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Diurnal variation of rainfall in Brahmaputra valley

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ABSTRACT. A study has been done of the diurnal variation of rainfall in Brahmaputra valley considering the mean hourly monthly rainfall at four stations distributed throughout the valley. It is found that a well marked diurnal variation in the rainfall exists with a maximum in the early morning hours and minimum in the afternoon hours in the area. It has been argued that this is mainly due to the mountain winds.

1. Introduction

An earlier study by Prasad (1970) has shown a marked diurnal variation of rainfall over Cherapunji with well marked maximum in the morning hours and equally marked minimum in the afternoon. Cherapunji is on the southern slope of Khasi-Jaintia hills at the height of 1313 m a.m.s.l. This suggested the possible effect of differential heating of air over plains compared with neighbouring mountain mass and resulting subsidence ring (Bleeker and Andre 1951; Malkus 1955). As this type of circulation will have greater effect in a wide valley due to mountainous effect from two sides, a narrow valley may come in continuation of the circulation set in over the adjacent mountains during intense heating. The point has been further examined in the present paper by studying the behaviour of rainfall in Brahmaputra valley.

2. Data

Monthly hourly rainfall data, as published in India Meteorological Department publication, *Annual Summary-Part A*, for the four stations : North Lakhimpur, Dibrugarh, Tezpur and Gauhati in Brahmaputra valley have been taken. The periods for which the data have been utilised are shown in Table 1. From these monthly hourly rainfall for different years the mean monthly hourly rainfall have been calculated by simple average method. The mean monthly hourly rainfall for the different stations have been shown in Tables 2 to 5.

3. Result

An examination of Tables 2-4 shows clearly that rainfall of the stations : North Lakhimpur, Dibrugarh and Tezpur during the period commencing from about midnight to about 6 hours in the morning is much more than the rainfall during the afternoon hours. Variation from maximum in the early morning hours to minimum in the afternoon and then again to the maximum is more or less regular. The feature is almost similar in all the seasons and all the stations. The only exception is the rainfall in March at Tezpur, where a double maxima exists, one in early morning and the other in afternoon.

To bring out the contrast more clearly, the six hourly rainfall between 00 to 06 hours (period of maximum) and between 12 to 18 hours (period of minimum) as percentage of the 24 hourly rainfall are shown in Table 6.

Examination of the Table 5 reveals that rainfall pattern at Gauhati is not uniform throughout the year. During pre-monsoon months of April and May and also during the month of June, the pattern is similar to that of Tezpur, Dibrugarh and North Lakhimpur. The pattern also remains the same during winter months November to February. During March and July to September it shows a double maxima one in the morning and the other in the afternoon. The rainfall in October is more or less uniformly distributed throughout the day.

TABLE 1

Station	Lat. (°N)	Long. (°E)	Height (m)	Period
North Lakhimpur	27°14′	94°07′	101	1957-1965
Dibrugarh (Mohanbari)	27°29′	95°01′	110	1955-1965
Tezpur	26°37′	92°47′	77	1959-1965
Gauhati	26°06′	91°35′	47	1956-1965

TABLE 2

Mean hourly rainfall (mm) of North Lakhimpur

Hours (IST) ending at	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
01	01·4	02·6	04·1	13·2	33·5	33·7	56·0	35·5	15·0	12·4	07·0	01·8
02	00·9	02·0	05·9	08·0	27·6	43·7	49·2	30·7	15·8	15·8	04·7	03·5
03	02·3	03·2	05·1	05·3	33·6	54·7	48·2	30·9	19·8	21·1	02·0	00·6
04	01·6	03·1	03·2	05·2	42·7	52·2	42·2	42·0	38·8	08·9	03·8	00·4
05	02·2	03·8	02·0	11·0	33·2	43·7	44·5	25·1	28·8	12·9	03·4	00·5
06	02·3	03·1	03·4	08·3	29·7	33·0	45·0	44·4	26·8	08·8	03·8	00·8
07	01·2	03·8	05·4	06·7	18·2	32·9	36·2	31·8	36·4	10·7	05·6	01·0
08	01·5	02·5	02·3	07·7	18·8	34·3	39·2	28·1	27·7	04·1	03·4	02·7
09	01·0	01·1	01·4	08·7	14·5	15·5	16·6	16·5	16·8	05·8	03·8	00·4
10	00·5	00·8	01·3	06·4	13·7	13·0	12·4	14·0	11·4	04·9	01·3	00.2
11	00·8	01·0	00·5	06·0	12·0	17·8	09·9	06·9	06·1	07·5	00·8	00·3
12	01·0	02·9	00·7	01·7	07·5	09·1	15·6	11·3	04·3	03·8	07·6	00·6
13	00·4	01·4	00·9	01·7	04·8	05·9	08·2	08·8	05·3	02·9	00·6	00·2
14	00·5	01·1	00·7	03·8	04·4	07·0	10·5	05·0	07·1	03·1	00·6	00·7
15	00·6	00·4	01·8	07·7	03·6	07·2	06·1	06·4	06·3	04·9	00·2	00·7
16	00·4	00·7	01·9	03·9	05·3	08·6	05·1	02·6	02·9	03·0	00·2	00·4
17	00·8	00·8	00·4	03·4	07·1	10·0	03·5	04·8	02·5	01·3	00·1	00·6
18	00·8	01·2	00·5	06·8	07·9	13·6	07·0	06·7	07·1	01·5	00·2	00·4
19	00·1	00·8	01·5	05·8	14·9	16·3	09·3	07·3	11·6	04·2	00·3	00·8
20	00·2	01·2	05·1	09·2	14·2	13·2	18·3	06·7	10·2	02·3	00·5	00·1
21	00·4	02·3	03·1	09·0	16·0	13·2	28·7	13·4	09·5	01·6	00·7	00·1
22	00·6	02·7	04·7	12·6	16·2	22·0	25·8	15·9	08·5	02·0	01·6	00·9
23	01·4	02·0	02·9	17·3	19·2	33·0	25·8	22·6	09·4	06·1	00·4	00·7
24	02·1	02·6	03·9	12·3	34·8	23·3	41·2	28·1	10·3	10·0	03·3	00·2

4. Discussion

The amount of rainfall depends on the rate of ascent and the moisture content of the air. Rate of ascent depends on the low level convergence, upper air divergence and instability. The low level convergence depends upon local features and the synoptic situation, while the upper air divergence depends only on the synoptic situation. The moisture content of the air depends upon the condensation, evaporation and advection of moisture. The synoptic situation and the radiational heating of the ground are the two factors chiefly responsible for causing instability at a place. Instability within cloud also develops due to radiational cooling of the cloud tops during night (Pedgley 1969).

If it is assumed that the synoptic situation has no preference for a particular hour of the day, the

TABLE 3

Mean hourly rainall (mm) of Dibrugarh

Hours (IST) ending at	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
01	01·9	03·5	07·9	13·6	27·4	20·3	36·2	27·3	14·6	09·7	01·5	00·3
02	03·2	04·7	04·5	14·1	18·8	27·5	46·6	35·5	12·0	11·4	01·8	00·7
03	01·7	04·4	05·9	15·2	23·7	30·7	48·8	39·3	22·6	14·7	03·0	01·5
04	02·1	05·2	05·0	17·2	24·4	35·2	44·7	34·2	16·4	11·1	01·0	01·0
05	01·2	05·7	05·2	07·0	21·1	31·0	38·5	39·5	20·3	16·3	01·7	01·3
06	01·3	03·5	05·7	09·8	14·9	36·1	33·7	27·2	28·3	12·9	01·6	02·6
07	01·0	04·6	03·8	04·6	18·2	23·2	26·2	22·5	24·8	11·7	01·5	01·6
08	01·3	02·4	03·0	05·9	20·3	21·5	18·4	17·0	15·1	08·8	00·6	01·6
09	01·1	02·0	03·9	05·5	15.9	16·1	15·5	15·1	11·1	06·2	00·5	00·3
10	00·3	01·3	04·8	05·8	11·4	14·5	14·0	15·0	09·0	05·9	01·0	01·0
11	00·4	00·6	03·4	03·3	09·0	13·9	14·6	17·1	09·4	04·0	02·0	00·6
12	00·4	00·8	02·7	03·0	06·1	09·6	09·2	10·6	10·3	03·9	00·8	00·2
13	00·3	00·6	02·9	03·1	05·2	05·1	07·5	04·4	05·7	02·6	00·1	00·3
14	01·0	01·4	02·2	02·6	04·0	05·3	06·6	02·8	01·9	01·4	00·1	00·1
15	00·2	01·0	01·6	03·3	03·9	05·2	04·2	01·4	02·0	02·6	00·6	00·9
16	00·3	01·2	00·9	02·4	03·1	05·0	02·7	02·6	01·7	00·5	00·0	00·2
17	00·4	01·0	01·6	06·1	07·2	16·5	05·1	08·3	03·7	00·3	00·2	00·5
18	01·6	01·7	02·8	07·0	05·0	06·1	12·4	04·6	05·2	00·4	00·3	00·5
19	01·3	01·9	02·9	04·7	05·9	06·9	10·1	02·8	03·4	03·0	00·4	00·2
20	01·2	01·6	03·4	08·3	06·2	06·9	10·2	04·0	02·6	03·5	00·6	00·3
21	01·6	03·5	03·5	14·6	07·7	13·6	13·4	07·0	05·6	03·1	00·6	00·4
22	01·6	03·5	06·4	15·3	13·2	11·6	16·5	10·5	03·4	01·1	00·9	01·0
23	01·7	02·6	05·3	11·9	15·3	20·5	24·7	14·7	06·2	03·7	00·6	00·8
24	02·8	03·2	06·5	12·7	26·3	25·9	40·5	13·9	06·2	04·8	02·3	01·0

diurnal variation of rainfall will depend on the diurnal variation of the following elements.

(*i*) *Instability* — Due to the heating of the ground during day and cooling during night instability of the atmosphere is more during the afternoon hours than during the morning hours over land.

(*ii*) *Moisture content* — During afternoon hours higher surface temperature and lower relative humidity cause evaporation to be maximum, wind also has a tendency to blow from water surfaces, thus advecting more moisture over land areas during afternoon hours. Consequent to this, other factors remaining the same, maximum of the diurnal variation of moisture content of the atmosphere, in general occurs in the afternoon.

(*iii*) *Low level convergence* — This may have any diurnal variation depending upon orography, situation of land and sea and general wind (Ramage 1965).

(*iv*) *Radiational cooling of the top of the cloud* — Obviously this will have maximum in the morning and minimum at the local noon and will not depend upon local features.

TABLE 4

Mean hourly rainfall (mm) of Tezpur

Hours (IST) ending at	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
01	00·2	00·3	02·9	11·0	18·8	19·2	22·9	25·9	03·8	02·7	00·6	00·2
02	00·5	00·7	01·9	09·2	19·8	22·2	23·4	22·5	04·4	12·0	01·0	00·3
03	00·3	01·6	01·0	10·9	20·1	23·7	26·5	20·5	13·8	05·0	01·6	00·0
04	00·4	02·4	00·6	05·9	23·6	16·4	15·8	34·0	08·9	03·7	01·8	00·0
05	00·4	00·2	01·0	08·3	18·5	32·5	21·8	18·3	31·5	01·5	01·0	00·1
06	00·0	00·2	00·9	06·4	10·8	25·9	25·1	13·9	20·7	03·8	01·0	00·1
07	00·0	00·0	01·6	07·9	14·1	19·1	22·2	14·2	14·9	08·1	00·3	00·0
08	00·0	00·0	01·1	05·6	18·3	14·5	10·5	13·6	10·0	09·8	00·2	00·5
09	00·8	00·0	00·1	01·6	17·3	11·9	10·4	08·2	09·0	02·2	00·2	00·1
10	00·2	00·0	00·8	01·8	08·5	13·7	05·5	10·4	09·9	05·0	00·0	00·1
11	00·1	00·0	01·1	06·8	03·9	09·5	05·6	04·7	09·4	02·8	00·0	00·0
12	00·3	00·0	03·5	02·8	03·9	06·3	05·4	01·0	03·4	03·0	00·0	00·0
13	00·0	00·0	02·6	00·1	03·9	04·9	05·3	00·3	03·3	01·2	00·0	00·4
14	00·0	00·0	01·0	00·0	01·6	05·2	03·0	02·0	00·6	01·1	00·0	00·1
15	05·0	00·0	00·2	00·2	03·2	06·3	01·4	01·7	02·9	02·0	00·0	00·0
16	00·6	00·0	02·2	00·2	02·9	01·8	01·3	04·9	02·2	02·0	00·0	00·0
17	00·1	00·0	04·2	00·7	04·8	04·4	05·7	01·6	00·6	01·1	00·0	00·0
18	00·0	00·0	00·7	03·0	06·2	02·0	05·0	05·0	00·3	00·7	00·0	00·0
19	00·0	0·15	01·5	01·8	12·1	10·7	08·3	04·9	01·8	02·2	00·1	00·0
20	00·0	00·4	00·9	03·2	07·0	04·0	15·9	04·2	04·1	04·1	00·3	00·0
21	00·0	01·0	02·7	07·3	17·5	06·6	14·5	04·6	02·4	00·6	00·6	00·1
22	00·4	01·7	04·8	13·0	17·4	11·1	11·1	05·3	06·7	02·5	00·8	00·6
23	00·2	00·7	02·2	06·2	23·5	07·7	13·3	12·5	05·7	02·9	00·8	00·0
24	00·1	01·2	01·9	07·2	21·4	18·8	25·8	13·2	07·3	04·6	00·7	00·1

The feeble morning maximum observed during monsoon season over the country in the previous study (Prasad 1970) indicates that its effect on diurnal variation of rainfall is feeble.

So, well marked morning maximum in the diurnal variation of rainfall in Brahmaputra valley is effect of low level convergence. During the night katabatic wind causes convergence in the valley, thus accentuating the rainfall activity. The

TABLE 5

Mean hourly rainfall (mm) of Gauhati

Hours (IST) ending at	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
01	00·3	00·7	01·7	06·5	10·5	11·6	13·7	10·7	04·6	01·5	00·3	00·1
02	00·4	00·8	01·5	09·0	09·5	17·1	16·6	13·4	09·4	01·4	01·2	00·0
03	00·4	00·7	04·6	10·2	23·9	11·9	16·5	16·9	05·2	04·4	00·6	00·2
04	00·3	00·3	03·5	06·3	18·3	13·9	17·0	15·1	07·8	04·3	00·3	00·1
05	00·3	00·2	00·9	03·7	12·3	20·2	22·0	15·9	13·3	02·0	00·2	00·0
06	00·0	00·6	01·9	08·0	21·4	14·1	20·0	12·5	03·6	02·1	00·1	00·0
07	00·3	00·1	02·3	05·4	20·0	16·9	15·6	03·8	04·2	04·0	00·5	00·0
08	00·5	00·1	01·7	04·3	15·1	14·9	12·7	07·6	05·3	03·1	00·1	00·0
09	00·2	00·0	01·1	01·7	07·5	17·1	04·6	02·1	04·6	02·4	00·0	00·0
10	00·2	00·4	00·2	03·3	13·3	14·2	04·8	02·7	03·1	01·8	00·2	00·0
11	00·2	00·2	00·9	01·3	11·2	11·2	03·9	03·3	04·2	02·2	00·2	00·0
12	00·1	00·4	00·9	00·8	08·8	07·4	03·7	06·1	08·3	08·0	00·2	00·0
13	00·5	00·0	02·0	00·4	07·4	10·1	07·2	09·7	05·5	01·6	00·1	00·0
14	00·6	00·3	02·1	00·6	06·2	14·7	10·5	09·9	07·4	03·2	00·0	00·0
15	01·3	00·5	00·8	00·5	08·0	11·6	21·3	11·4	06·7	02·2	00·0	00·0
16	00·7	00·0	01·2	03·6	05·8	08·9	17·3	15·0	07·0	02·8	00·0	00·0
17	00·9	00·2	01·5	04·1	03·8	08·1	14·0	15·8	03·6	02·7	00·0	00·0
18	00·2	00·1	01·6	04·8	01·7	08·0	22·3	11·6	02·4	00·7	00·0	00·6
19	00·9	00·6	02·1	04·9	01·9	04·5	16·5	11·1	01·7	02·7	00·2	00·0
20	00·9	01·0	01·3	06·6	09·2	04·0	08·6	21·9	03·4	03·8	00·3	00·1
21	00·5	00·6	02·8	07·3	10·5	09·6	07·0	11·4	02·1	01·5	00·2	00·3
22	00·5	01·2	01·3	16·7	12·5	08·5	10·0	14·9	04·1	02·2	00·3	00·2
23	00·3	01·3	00·7	06·2	10·7	10·5	10·8	08·1	07·8	03·4	00·1	00·9
24	00·3	01·6	01·8	09·8	11·3	07·9	11·7	09·3	05·3	01·8	00·2	00·1

anabatic wind, during day, causes low level divergence resulting in subsidence. This suppresses the rainfall activity in the afternoon.

Table 7 gives mean dew point temperature for the month of May 1968 at surface and 700 mb over Gauhati and Calcutta at 0000 and 1200 GMT. It is seen that dew point temperature at Gauhati is higher in the afternoon than in the morning at surface while at 700 mb it is higher in the morning than in the afternoon. At Calcutta it is just opposite.

If sufficient supply of moisture is available, the diurnal variation of dew point temperature follows the temperature line in absence of precipitation, *i.e.*, it will have a minimum in the morning and maximum in the afternoon. During summer and in absence of sufficient supply of moisture, the dew point temperature will be higher in the morning than in the afternoon at surface, as moisture will be transported to higher level by convection and evaporation will not be able to make good the loss. At some higher level (depending on the penetration of convective activity) the dew point temperature will be less in the morning than in the afternoon.

Behaviour of the dew point temperature at Calcutta in May 1968 is in accordance with the above

TABLE 6

Rainfall during 00 to 06 and 12 to 18 hr as percentage of 24 hr rainfall

Hours (IST)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						North Lakhimpur						
00-06	43	38	38	32	46	47	47	47	43	50	45	40
12-18	14	12	10	16	08	09	07	08	09	10	03	16
						Dibrugarh						
00-06	40	44	36	40	41	45	50	54	47	53	45	39
12-18	10	11	13	12	09	11	08	06	08	05	06	13
						Tezpur						
00-06	35	51	20	43	37	47	42	54	47	34	64	27
12-18	20	00	24	03	08	08	07	06	06	10	00	15

TABLE 7

Dew point temperature (°C) of May 1968*

	Gauhati		Calcutta	
	00 GMT	12 GMT	00 GMT	12 GMT
Surface	21·6	23·3	25·4	23·7
700 mb	2·9	0·9	—2·3	—1·7

*Taken from *Aerological Data of India*, May 1968

argument but it is reverse at Gauhati, suggesting absence of convective activity in the afternoon at Gauhati. It may be noted that diurnal variation of dew point at surface is opposite to that of rainfall both at Gauhati and Calcutta. Thus behaviour of dew point temperature at Gauhati also suggests supression of convective activity in the afternoon during summer in the valley.

The uniform effect throughout the year seems due to combined effect of both the mountain winds. The former is more effective during winter while the latter in summer. During the monsoon months when mountain winds are expected to be less effective (due to cutting of incoming solar radiation during day and out going long wave radiation during night on account of cloudiness and high moisture content of the atmosphere), the difference seems due to the sensitiveness of the monsoon air to small difference in the low level convergence aided with radiational cooling of cloud tops. A different characteristic behaviour of diurnal variation of rainfall at Gauhati seems due to the fact that the station is near the exit of the valley and thus the effect is to some extent reduced. As may be expected the variation is similar to other stations during summer months and difference exists only in the months when both mountain winds are less effective.

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