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Modelling diurnal pattern of relative humidity from daily air temperature and relative humidity data of Hyderabad

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ABSTRACT

This study presents a simple methodology to estimate diurnal patterns in dew point temperature/relative humidity on weekly basis from mean minimum temperature or the morning relative humidity under semi-arid climatic conditions of Hyderabad. The sinusoidal and exponential models for day time and night time temperature pattern have been utilized in working out the diurnal patterns of the relative humidity on weekly basis at Hyderabad. Diurnal variation in dew point has been found to have, by and large, a set pattern depending upon the morning dew point temperature. Diurnal relative humidity patterns have been worked out both from the estimated dew point/relative humidity and the actual recorded relative humidity. This model is expected to be quite useful for long term retrospective agro-climatological studies wherein daily relative humidity and/or diurnal patterns thereof are required as input.

Key Words: Diurnal modelling, dew point temperature, relative humidity

Availability of hourly relative humidity data is a key requirement for the estimation of epidemic dynamics of plant fungal pathogens, in particular for the simulation of both the germination of the spores and the infection process (Bregaglio *et al.*, 2010). In most cases these data are not readily available. Presently daily data on temperature and relative humidity is being recorded at several locations in IMD (India Meteorological Department) at specified timings. To fill up any gaps in daily data on humidity as well as to model diurnal patterns several researchers (Butler, 1992, Ephrath *et al.*, 1996; Kimball *et al.* 1997; Hubbard *et al.* 2003 and Sköld, *et al.* 2007) have presented different methodologies.

MATERIALS AND METHODS

The long term (1995-2008) hourly data on different weather parameters including the relative humidity for Hayathnagar Research Farm of Central Research Institute for Dryland Agriculture, Hyderabad (17° 20' N, 78° 35' E, 515.5 m.a.m.s.l.) recorded by an automatic weather station (Campbell Scientific Inc., Logan, USA) were used. The air temperature and relative humidity were recorded at standard hours i.e. 0700 and 1400 h L.M.T. (0716 h and 1416 h IST) as well. The AWS data were compared with manual data, recorded with standard dry and wet bulb thermometers put in Stevenson screen of a standard class 'A' meteorological Observatory. Regression equations were fitted between observatory and AWS data on temperature and relative humidity. The regression coefficients for both the temperature and the relative humidity were incorporated in logger programme. Daily hourly data on relative humidity were averaged to get daily mean hourly values for all the 52 weeks year wise. Subsequently the data from 1995-2007 were pooled to work out the diurnal dew point pattern using standard equations (Allen *et al.,* 1998) and the following relationship which has been worked out from Teten's (1930) equation after taking natural log and re-arrangement.

$$T_{dew} = \frac{237.3\ \ln(e) + 116.994}{16.776 - \ln(e)}$$

Where

T_{dew} is dew point temperature (°C), and ln(e) is natural log of actual vapour pressure (k Pa)

Hourly dew point multipliers were worked out by dividing mean hourly week wise (1995-2007) dew point temperature with morning time dew point temperature for all the 52 weeks. Table 1 shows these multipliers for few selected weeks which were selected for detailed comparison of the methodology. Hourly dew point temperature during test year of 2008 was estimated by multiplying the morning dew point temperature during different weeks by hourly dew point multipliers in respective weeks. The hourly actual vapour pressure was estimated using Teten's (1930) equation and the hourly dew point temperature mentioned just before. Hourly saturation vapour pressure during the test year 2008 was worked out from the hourly temperature data as estimated by the following equations (Srivastava *et*

Table 1: Hourly values of dew point multipliers during few selected weeks in respect to the dew point temperature at the mean minimum temperature at HRF, Hyderabad.

Weeks	Time in hours																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	1.04	1.03	1.02	1.01	1.00	1.03	1.07	1.13	1.17	1.16	1.10	1.06	1.02	1.00	0.99	0.99	1.00	1.02	1.03	1.04	1.04	1.04	1.04	1.03
11	0.96	0.96	0.97	0.97	0.97	0.98	1.00	1.02	0.99	0.93	0.86	0.80	0.75	0.72	0.71	0.72	0.73	0.75	0.79	0.83	0.87	0.90	0.93	0.95
21	0.97	0.98	0.97	0.98	0.99	1.00	1.02	1.03	1.03	1.01	0.98	0.95	0.92	0.89	0.87	0.86	0.88	0.90	0.92	0.94	0.94	0.95	0.96	0.98
31	1.02	1.01	1.01	1.01	1.00	1.00	1.01	1.02	1.03	1.05	1.06	1.06	1.06	1.06	1.06	1.06	1.05	1.05	1.05	1.04	1.04	1.04	1.03	1.02
41	1.01	1.00	1.00	0.99	1.00	1.00	1.05	1.08	1.10	1.10	1.09	1.09	1.08	1.08	1.07	1.06	1.06	1.06	1.05	1.05	1.04	1.03	1.02	1.01
51	1.02	1.01	1.01	1.00	1.00	1.03	1.07	1.14	1.17	1.15	1.11	1.07	1.04	1.03	1.02	1.03	1.05	1.06	1.05	1.06	1.06	1.05	1.04	1.03

al., 2010) in conjunction with Teten's (1930) equation.

$$T(t) = (Tn + c) + (Tx - (Tn + c))\ Sin\left(\pi \frac{t - 6.5}{D + 2a}\right)$$

$$T(t) = (Tn + c) + (Ts - (Tn + c))\ Exp(-\frac{bH}{N})$$

Where

T(t) = Temperature (°C) at local standard time 't',

Tx = Maximum temperature (°C),

Tn = Minimum temperature (°C),

c = A constant (°C) – temperature difference between weekly mean minimum and that at 06:30 A.M.,

t = Local standard time in hours from 06:30 A.M. till sunset,

D = Day length in hours,

a = Lag coefficient,

Ts = Temperature at sunset (°C),

N = Night length in hours (24-D),

b = Night time temperature coefficient,

H = Time in hours since sunset to 06:30 A.M.

Diurnal patterns of air temperature, dew point temperature and relative humidity are plotted (Fig. 1) for selected weeks i.e. weeks 1, 11, 21, 31, 41 and 51 representing some of the features during the study period. The weeks were selected falling in summer, pre-monsoon, monsoon, post-monsoon and winter. Relationships between minimum temperatures vs. dew point temperature were studied by plotting dew point vs. minimum temperature for all the 52 weeks. It was found that there were two distinct patterns. Therefore, two plots (Fig. 2a and 2b) were made. One was for the minimum temperature during the period of 1-6 and 18-52 weeks vs. dew point temperature during morning. The other one was for the minimum temperatures during 7-17 weeks vs. the dew point temperature in the morning. Observed vs. estimated dew point temperatures during 2008 were plotted in Figs. 3a and 3b for the two periods. Test results on hourly observed relative humidity vs. estimated values – one using minimum temperature for dew point and the other using morning relative humidity for dew point, were plotted in Figs 4a, b, c and d for selected weeks i.e. weeks 1, 11, 21, 31, 41 and 51. Observed vs. estimated relative humidity for all the 52 weeks were plotted in Fig. 5a and b using minimum temperature for dew point estimation or the actual morning time dew point during the test year 2008.

RESULTS AND DISCUSSION

Diurnal patterns of air temperature, dew point temperature and relative humidity during selected weeks

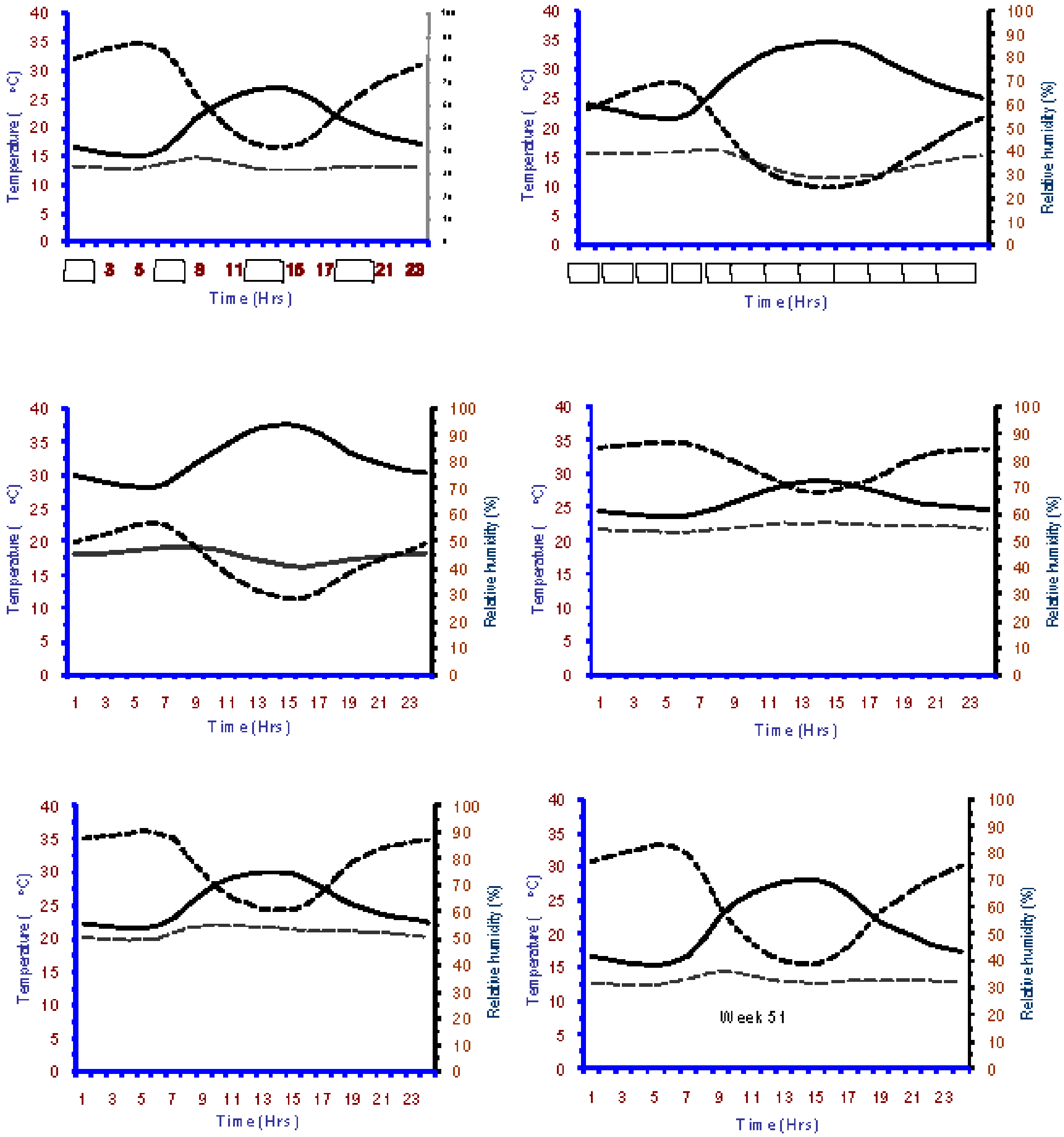

Fig. 1: Diurnal patterns of air temperature, dew point temperature and relative humidity at HRF, Hyderabad Data: 1995-

of 1, 11, 21, 31, 41 and 51 are plotted in Fig.1 in respect to Hyderabad. It is observed that the diurnal temperature and relative humidity have relatively large variation and are generally in opposite phase. The dew point temperature shows quite less variation over the entire 24-hr period. It is quite stable during the monsoon week 31. Therefore, hourly dew point temperature was worked out by multiplying the morning dew point temperature during the test year 2008 by the hourly multipliers. Actual vapour pressure in turn was estimated by Teten's (1930) equation. Fig. 3a shows the scatter plot of observed vs. estimated dew point temperature for the period of weeks 1-6 and 18-52 along with 1:1 line for the test year of 2008. It can be seen that most of the points lie at/near the line. The polynomial equation used to estimate dew point temperature from the daily mean minimum temperature is given in Fig. 2a. Fig. 3b shows scatter plot of observed vs. estimated dew point temperature during the period of summer weeks 7-17 along with 1:1 line for the

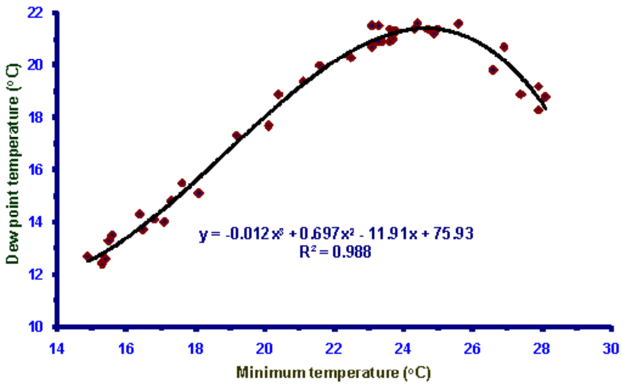

Fig. 2a: Relationship between dew point and corresponding minimum temperature during 1 - 6 and 18 - 52

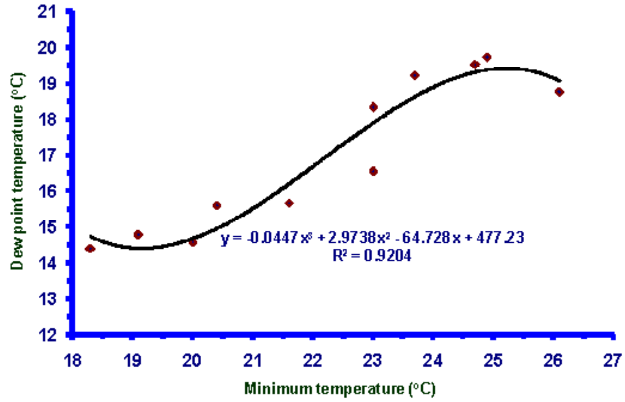

Fig. 2b: Relationship between dew point and corresponding minimum temperature during 7 - 17 weeks

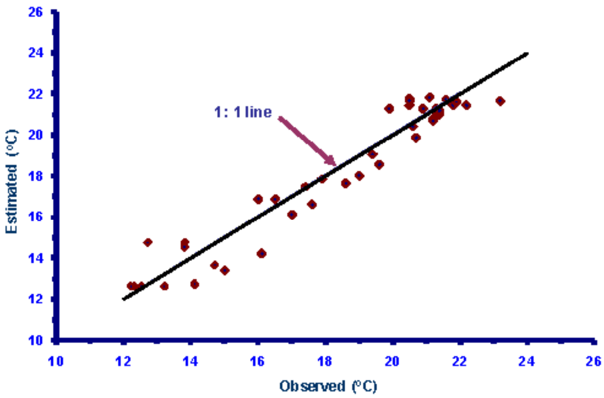

Fig. 3a: Observed and estimated dew point temperature during 1 - 6 and 18 - 52 weeks during 2008

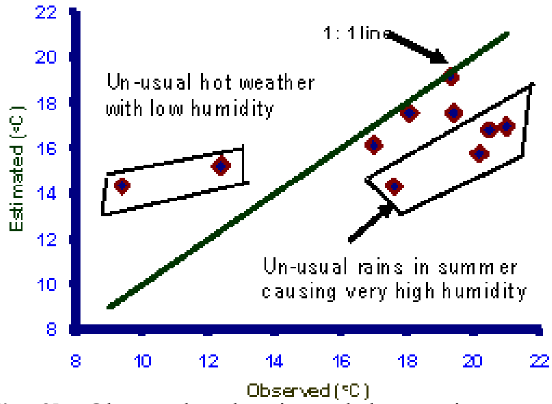

Fig. 3b: Observed and estimated dew point temperature during 7 - 17 weeks during 2008

year 2008. It is observed that there are large deviations from the 1:1 line. The deviations are due to either un-usual hot weather with abnormally low relative humidity or due to un-seasonal heavy rains in summer causing very high humidity. Under such large departures in weather parameters, the dew point and in turn the relative humidity can not be correctly estimated from the daily mean minimum temperature data unless corrected for the abnormal situation.

Fig. 4 shows diurnal patterns of observed and estimated (using daily mean minimum temperature or daily mean morning relative humidity) relative humidity during the weeks 1, 11, 21, 31, 41 and 51 representing most of the situations likely to occur under Hyderabad conditions. Diurnal pattern of relative humidity worked out from the morning relative humidity appear to have an edge as compared to that worked out from the daily mean minimum temperature. Anyway the plots show that both the approaches are reasonably satisfactory.

Fig. 5a shows the scatter diagram along with 1:1 line for observed vs. estimated (using daily mean minimum temperature) hourly relative humidity for all the 52 weeks during 2008. Fig. 5b shows similar plot except that the diurnal relative humidity was worked out from the daily mean morning relative humidity. Fig. 5b represents a better fit. However, in the absence of actual data on morning relative humidity, one can estimate it from the daily mean minimum temperature except of course for few abnormal weeks during the period of 7-17 weeks.

CONCLUSIONS

Dew point temperature and in turn the relative humidity/ pattern could satisfactorily be estimated from the daily mean minimum temperature during the period of weeks 1-6 and 18-52. The coefficient of determination has been 0.9883. However, for the period of summer weeks 7-17, it may not be

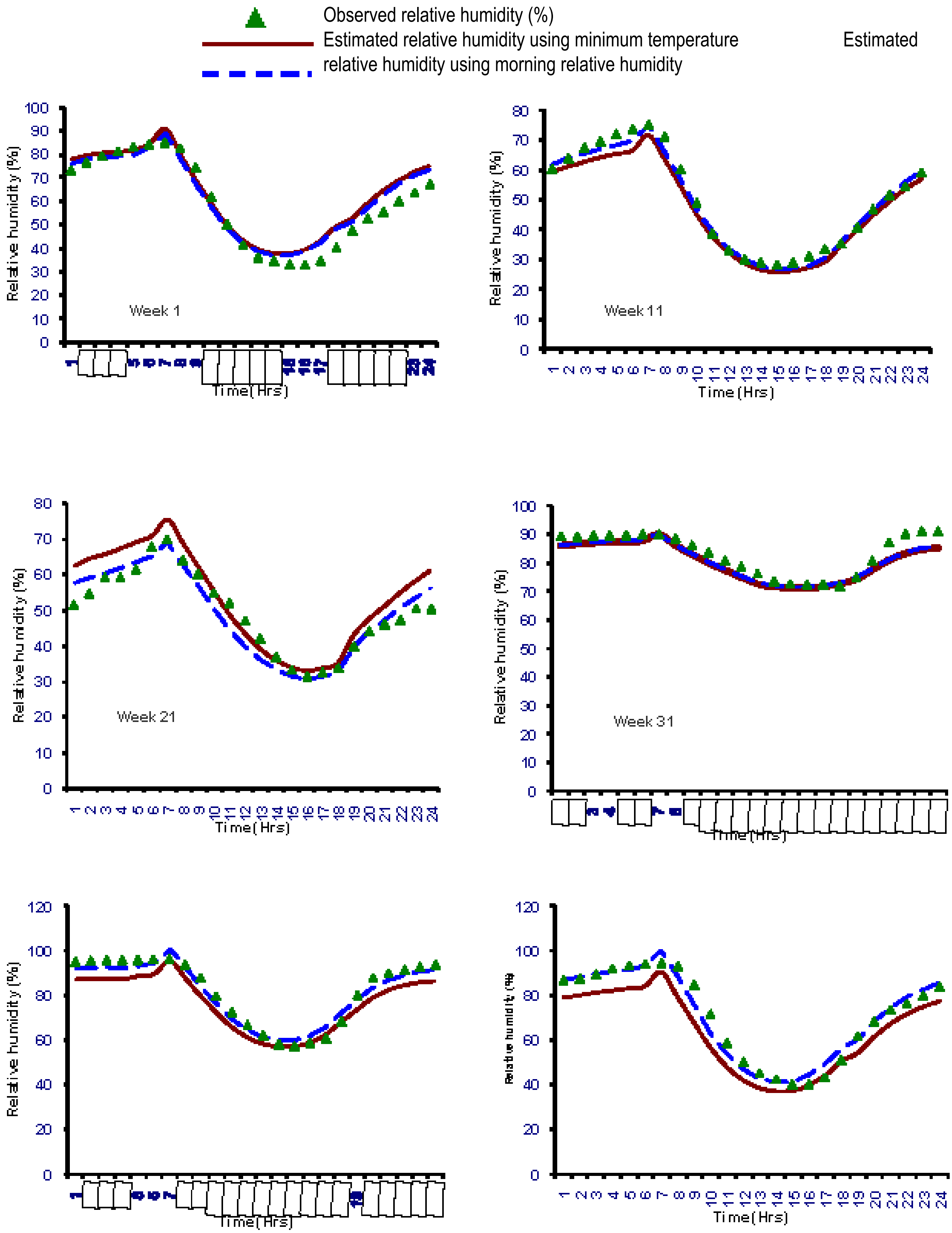

Fig. 4 : Observed vs estimated hourly relative humidity (%) on weekly basis at Hyderabad (2008)

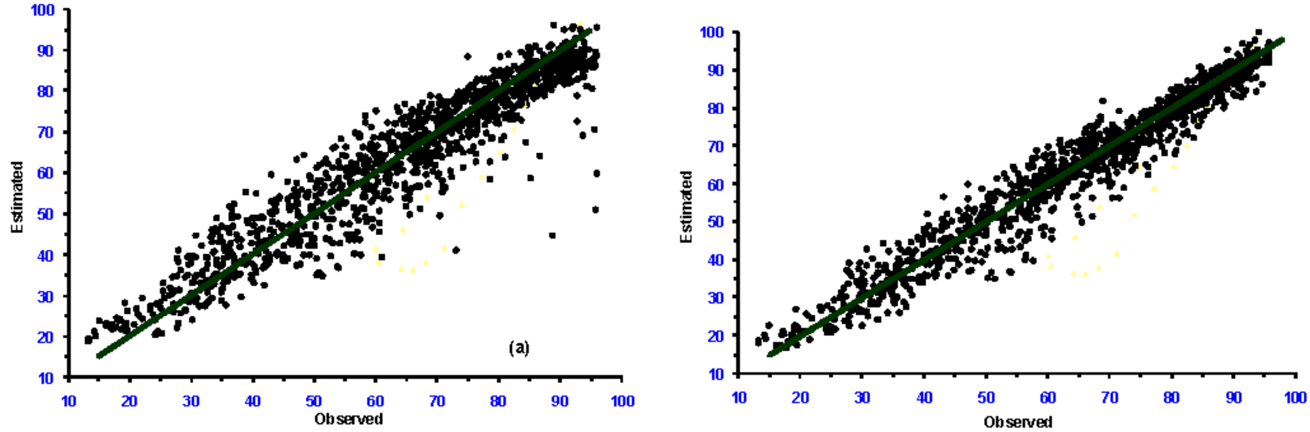

Fig. 5 : Observed vs estimated hourly relative humidity (%) on weekly basis at Hyderabad (2008) : (a) using minimum temperature (b) using morning relative humidity

that satisfactory as the coefficient of determination is 0.9204 only. If, there are large deviations in weather conditions (un-seasonal heavy rains/ heat waves) from the normal during these summer weeks, then diurnal pattern in relative humidity could be satisfactory only if, it is estimated from daily morning time relative humidity records.

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