatures recorded manually with the help of screen thermometer. The lag coefficients '*a*' for day time temperature, '*b*', for night time temperature, '*c*', for minimum temperature are also required. Temperature recorded for every minute in the automatic weather station are required for estimation of these coefficients. The values of the coefficients *a*, *b* and *c* so obtained were 2.69, 1.423 and -1.725 respectively. The result indicated that the estimated daily mean values were in close agreement with the corresponding actual values recorded by automatic weather station.

APPENDIX

(a) *Calculation of 'Y', 'Z', 'm' and 'n'*

$Y = 24\ (u/3.14)$, where $u = \tan^{-1}\ (Tm_1/Tm_2)$

$Tm_1 = [1-\{-\tan(\text{latitude in radian of a station})D\}^2]^{1/2}$

$Tm_2 = [-\tan(\text{latitude in radian of a station})\tan(D)]$,

$D = (0.4014)\ \sin\ [6.28(\text{jday-}77)/365]$ and $Z = 24\text{-}Y$

Now, if $tb < tr < te$ then $m = tr - tb$ where, tr = hr *i.e.*, specified hour at which temperature has to be found out and $tb = 12\text{-}Y/2+C$, $te = 12+Y/2$ under such condition,

$Thr = (Tx\text{-}TN)\ \sin\ [3.14m/(Y+2a)]+t_N$

Now, $n = tr\ \text{-}te$ when $tr > te$, and $tn = (24+te)+tr$ when $tr < tb$

Here $Thr = TN+(Ts\text{-}TN)\ \exp(\text{-}bn/Z)$

Where $Ts = (Tx\text{-}T_N)\ \sin[3.14(Y\text{-}C)/(Y+2a)]+T_N$

(b) *Calculation of temperature at 0500 and 1800 hr, for the 320 Julian day 1993*

The input data required are temperatures and latitude. Here, Max. = 32, Min. = 20.5 and latitude 23.58° = 0.4 radian

(c) *Calculation of day length (Y) and input night length (Z)*

$D = 0.4014\ \sin[6.28(320\text{-}77)/365]=\text{-}0.35$,
$Tm_1 = 0.988$, $Tm_2=0.15$

$u = \tan^{-1}(0.988/0.15)=1.42$

$Y = (1.42/3.14)24=10.85$ hr

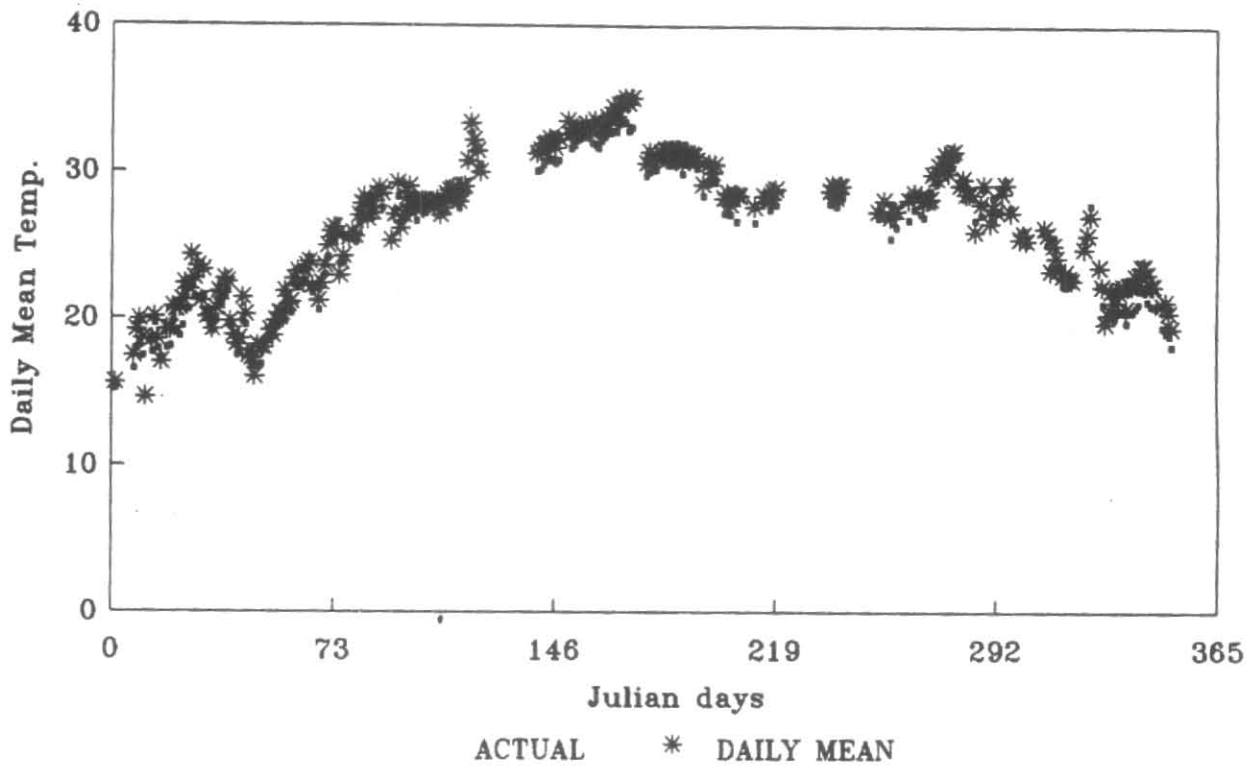

Fig.4. Observed and simulated daily mean temperature for the year 1992

Night length (Z) = 24-10.85hr = 13.15hr

(d) *Estimation of temperature at 0500 hr*

$Tr = 5$, $tb = 4.79$, $te = 17.43$, $m = 0.21$

$T_5 = (32\text{-}20.5)\ \sin[3.14(0.21)/\{10.85+2(2.69)\}] + 20.5 = 20.96°C$

(e) *Estimation of temperature at 1800 hr*

tr=23 hrs, tb=4.79, te=17.43, m=Y-C=12.635

Now, as $tr > te$, second equation will be used and n=5.57

Ts=(32-20.5)sin[3.14(12.64)/{10.85+2(2.69)}]20.5 =27.88°C

T_{23} = 20.5+(27.88-20.5)exp[(-1.423)5.57/13.15] = 24.53°C

The respective measured temperatures by automatic weather station were 20.25° and 25.9°C

Similarly, temperature at each hour also could be estimated.

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