Indian J. Met. Geophys. (1973), 24, 1, 37-42

551·576·2 : 555·571

Cloudiness in relation to moisture and convergence

R. C. BANERJI, D. S. UPADHYAY, D. K. MISRA and H. C. ARYA
State Meteorological Centre, Jaipur

(Received 18 November 1971)

ABSTRACT. The day to day variation of moisture content and lower level convergence pattern over New Delhi have been examined with a view to find a correlation between these two meteorological parameters and different cloud types and amounts. An empirical relationship has also beenestablished. This study reveals the mean values of moisture content in a vertical air column and lower level convergence, most favourable for the development of different cloud types and low cloud amounts along with their confidence bands.

1. Introduction

Moisture and convergence are the main factors on which the type and also the amount of clouds over an area depend. This sample study attempts to discuss various aspects of inter-dependence between cloud amounts and types, humidity and convergence at Delhi, taking into consideration six months daily observations.

Study of convergence and its change during twentyfour hours in association with humidity and stability index values and their role in the production of convective activities has already been undertaken by a number of authors with the aim of finding objective methods for the forecasting of thunderstorm/duststorm. Moisture,convergence and stability index have been shown to be mainly responsible for the occurrence of convective activities. Ghosh (1970) also used convergence and its variation as an aid for forecasting heavy rainfall over Delhi and neighbourhood. Though it is well known that cloudiness is directly related to moisture and lower level convergence, only a few studies have so far been made to study this relationship. It was thought worthwhile to compute moisture content in a vertical air column and the horizontal convergence at lower levels and to correlate these factors with specific cloud types and low cloud amounts separately.

2. Data

A stratified sample for Delhi (Safdarjung) of six months size, June, July, August, September and December 1968 and January 1969 is taken for the present study. Daily 00GMT surface and upper air observations were considered and mean humidity of the air column between surface to 700-mb level is computed by

$$\bar{H} = \frac{\sum_i H_i \, \delta p_i}{\sum_i \delta p_i}$$

where H_i is the mean humidity between the layers of thickness δp_i.

The daily values of convergence at 900 metres have been obtained from the tables of Surendra Kumar (1970). These valnes have been computed by Bellamy's Graphical Methods taking Ambala, Bareilly and Jaipur as the vortices of the triangle chosen.

The month-wise raw plot of surface temperature, mean humidity between surface and 700-mb level, wind speed in mps and convergence at 900-m level, type and amount of clouds are shown in Fig. 1. As such these plots do not show any regular feature or association between the parameters.

3. Analysis

The clouds have been categorised into four types in this study—(*i*) Stratus, (*ii*) Stratocumulus and cumulus, (*iii*) Medium clouds, and (*iv*) High clouds. The cumulonimbus cloud has not been considered for the want of suitable frequency of occurrence during the period considered for study.

For each of these types 10×10 contingency table has been prepared and the percentage probabilities of the occurrence of each of these types corresponding to different humidity and convergence bands is computed which are shown in three dimensional histograms (Figs. 2 and 3). The parallelepiped of lower heights have been filtered out and with the help of remaining distribution, the mean values of humidity and convergence associated with each type of cloud together with their standard deviations have been calculated. The mean and σ limits are given in Table 1.

Formation of stratus clouds show a bimodal character in respect of convergence. The most probable occurrence of stratus clouds is observed to be associated with mean humidity of 85 per cent and two convergence values of 10^{-5}/sec and 5×10^{-5}/sec. It is observed that the mean humidity of the atmospheric column steadily decreases with the increase in cloud height. The convergence

TABLE 1

Cloud type	Mean		Confidence bands	
	Humidity (per cent)	Convergence (10^{-5}sec^{-1})	Humidity (per cent)	Convergence (10^{-5}sec^{-1})
St	85	1 & 5	78, 92	0·0, 2·0 & 4·0, 6·0
Sc/Cu	81	2·2	76, 86	0·2, 4·2
Medium	64	2	55, 73	1·5, 3·5
High	60	0·5	54, 66	—0·4, 1·6

TABLE 2

Frequency of days with $0 \leqslant Nh \leqslant$ 2 octas

Humidity (H) (%)	Convergence (10^{-5} sec^{-1})										
	≤ -8	—8 to —6	—6 to—4	—4 to—2	—2 to 0	0 to 2	2 to 4	4 to 6	6 to 8	>8	Total
25-50	6	8	8	6	12	1	1	3	1	1	47
50-60	0	6	7	6	10	7	3	1	3	1	44
60-70	1	2	1	2	1	1	2	1	0	0	11
70-80	0	0	0	2	2	0	2	0	1	0	7
80-90	0	0	0	0	0	0	1	1	0	0	2
90-100	0	0	0	0	0	0	0	0	0	0	0
Total	7	16	16	16	25	9	9	6	5	2	111

TABLE 3

Frequencies of days with $2 \leqslant Nh \leqslant$ 4 octas

Humidity (H) (%)	Convergence (10^{-5} sec^{-1})										
	≤ -8	—8 to—6	—6 to—4	—4 to—2	—2 to 0	0 to 2	2 to 4	4 to 6	6 to 8	>8	Total
25-50	2	0	1	0	0	0	1	1	1	—	6
50-60	0	0	2	0	0	0	1	0	1	1	5
60-70	0	0	0	0	0	0	0	0	0	0	0
70-80	0	0	0	0	2	3	3	2	1	0	11
80-90	0	0	0	0	1	2	2	1	1	0	7
90-100	0	0	0	0	0	0	0	1	0	0	1
Total	2	0	3	0	3	5	7	5	4	1	30

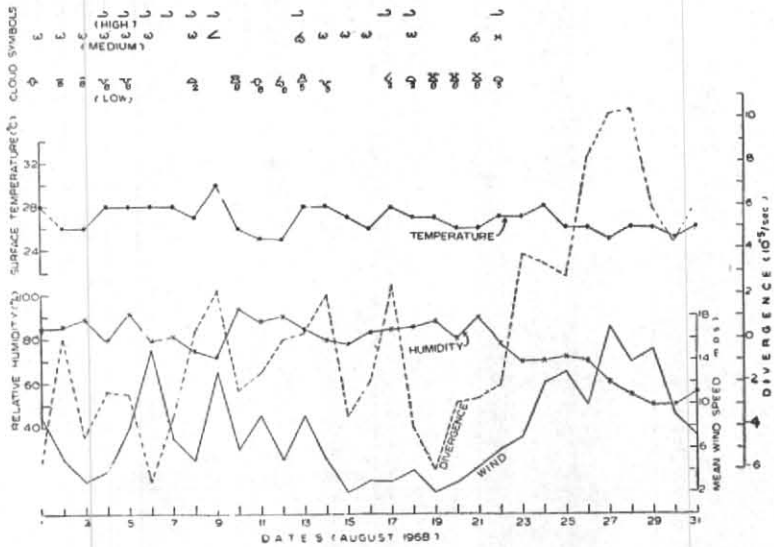

Fig. 1

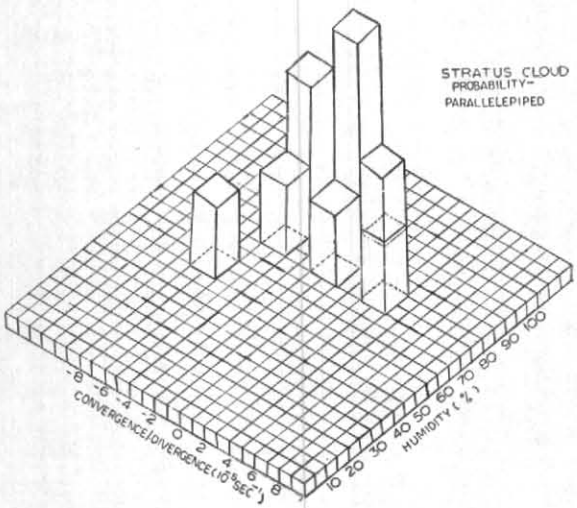

Fig. 2

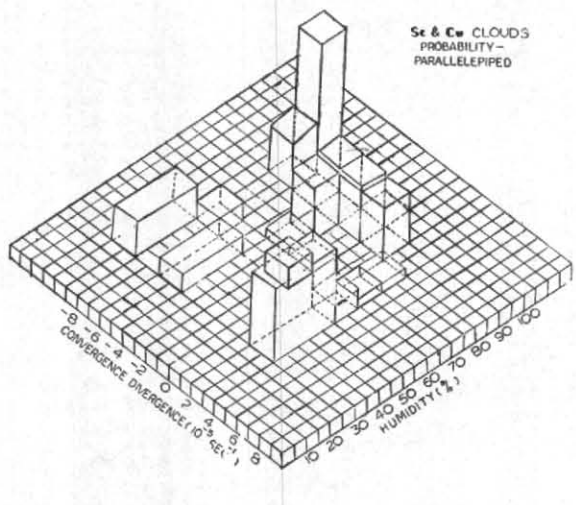

Fig. 3

Vertical axis—The heights of the lower parallelepipeds are fractions of the height of the highest parallelepiped, taken as unit

values, however, do not exhibit a clear trend which may be associated with cloud types. The highest variation of convergence values ranging between 0·2 to 4·2 units is noticed for stratocumulus and cumulus. The convergence of the order of 5 units observed with stratus clouds seems to be the result of heavy moisture advection at 900-m level.

4. Computation of statistics and discussion

The frequencies of days with different coverage of sky by low clouds (octas), corresponding to different bands of humidity (H) and convergence (C) are given in contingency Tables 2 to 5. Here convergence values are considered positive. Negative values of C are divergence.

The representative values of humidity and convergence for different cloud amounts based on probability considerations are given in Table 7.

The values of total correlation coefficients from the bivariate distribution are

$r_{NH}=0\cdot937$, $r_{NC}=0\cdot471$ and $r_{CH}=0\cdot383$

The partial correlation coefficients $r_{NH\cdot C}$,

TABLE 4

Frequencies of days with 4 $\leqslant Nh \leqslant$ 6 octas

Humidity (H) (%)	Convergence (10^{-5} sec^{-1})										
	<-8	-8 to -6	-6 to -4	-4 to -2	-2 to 0	0 to 2	2 to 4	4 to 6	6 to 8	>8	Total
25—50	0	0	1	0	1	0	0	0	0	1	3
50—60	0	0	1	0	1	0	0	0	0	0	2
60—70	0	0	0	0	0	1	0	0	0	0	1
70—80	0	0	0	0	1	1	1	0	0	0	3
80—90	0	0	0	0	1	1	1	1	0	0	4
90—100	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	2	0	4	3	2	1	0	1	13

TABLE 5

Frequencies of days with 6 $\leqslant Nh \leqslant$ 8 octas

Humidity (H) (%)	Convergence (10^{-5} sec^{-1})										
	<-8	-8 to -6	-6 to -4	-4 t	-2	-2 to 0	0 to 2	2 to 4	4 to 6	6 to 8	>8	Total
25—50	0	0	0	0	0	0	0	0	1	0	1
50—60	0	0	0	0	2	1	0	0	1	0	4
60—70	0	0	1	0	0	0	1	0	0	0	2
70—80	0	0	0	1	0	0	2	1	0	0	4
80—90	0	0	0	0	0	1	3	2	0	0	6
90—100	0	0	0	0	0	3	2	1	0	1	7
Total	0	0	1	1	2	5	8	4	2	1	24

TABLE 6

Sky coverage Nh (octas)

Observed	0	1	2	3	4	5	6	7	8
Computed	0	0	4·2	4·5	5·3	6·2	5·8	6·8	7·8

$r_{NC\cdot H}$ and $r_{CH\cdot N}$ taking Yule's standard notation have been computed using the formula

$$r_{NH\cdot C}=(r_{NH}-r_{NC}\cdot r_{HC})/(\sqrt{1-r^2_{NC}}\sqrt{1-r^2_{HC}})$$

and similarly for $r_{NC\cdot H}$ and $r_{CH\cdot N}$. These values are

$$r_{NH\cdot C}=0\cdot935,\quad r_{NC\cdot H}=0\cdot359 \quad \text{and}$$
$$r_{CH\cdot N}=-0\cdot194$$

All the three multiple correlation coeffcients are about 0·9. These results show the obvious dominance of humidity over cloud amounts as all the three correlation coefficients between humidity and cloud amount exceed 0·9. The partial correlation between convergence and cloud amounts is positive but the value is much less. This shows that though the convergence is favourable for cloudiness but by itself is not conducive to cloudiness. The total and partial correlation coefficients between horizontal convergence and mean atmospheric humidity show different signs which clearly indicates that no definite relationship exists between the two.

The partial regression equation

$$(N-\bar{N})=b_{NH\cdot C}\,(H-\bar{H})+b_{NC\cdot H}\,(C-\bar{C})$$

of humidity and convergence on cloud amount have been obtained where $b_{NH\cdot C}$ and $b_{NC\cdot H}$ are the partial regression coefficients. The formulae are

$$b_{NH\cdot C}=r_{NH\cdot C}\,(\sigma_{N\cdot CH}/\sigma_{H\cdot NC}),$$
$$b_{NC\cdot H}=r_{NC\cdot H}\,(\sigma_{N\cdot CH}/\sigma_{C\cdot NH})$$
$$\sigma^2_{N\cdot HC}=\sigma^2_N\,(1-r^2_{NH})\,(1-r^2_{NC\cdot H})$$
$$\sigma^2_{H\cdot NC}=\sigma^2_H\,(1-r^2_{NH})\,(1-r^2_{HC\cdot N})$$
$$\sigma^2_{C\cdot NH}=\sigma^2_C\,(1-r^2_{CN})\,(1-r^2_{CH\cdot N})$$

The regression equation comes out to be

$$N=0\cdot128\,H+0\cdot390\,C-5\cdot652.$$

The standard error of these regression coefficients have been computed by

$$\sigma b_{NH\cdot C}=(\sigma_{N\cdot HC}/\sigma_{H\cdot NC})\sqrt{(1-r^2_{NH\cdot C})/n}=0\cdot161$$

$$\sigma b_{NC\cdot H}=(\sigma_{N\cdot CH}/\sigma_{C\cdot NH})\sqrt{(1-r^2_{CN\cdot H})/n}=0\cdot131$$

Table 6 shows the observed and computed values of sky coverage, (N_h), in octas on the basis of the regression equations.

The value of $\chi^2=2\cdot2$ is highly insignificant at 5 per cent level of significance. Thus the empirical formula

$$N=0\cdot13\,H+0\cdot39\,C-5\cdot65$$

TABLE

	Nh (octas)	H (per cent)	C (10^{-5}sec^{-1})
	0	37	—1
	1	37	—1
	2	55	7
	3	72	2
	4	75	3
	5	85	2
	6	85	1
	7	75	4
	8	95	3
Mean	4	68·4	2·3
Standard deviation	2·6	17·8	2·3

for estimating cloud amounts for particular values of convergence and humidity is statistically consistent. This formula can be further simplified to $15N=2H+6C-87$ where C is in the units of 10^{-5} sec $^{-1}$.

5. Conclusions

(*a*) As it is evident from high degree of partial correlation coefficient about 0·9 noticed between N and H, the moisture contents in the atmospheric column from the surface to about 3 km height mainly governs the type and the amount of cloudiness. Cloudiness is found to be less dependent on convergence though the convergence favours certain cloud types and more sky coverage owing to a positive correlation of about 0·4 between the two.

(*b*) The empirical relation for estimating cloud amounts on the basis of observed values of mean humidity (H) and convergence (C) is

$$15N=2\,H+6C-87$$

where the regression coefficients are highly significant considering the data under study.

(*c*) The results obtained above are essentially based on a small sample study and they have to be tested further by taking larger samples of varying nature and period.

Acknowledgement

The authors wish to express their thanks to the staff of State Meteorological Centre, Jaipur, for their valuable help in computation and drawings.

REFERENCES

Bellamy, J. C.	1949	*Bull. Amer. Met. Soc.*, **30**, 2, pp. 45-49.
Ghosh, A. K.	1970	*Indian J. Met. Geophys.*, **21**, 1, pp. 65-70.
India met. Dep.	1968	*Aerological data of India.*
	1969	*Ibid.*
Kumar, Surendra	1970	*India met. Dep. Sci. Rep.*, 133.
Ramalingam, N.	1960	*Nature*, **185**, p. 900.
Yule, G. U. and Kendall, M. G.	1949	*An Introduction to the Theory of Statistics.*