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Diurnal variation of relative humidity over Calcutta (Alipore) and a statistical approach for forecasting minimum relative humidity

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सार — कलकत्ता (अलीपुर) में वर्ष 1981 से संबंधित आपेक्षिक आर्द्रता में दैनिक परिवर्तन संबंधी स्थिति के अध्ययन से पता चलता है कि (*i*) आ. आर्द्रता $<$40 प्रतिशत वाली सबसे शुष्क समय मध्य दिसम्बर से मध्य फरवरी के बीच 1500 बजे भा. मा. स. के लगभग, और नवम्बर माह में भी 1400 भा. मा. स. के आसपास होता है, (*ii*) आ. आर्द्रता $>$90 प्रतिशत का आर्द्र समय पूरे वर्ष के दौरान 0600 भा. मा. स. के लगभग रहता है। घंटेवार आ. आ. मूल्यों में परिवर्तन मानसून के महीनों के दौरान प्रातःकाल सबसे कम होता है, तथापि किसी भी महीने में दिन के समय, उच्चतम परिवर्तन उस महीने के न्यूनतम आ. आ. के होने के समय से मेल नहीं खाते हैं।

अलीपुर में 1950 से 1980 (1956 को छोड़कर) तक के वर्ष भर के आंकड़ों पर आधारित न्यूनतम और अधिकतम आ. आ. के पंच-दिवसावधि प्रसामान्यों (पेन्टॉड नौर्मलस) की संगणना की गई है।

(*i*) पूर्व दिवस के 12 बजे ग्री. मा. स. और उस दिन के 03 बजे ग्री. मा. स. के अनुरूप आ. आ. की अनियमितताओं के साथ उस दिन के आ. आ. के न्यूनतम मूल्य, (*ii*) 03 और 06 बजे ग्री. मा. स. के उन मूल्यों के साथ न्यूमतम आ. आ. के 24 घंटे के परिवर्तन के बीच सहसंबंध गुणांक से पता चलता है कि उस दिन के न्यूनतम आ. आ. और 06 बजे ग्री. मा. स. के आ. आ. के 24 घंटे के परिवर्तन के मध्य काफी अच्छा संबंध है।

ABSTRACT. A case study on diurnal variation of relative humidity over Calcutta (Alipore) for 1981 reveals (*i*) Driest period of RH $<40\%$ around 1500 IST between mid-December to mid-February and also around 1400 IST in the month of November, (*ii*) Moist period of RH$>90\%$ around 0600 IST during the whole year. The variability of the hourly RH values is lowest during monsoon months in the early morning, however, the highest variability during a day in any month does not coincide with time of occurrence of the minimum RH of that month.

Pentad normals of minimum and maximum RH over Alipore through the year have been computed based on data from 1950 to 1980 (excluding 1956).

Correlation coefficients between (*i*) minimum value of RH of a day with the anomalies of RH corresponding to 03 GMT of the day and 12 GMT of the previous day and (*ii*) 24-hr change of min. RH with those values for 03 and 06 GMT shows that there is a good correlation between 24-hr change of RH of 06 GMT and that of the minimum RH of the day.

1. Introduction

Water vapour is one of the most important parameters in the atmosphere for causing precipitation. Out of a number of parameters, mixing ratio, sp. humidity and relative humidity are widely used to describe the amount of water vapour present in the atmosphere.

The term relative humidity indicates how near the atmosphere is to saturation. On the other hand, mixing ratio indicates the amount of water vapour present in the atmosphere in absolute terms. As the capacity of the atmosphere to hold maximum moisture increases with the increase in temperature, the relative humidity will decrease with the increase in temperature provided mixing ratio is constant and *vice versa*. The diurnal and seasonal variation of relative humidity is, therefore, a combined effect of the variation of both mixing ratio and temperature. Although the diurnal variation of temperature is quite simple, the diurnal variation of mixing ratio depends upon the diurnal variation of condensation, evaporation, diffusion and to a negligible degree, air pressure. Condensation is generally a night to early morning phenomenon. Evaporation on the other hand, increases during the day time period although it is strongly influenced by strong wind, relative humidity and nature of the surface. Diffusion of the water vapour depends on the vertical convection and vertical distribution of moisture. However, air aloft is normally drier than low level air, and as convection develops vertical diffusion of water vapour may off set evaporation process and cause a secondary afternoon minima (Jenkins 1945). Obviously the diurnal variation of mixing ratio must depend on locality. Shaw (1936) gave tables indicating the diurnal variation of vapour pressure in mb for various places. Converting this into gm/kg (Jenkins 1945) the average daily variation of mixing ratio for Calcutta during pre-monsoon hot dry season is near 2.5 gm/kg.

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The present work is mainly an effort to establish a statistical regression equation for forecasting minimum value of relative humidity in Alipore. Climatological values are intended to be used, however, the pentad normals for minimum values of R.H. were not available for Alipore. The pentad normals of minimum as well as maximum R.H. are, therefore, computed for Alipore. Before the said statistical approach a case study has been made on the diurnal variation of relative humidity in Alipore for each month and the nature of day to day variability in the hourly values of R.H. for each month.

2. Data

(a) *Normal values of maximum and minimum relative humidity*

Thirty years data have been taken to evaluate pentad normal values of maximum and minimum R.H. in Calcutta. The data were taken from 1950 to 1980 except the year 1956 for which data were not available. The pentad normal values have been computed. The same pentads have been taken which are in use in India Met. Dep. for other meteorological parameters. At present the normal values of R.H. corresponding to 0830 and 1730 IST are only available. For each pentad 150 values were generally available, mean value of which was taken as the pentad normal. The values, thus obtained, are given in Table 1.

(b) *Diurnal and seasonal variation of relative humidity*

Hygrograph data of 1981 has been considered and the following computations were made :

(*i*) The hourly mean value of R.H. for each month,

(*ii*) The mean time of occurrence of maximum & minimum R.H. for each month,

(*iii*) The standard deviation of hourly R.H. values for each month,

(*iv*) The standard deviation value in hours and minutes of the time of occurrence of maximum & minimum R.H. for each month of the year and

(*v*) The standard deviation of the monthly mean value of R.H. for each hour.

The computed values of (*i*) & (*iii*) are plotted and analysed (Figs. 1 and 2).

The computed values of (*ii*) , (*iv*) and (*v*) have been plotted on graphs (Figs. 3, 4 and 5 respectively).

3. Discussion

3.1. The following chief features are brought out from the pentad normals of :

(a) *Minimum relative humidity*

(*i*) The lowest value of minimum R.H. during the whole year (27 %) occurs in the 15th pentad (12-16 March) of the year.

(*ii*) The highest value of the minimum R.H. during the whole year (70%) occurs in the 44th pentad (4-8 August) of the year.

TABLE 1

Normal values of maximum and minimum relative humidity over Alipore (Calcutta)

Pentad	Max	Min	Range	Pentad	Max	Min	Range	Pentad	Max	Min	Range
1	93	39	54	26	88	49	39	51	96	68	28
2	92	38	54	27	91	50	41	52	96	67	29
3	94	37	57	28	91	48	43	53	96	63	33
4	92	37	55	29	91	50	41	54	96	64	32
5	92	39	53	30	91	50	41	55	97	65	32
6	93	36	57	31	92	54	38	56	96	61	35
7	91	36	55	32	93	54	39	57	96	59	37
8	91	35	56	33	93	56	37	58	96	54	42
9	92	33	59	34	93	63	30	59	96	53	43
10	91	31	60	35	91	63	28	60	92	53	39
11	90	31	59	36	95	65	30	61	96	52	44
12	88	29	59	37	93	66	27	62	94	46	48
13	92	32	60	38	95	68	27	63	95	46	49
14	91	31	60	39	95	68	27	64	95	43	52
15	90	27	63	40	92	68	24	65	95	43	52
16	91	30	61	41	95	66	29	66	91	42	49
17	92	33	59	42	95	69	26	67	93	41	52
18	91	33	58	43	95	68	27	68	91	40	51
19	92	34	58	44	95	70	25	69	94	41	53
20	87	35	52	45	95	67	28	70	93	40	53
21	90	37	53	46	95	69	26	71	94	39	55
22	90	39	51	47	95	67	28	72	95	38	57
23	91	40	51	48	95	67	28	73	94	39	55
24	91	44	47	49	99	67	32				
25	90	47	43	50	95	66	29				

(b) *Maximum relative humidity*

The variation of maximum R.H. throughout the year is generally not significant being about 92 ± 5%.

3.2. The analysis of the mean hourly values of the R.H. corresponding to each month (Fig. 1) reveals that :

(*i*) The atmosphere (near the surface) is driest, *i.e.*, lowest value of R.H., during middle of December to middle of February around 1500 IST and also during the month of November between 1400 and 1500 IST. The value being 35 to 40%.

(*ii*) The atmosphere is generally most moist, *i.e.*, highest value of R.H. between 0500 & 0600 IST during the whole year. However, the duration of the day with

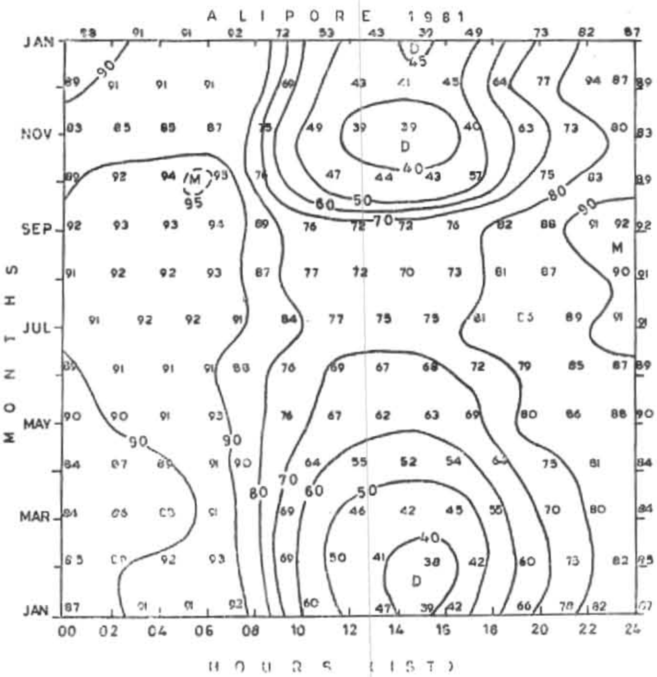

Fig. 1. Monthly mean values of R.H. for of Alipore

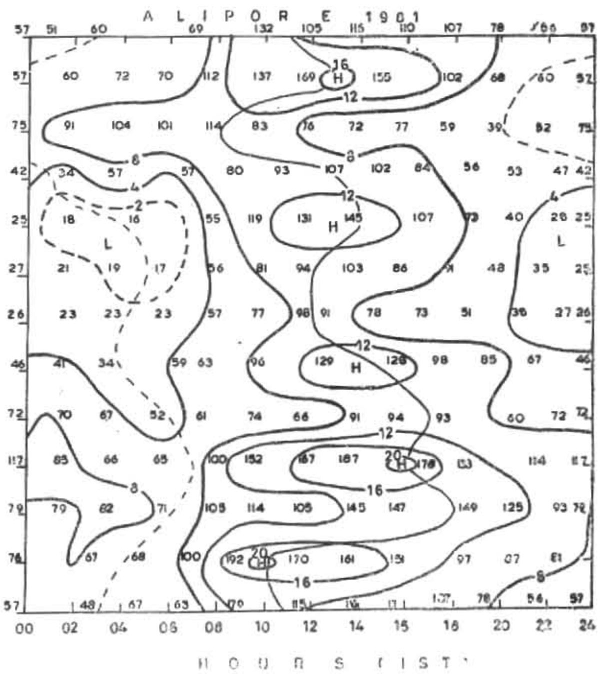

Fig. 2. Standard deviation of hourly R.H. for each month

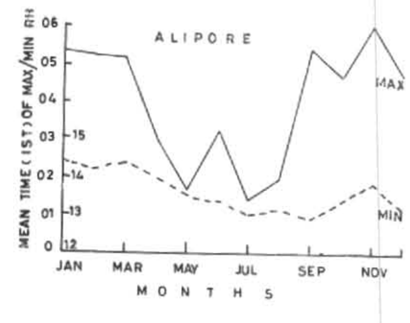

Fig. 3. Computed values of mean time of occurrence of max. and min. R.H.

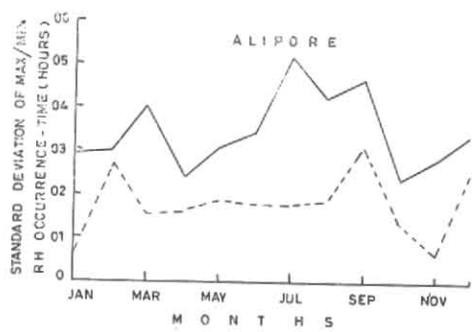

Fig. 4. Computed values of standard deviation in hours and minutes of the time of occurrence of max. & min. R.H. for each month of the year

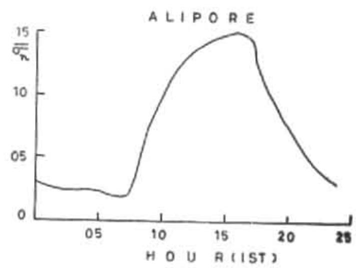

Fig. 5. Computed values of standard derivation of monthly mean of R.H. for each hour

R.H.$>$90% is least in the month of March (about 2 hr) and is highest in the monsoon months especially in the month of September (about 11 hr).

(*iii*) During the monsoon months especially between middle of June to middle of September the R.H. never goes below 70%.

(*iv*) During the afternoon when the R.H. is generally lowest throughout the year, this lowest value gradually increases from a lowest value of 40% to highest value of 70% in a span of 4 months (middle of February to middle of June) whereas the decrease of this value from 70% to 40% after the monsoon is over is rather sharp, *i.e.*, within a month (middle of September to middle of October). The explanation is rather simple. After the winter, during the pre-monsoon season, the anticyclone the over Bay causes gradual moisture incursion over the station and also the pre-monsoon convective activities reduce the dryness gradually till the monsoon sets in, whereas after withdrawal of the monsoon the dry

TABLE 2

Correlation coefficient r between x and y and coefficient a and b of the regression equation $y = a + bx$

	Correlation coefficient					Correlation coefficient				
	σx	σy	r	a	b	σx	σy	r	a	b
			January					**July**		
$y = H^{24}_{N}$, $x = H^{24}_{03}$	12.33	10.24	0.05	0.4	0.04	8.67	7.39	0.45	—0.1	0.4
$y = H^{24}_{N}$, $x = H^{24}_{06}$	11.98	10.24	0.81	0.05	0.7	10.57	7.39	0.6	0.1	0.4
$y = H_N - \bar{H}_N$, $x = H_{03} - \bar{H}_{03}$	10.25	10.4	0.23	0.1	0.25	7.0	5.82	0.47		
$y = H_N - \bar{H}_N$, $x = H_{12} - \bar{H}_{12}$	8.21	10.4	0.41	—0.9	0.5	7.6	5.82	—0.16	—	—
			April					**November**		
$y = H^{24}_{N}$, $x = H^{24}_{03}$	10.0	13.27	0.36	0.9	0.5	11.09	5.93	0.22	0.3	0.1
$y = H^{24}_{N}$, $x = H^{24}_{06}$	12.69	13.27	0.8	0.5	0.8	7.45	5.93	0.72	0.2	0.6
$y = H_N - \bar{H}_N$, $x = H_{03} - \bar{H}_{03}$	11.81	16.71	0.75	8.7	1.1	8.69	6.69	0.53	—4.0	—0.4
$y = H_N - \bar{H}_N$, $x = H_{12} - \bar{H}_{12}$	15.62	16.71	0.72	4.7	0.8	6.29	6.69	0.45	—5.1	0.5

northeasterlies set in rather rapidly and hence afternoon dryness increases rather sharply.

3.3. The analysis of the standard deviation of the hourly R.H. values for each month (Fig. 2) reveals the following :

The day to day variability of the hourly R.H. values is least in early morning hours between 0100 and 0600 IST.

This is highest around 1000 IST in February and around 1600 IST in April.

3.4. Fig. 3 gives the variation of mean time of occurrence of the maximum R.H. (solid lines) for each month. During September to March, the time of occurrence of maximum R.H. is generally around 0500 IST. On the other hand the mean time of occurrence of the minimum R.H. (dashed line) is rather invariant throughout the year between 1300 and 1400 IST. A downward trend, however, is observed between March to September.

3.5. Fig. 4 gives an idea of the day to day variability of the time of occurrence of maximum (solid line) as well as minimum (dashed line) R.H. It indicates that the said variability is generally more for maximum R.H. than for minimum R.H. throughout the year. Secondly the said variability for maximum R.H. values are more during monsoon months than other period of the year. The reason is that the occurrence time of the maximum value of R.H. highly depends also on the time of rainfall and need not be in the early morning hours every day.

The effect of rain is more during monsoon than other months.

3.6. Fig. 5 gives an idea of the month to month variability of the mean hourly R.H. This indicates that during 1500 to 1600 IST the month to month variability in R.H. value is maximum where as it is minimum in the early morning hours. This is also in conformity with the analysis in Fig. 1.

4. Forecasting of minimum relative humidity

The minimum relative humidity occurs during afternoon when the maximum temperature of the day occurs and *vice versa*. To forecast the minimum R.H. accurately we require to know all the parameters discussed in the first section accurately and to establish a regression equation among them. Obviously this is a very difficult task and to solve the problem we may have to use a fast computer to analyse and solve the equations involved and give a forecast value of the minimum R.H. Before we arrive to that stage of sophistication in forecasting minimum R.H. we may use some method based on the normal values and 24-hr tendency. The idea here is that the effect of the parameters, *viz.*, temperature, wind, diffusion, convection and condensation are generally involved during the previous 24 hours to give the values of R.H. available at the forecast time. If the same trend continues for a few hours more then we may be able to give a forecast value of the minimum relative humidity. In addition to this method we have climatological values which may also help giving a forecast value of the minimum R.H.

The data available at the time of forecast, *i.e.*, at 0600 GMT are :

(a) Normal values of (*i*) minimum R.H. $\bar{H}_N$, (*ii*) R.H. at 03 GMT $\bar{H}_{03}$ and (*iii*) R.H. at 12 GMT of previous day $\bar{H}_{12}$;

(b) R.H. values of 03, 06 GMT of the day and the 12 GMT of the previous day; H_{03}, H_{06} and H_{12} respectively and

(c) Minimum R.H. values of previous day H_N

Assuming a linear relationship the following relations may be expected to hold :

(*i*) Based on tendency or persistence

$$\overset{24}{H}_N = a + b\overset{24}{H}_{03} \tag{1}$$

$$\overset{24}{H}_N = a + b\overset{24}{H}_{06} \tag{2}$$

where, $\overset{24}{H}_N$, $\overset{24}{H}_{03}$ and $\overset{24}{H}_{06}$ are 24 hours change of the value of minimum R.H., 03 GMT R.H. and 06 GMT R.H, obviously the coefficients of the regression Eqns. (1) and (2) are different.

(*ii*) Based on normal values or climatology

$$H_N - \bar{H}_N = a + b\,(H_{03} - \bar{H}_{03}) \tag{3}$$

$$H_N - \bar{H}_N = a + b\,(H_{12} - \bar{H}_{12}) \tag{4}$$

All the above four equations are of the form :

$$y = a + bx \tag{5}$$

To find out the coefficients of the above regression equations we may use the method of least squares using past data. Multiplying by x on both side of Eqn. (5) we get :

$$xy = ax + bx^2 \tag{6}$$

Using n numbers of data,

$$\Sigma\, y = a\, n + b\, \Sigma\, x$$

and $$\Sigma\, xy = a\, \Sigma\, x + b\, \Sigma\, x^2$$

Solving the above equations :

$$b = \frac{\Sigma\, x\, \Sigma\, y - n\, \Sigma\, xy}{(\Sigma\, x)^2 - n\, \Sigma\, x^2} \tag{7}$$

and using this value of b in the first equation :

$$a = \frac{\Sigma\, y - b\, \Sigma\, x}{n} \tag{8}$$

Before arriving at the regression equation and evaluating the coefficients of the regression equation the correlation coefficients should be found out between x and y corresponding to each Eqns. (1) to (4). If the correlation coefficient is very low it will be futile to try a regression equation.

In the present study data of 1981 has been used to find out the correlation coefficients and subsequently the coefficients a and b were evaluated in such cases where a good correlation exist.

4.1. *Data* — One months data for the representative month of each season have been taken, *viz.*, January, April, July and November, for winter, pre-monsoon, monsoon and post monsoon seasons (although October is the representative month, November has been taken being the middle month of the post monsoon season). The computed values are given in Table 2.

4.2. *Discussion* — It is found that the best correlation exists between $\overset{24}{H}_N$ and $\overset{24}{H}_{06}$ which are 0.81, 0.8, 0.6 and 0.72 for January, April, July and November respectively. The regression equations thus obtained were tested for the year 1982.

It is found that the percentage of days when the minimum R.H. forecast was correct within 5%, using Eqn. (2), are 68, 57, 58 and 73 and within 10% are 94, 84, 84 and 96 for January, April, July and November respectively.

Eqns. (3) and (4) do not give good result except for the month of April when those figures are 50% and 77% using Eqn. (3) and 50% and 73% using Eqn. (4). Eqn. (1) does not give any good result.

Here it may be mentioned that the correlation coefficient between 24 hours change in the minimum value of R.H. and the 24 hours change in R.H. value ending at 06 GMT of the previous day is very poor.

5. Conclusion and remarks

The normal values of the relative humidity and the case study on the diurnal and seasonal variation of the relative humidity over Alipore gives an idea of the maximum/minimum range of R.H. during a day, its hour to hour and month to month variability. These values may be useful for some industries which require particular type of relative humidity for manufacture of their goods.

The forecasting of minimum value of relative humidity on any day, well in advance, is quite difficult becasue of its sudden change due to change in mixing ratio and temperature caused by change in prevailing wind, rainfall, cloudiness etc. However, the 24-hr change in R.H. value at 06 GMT of the day is useful but is rather late to have any forecast value.

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References

Jenkins, G.R., 1945, *Handbook of Meteorology*, edited by F.A.. Berry, Jr. *et al.*, 751 pp.

Shaw, Sir Napier, 1936, *Manual of Meteorology*, Vol. II, 2nd ed. Cambride University Press, London, 136 pp.