551·515.4 (54)

Diurnal variation of thunderstorms in India during different seasons

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1. Introduction

The earliest study of thunderstorm frequencies in India was by Dallas (1900) who discussed observations taken at 10 stations in India during the year 1897. Since then there have been several studies but most of the climatological studies were restricted to particular places or small areas (Desai and Mull 1938) or with more restricted definitions of thunderstorm, *viz.*, those associated with rainfall (India met. Dep. 1944, Venkiteshwaran 1932, 1935). There has, however, been no systematic study on the diurnal variation of thunderstorm occurrences over the Indian continent as a whole and an attempt has been made in this paper to present the results of such a study. A knowledge of this would be of considerable practical value as an aid to the issue of aviation forecasts of this important aviation hazard.

2. Data

The break-down of the observational data of thunderstorm occurrences from the daily to hourly frequency of occurrence is beset with serious difficulties, the chief difficulty being absence of reliable hourly observations at a large network of observatories well distributed over the country. During recent years the number of observations per day have been increased at most of the main observatories particularly at aerodrome stations and it is believed that more thunderstorm reports are being logged in the meteorological registers than in the past. Even so, the data coverage is far from satisfactory and more systematic observations are necessary. The deficiencies of the data have been fully realised and kept in mind in this analysis and only broad conclusions have been given.

The data used for the present study were extracted from the *Monthly Meteorological Registers* of 47 observatories in India for the five years after 1940. The distribution of the stations is shown in Fig. 1. All occasions when thunderstorms occurred, with or without precipitation, at a station have been counted as thunderstorms occurring at the station.

3. Method of analysis

The frequencies of thunderstorms were originally tabulated for each of the 24 hours of the day. A thunderstorm spreading over 3 hours has been taken to belong to all the 3 hours. A table giving the monthly frequency of occurrence of thunderstorms for each 3-hour period was first prepared. The data were, however, on further consideration combined to give occurrences for the four 6-hourly periods 03-09, 09-15, 15-21 and 21-03 IST for the 4 seasons, since this combination gave a clearer picture of the diurnal distribution. These six-hourly frequencies are given in Table 1. The seasons have been taken as winter (January and February), hot weather (March, April and May), monsoon (June to September) and post-monsoon or retreating monsoon (October to December). Table 1 gives also the percentage frequency ($\%F$) obtained by dividing the number of occurrences N for each 6-hourly period of a season by the total number (ΣN) of occurrences during all the four diurnal periods. In addition to the 6-hourly percentage F, the percentage probabilities of occurrence of thunderstorms for the various diurnal periods of the different

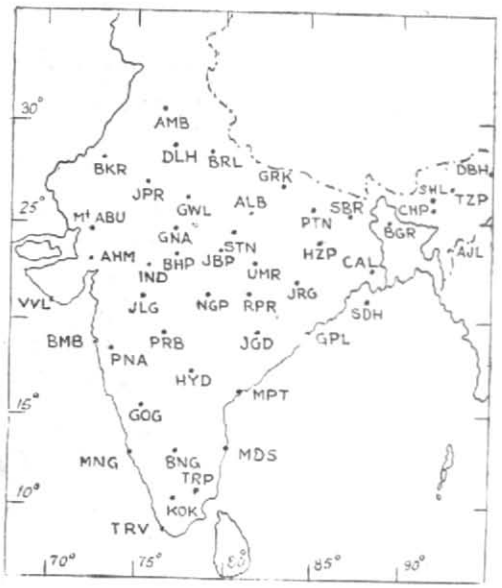

Fig.1. Station net work used in the analysis

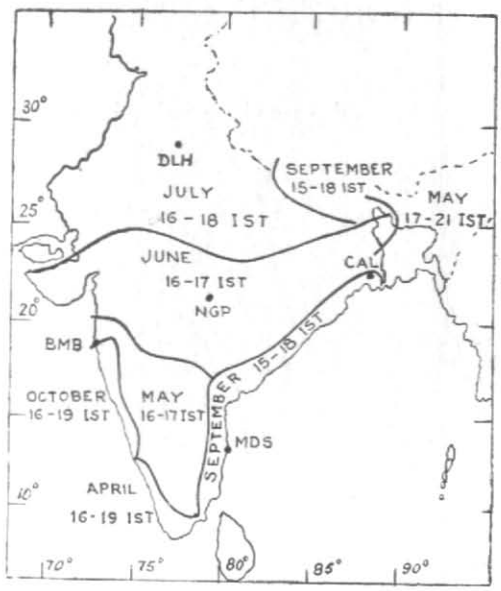

Fig. 2. Month and time(IST) of maximum thunderstorm activity

seasons as defined by Shands and others (U. S. W. B. 1947, Conrad and Pollak 1950 and Shands 1948) are also given under the column $\%P$ of Table 1. The $\%P$ (percentage probability or chance) of occurrence was obtained by dividing the number of thunderstorm occurrences during a 6-hour period of a season by the total number of such mathematically possible periods in the same season during the 5 years under study (*e.g.*, the winter season, January—February, has a total number of 300 such 6-hourly periods). The fifth line of the tabulation for each station gives the annual values.

4. Isoceraunic maps

The frequencies N from Table 1 were plotted in maps of India and isoceraunic lines giving lines of equal frequencies of occurrence drawn and maps showing mean annual and seasonal thunderstorm occurrences and the diurnal variation during the different seasons and for the year as a whole constructed. The $\%F$ values of the occurrences during the four periods of the season and for the year as a whole were also plotted. Figs. 3 to 7 show the diurnal pattern of isopleths of percentage frequency of occurrence of thunderstorms.

5. Discussion

5.1. *Annual*—The region of maximum frequency of occurrence of thundery activity during the year lies over northeast India with about 300 to 400 occurrences per year; the South Indian Peninsula, south of lat. 10°N, coming next in rank of frequency with 200 or more occurrences per year. The areas of east Uttar Pradesh, north Madhya Pradesh and the Peninsular India lying between lat. 10°N to 16°N generally get a frequency of 100 to 200 occasions per year. The areas of low frequency of thunderstorm activity are the north Konkan, Kutch and Saurashtra in the west and Andhra coast in the east.

When we consider the diurnal variability for the year as a whole it is seen that the period 15-21 hours is generally the most dominant period of thunderstorm activity with more than 50 per cent of occurrences during the period, though some of the coastal districts get a good proportion of thunderstorms during late night and early morning hours.

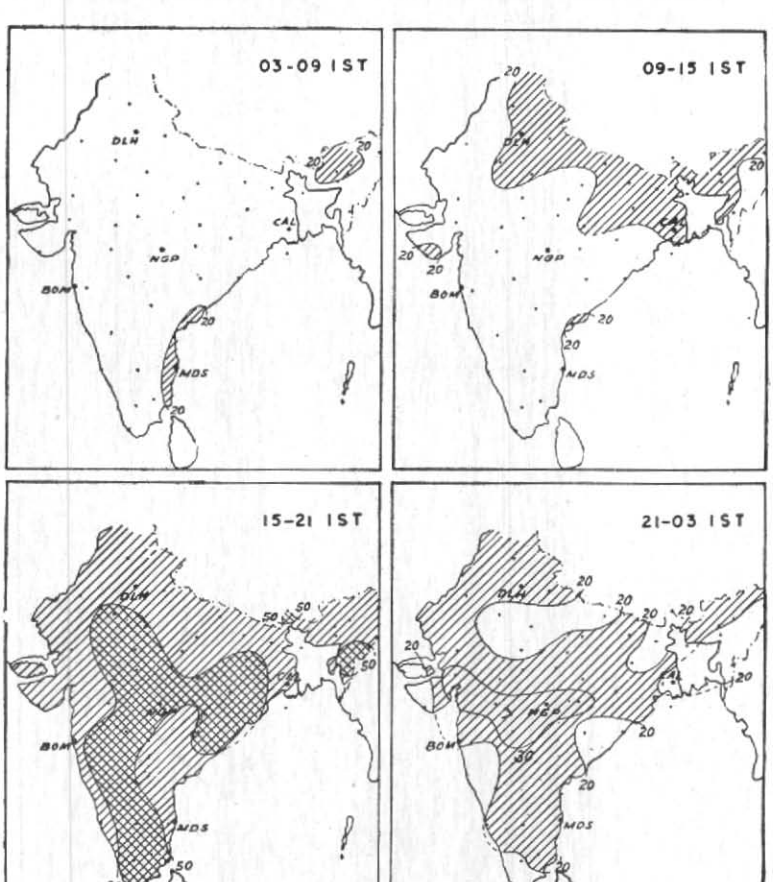

Fig. 3. Percentage of thunderstorm occurrences in different periods of the day during the year

5.2. *Winter season (January-February)*— During winter months the thunderstorm activity is maximum over northeast India with 20 to 60 occasions. The east Uttar Pradesh and adjoining areas of north Madhya Pradesh receive 10 to 20 or more occurrences.

The concentration of thunderstorm activity over the areas mentioned above during this season is associated with the passage from west to east of shallow lows called western disturbances or of troughs in the middle and upper tropospheric westerlies. These thunderstorms can be considered as upper cold frontal types occurring during all parts of the day. These thunderstorms over east Uttar Pradesh and nearby areas are frequently accompanied with hail also during this season, indicating existence of violent upward vertical currents associated with such situations. From an unpublished study of the hailstorm distribution in India (Iyer and Hariharan) it is seen that the districts of the above mentioned area experience nearly 60 to 70 per cent of the annual hail frequency during this season and these occur mostly during 15-2100 IST.

The period 15-2100 IST shows a preponderance of thunderstorm activity with 10-40 occasions over northeast India and 4-10 occasions over central parts of the country

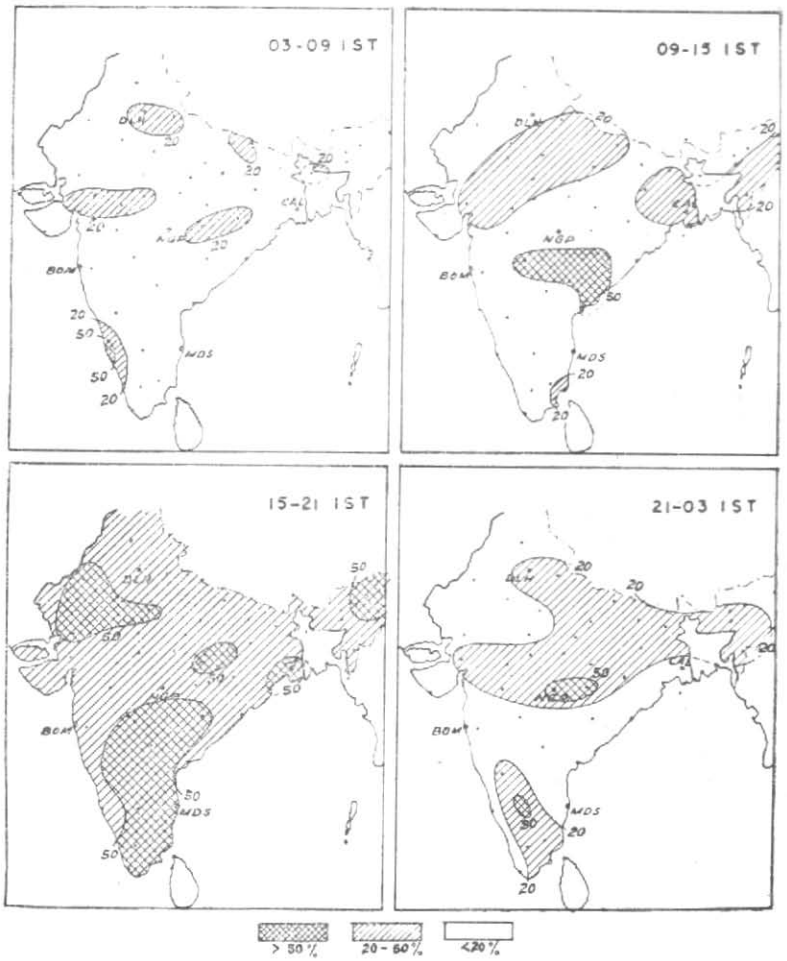

Fig. 4. Percentage of thunderstorm occurrences in different periods of the day during Winter (January and February)

along the Gangetic plain. The other diurnal periods also during this season experience about 4 thunderstorms each in these areas.

The Peninsular India south of lat. 10°N experiences 10 to 20 occurrences of thunderstorms during this season and out of these 50 to 70 per cent of thunderstorm activity occurs during 15-2100 IST. Synoptically these thunderstorms are associated with the passage westward of shallow troughs or waves in the easterlies, which give light showers over this part of the country in this season due to coastal convergence and orographic uplift. It is also of interest to note that the Konkan, Kutch, Saurashtra and Circars coastal areas are generally free from thunderstorm activity in this season.

5.3. *Hot weather season* (*March, April and May*)—As season advances from the cold season to the hot season thunderstorm activity also generally shows considerable increase, the area of maximum activity being the northeast India with 100 to 150 thundery occasions per season. Indian Peninsula south of lat. 15°N gets 50 to 100 occurrences and east Uttar Pradesh and north Madhya Pradesh get 30 to 40 occasions a season. The rest of the Indian area experiences 2 to 20 occasions showing a very wide range of variability.

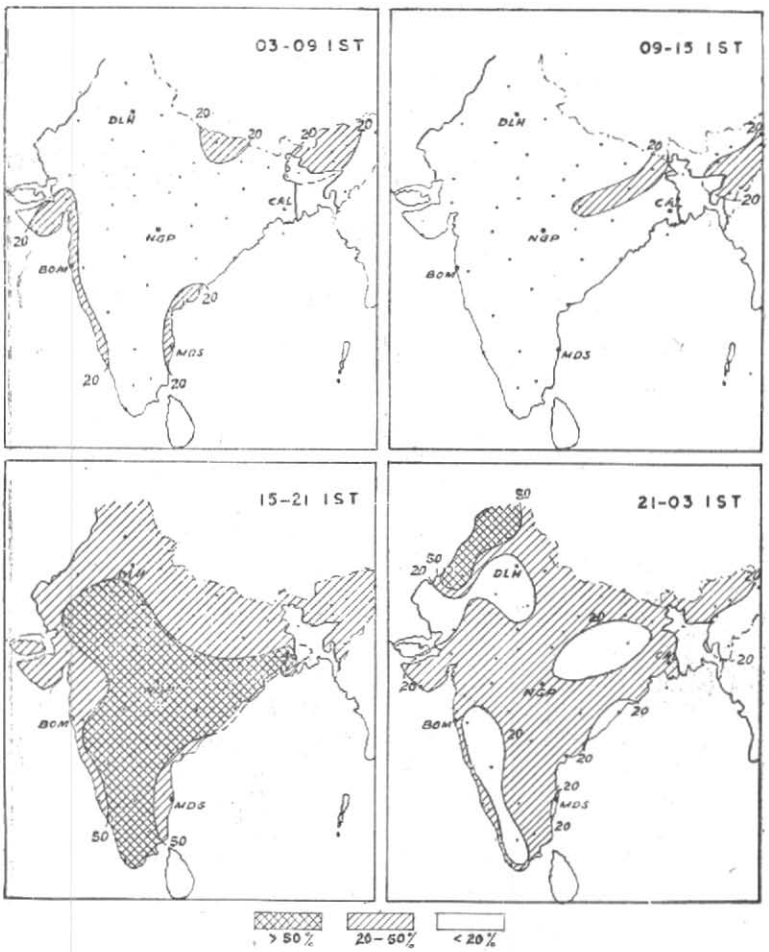

Fig. 5. Percentage of thunderstorm occurrences in different periods of the day during Hot Weather (March-May)

Thunderstorm activity over the interior parts of the continent reaches its maximum in the afternoon hours of 15-2100 IST and attains a minimum during night and morning. These afternoon thunderstorms due to convective instability, are caused by intense insolation which reaches its maximum also during this period of the day (the maximum temperature epoch).

These insolational thunderstorms (of the convective instability type) are modified by orography, and the mountainous regions of the country experience thunderstorm activity towards late evening or early night hours. Areas in Assam, Mysore and Kerala coast experience thunderstorms of the above mentioned type during this season. This is also the season of devastating thunderstorm activity usually called Nor'westers which occur in Bengal, Bihar, Orissa and Assam and these bear great similarity in their destructive capacity to the tornadoes and line-squalls met with in other parts of the world. The Kerala coast gets its violent pre-monsoon thunderstorms during night and early morning hours of the day in May. It may be of interest to note that 60 to 80 per cent of hail occurrences of the year occur during this season during the period 12-1800 IST over most of the districts of India in association with thunderstorms as a result of the high

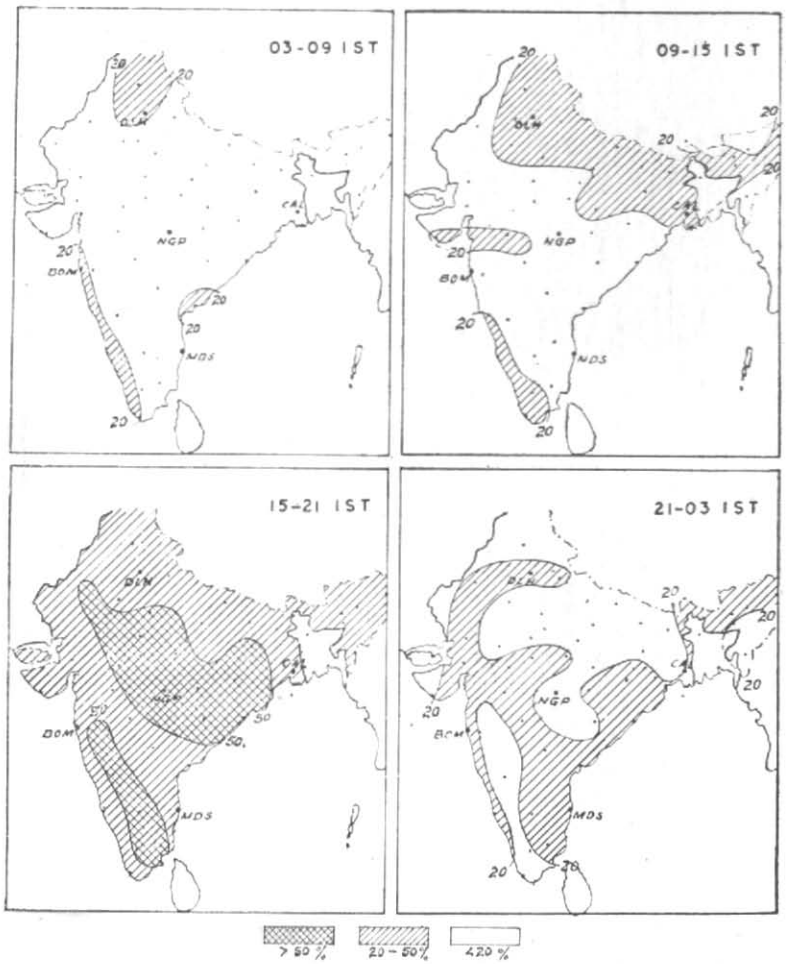

Fig. 6. Percentage of thunderstorm occurrences in different periods of the day during Monsoon (June—September)

vertical upward currents in them. The hailstorm occurrence is maximum in north India and only the plateau and hilly regions of south India get a few thunderstorms accompanied by hail in this season (Iyer and Hariharan).

5.4. *Monsoon season (June-September)*—The southwest monsoon gets established over the Indian continent during the beginning of June and holds sway till the end of September. This season is also further characterised by very heavy rainfall over parts of India. Storms and depressions of the Bay of Bengal form at the head Bay and travel generally northwest till they merge into the seasonal low over northwest India. The Gangetic valley of Bihar and Bengal and the mountainous areas of Assam experience the maximum thunderstorm frequency of 40 to 100 or more occurrences during this season in association with these depressions. The Tamilnad areas of the Peninsula to the east of the Western Ghats also experience 40 or more thunderstorms and the west coast of India gets 10 to 20 thunderstorms during this season. The regions of minimum thundery activity in this season are the areas of the Kutch, Saurashtra and the coastal districts of Andhra Pradesh.

The diurnal variation in this season also shows a maximum during 15-2100 IST with 50 to 60 per cent of thunderstorms occurring in the interior of the country. The coastal

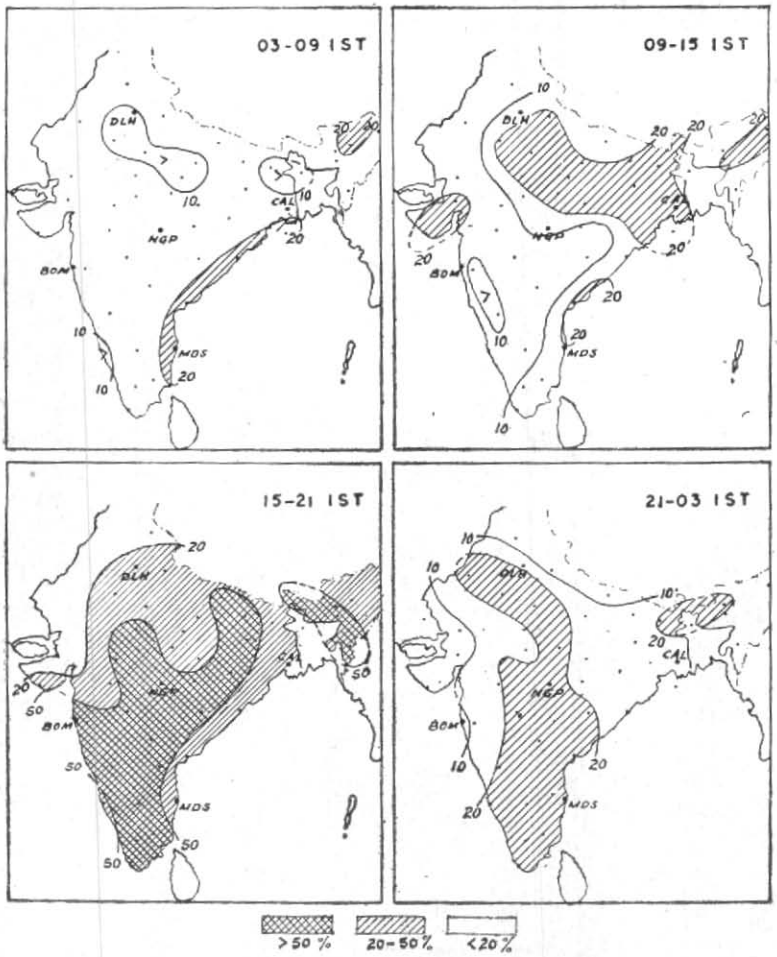

Fig. 7. Percentage of thunderstorm occurrences in different periods of the day during Post-Monsoon (October—December)

districts of Kerala and Konkan experience 20 to 30 per cent in almost all the diurnal periods with a maximum during night and a minimum during the day time period of 09-1500 IST. Areas of Bengal, Assam and Orissa get more than 20 per cent of the thunderstorms during night hours also, in association with the passage inland of the monsoon depressions and cyclonic storms moving inland from the head Bay of Bengal.

5.5. *The post-monsoon season* (*October—December*)—This is the season when the southwest monsoon begins to retreat from the country and is replaced by the northeast monsoon which holds sway till the end of the season and also sometime later. The area o maximum thunderstorm activity has shifted in this season to the Peninsula south of Lat. 15°N with 40 to 80 occurrences per season and northeast India coming next getting 20 to 40 occasions per season. The Tamilnad districts of the Peninsula get their main rainfall of the year during this season.

The diurnal period of maximum thunderstorm activity is 15-2100 IST and the late night and morning hours are generally free from thunderstorms over major portions of the country. Night thunderstorms between 21-0300 IST are, however, in evidence during this season over the Kerala coast. The

districts of the Coromondal coast also experience early morning thunderstorms between 03-0900 IST. The Bay of Bengal area east of the Madras coast is the region of formation of maximum cyclonic storms and depressions during this season and most of the thunderstorm activity over this coast occurs in association with these disturbances. The thunderstorms are mostly due to the convergent action of the moisture laden winds, the onshore northeasterlies of this season when it strikes the east coast of India.

5.6. Figs. 3 to 7 give the percentage frequency distribution of thunderstorm occurrences during the different diurnal periods for the year as a whole and for the different seasons. The month and time (IST) of maximum thunderstorm activity in different regions of India has been given in Fig. 2 for facility of ready reference.

6. Some general features

Certain coastal areas experience the interplay of land and sea breeze mainly in the hot season and the boundary between these two air streams behaves as a quasi-cold front and produces thundershowers which move inland with the advancing surge of sea breeze. Later at night when land breeze pushes the sea breeze back into the sea the coastal areas get sharp thundershowers again. Madras coast is one such area which experiences 2 spells of thunderstorm activity once in the evening and again at night hours on such occasions.

It is generally known that thunderstorms over the sea area are nocturnal phenomena and the data of Saugor Island may probably be taken to represent such conditions. The records of the observatories in the islands of Minicoy in the Arabian Sea and Port Blair in the Bay of Bengal when analysed are likely to reveal this fact more conclusively. Further work will, however, be required for a fuller understanding of these features.

7. Concluding remarks

In conclusion it can be stated that the facts and figures about thunderstorms presented in this paper, in spite of the obvious limitations of the data, have yielded valuable information of practical utility primarily to the aviation weather forecaster in his day-to-day work. In addition to meteorologists and aviation interests, a knowledge of the probability of thunderstorm occurrences in the country is of great value to enterprises like hydro-electric and electric power undertakings, industrial and defence establishments and a wide variety of other public utility interests. The need for a more detailed and critical examination of thunderstorm occurrences based on a study of at least 10 years of hourly reports from as large a number of stations as possible is however, stressed which is likely to reveal many more interesting features of great practical and forecasting value about thunderstorm occurrences in India.

8. Acknowledgement

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TABLE 1

Diurnal variation of thunderstorm occurrences in India

(Total frequencies in the 5-year period)

	03-0900 IST			09-1500 IST			15-2100 IST			21-0300 IST			ΣN	Seasonal (%N)
	N	F (%)	P (%)	N	F (%)	P (%)	N	F (%)	P (%)	N	F (%)	P (%)		
						ALIPORE								
W	2	6·2	0·7	7	21·9	2·3	20	62·5	6·7	3	9·4	1·0	32	2·1
H	31	8·1	6·7	44	11·5	9·6	208	54·5	45·2	99	25·9	21·5	382	25·3
SM	87	8·6	14·3	368	36·4	60•3	438	43·2	71·8	120	11·8	19·7	1013	67·2
PM	12	15·0	2·6	39	48·8	8·5	26	32·5	5·7	3	3·7	0·7	80	5·3
T	132	8·8	7·2	458	30·4	25·0	692	45·9	37·8	225	14·9	12·3	1507	
						AMBALA								
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H	1	3·1	0·2	2	6·3	0·4	13	40·6	2·8	16	50·0	3·5	32	39·5
SM	13	26·5	2·1	17	34·7	2·8	13	26·5	2·1	6	12·2	1·0	49	60·4
PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T	14	17·3	0·8	19	23·5	1·0	26	32·1	1·4	22	27·2	1·2	81	
						ALLAHABAD								
W	18	17·8	6·0	29	28·7	9·7	29	28·7	9·7	25	24·8	8·3	101	11·1
H	12	11·1	2·6	12	11·1	2·6	47	43·5	10·2	37	34·3	8·0	108	11·9
SM	104	15·4	17·0	113	16·7	18·5	267	39·6	43·8	191	28·3	31·3	675	74·2
PM	3	11·5	0·7	7	26·9	1·5	12	46·2	2·6	4	15·4	0·9	26	2•9
T	137	15·1	7·5	161	17·7	8·8	355	39·0	19·4	257	28·2	14·0	910	
						AHMEDABAD								
W	6	33·3	2·0	4	22·2	1·3	4	22·2	1·3	4	22·2	1·3	18	7·6
H	6	37·5	1·3	1	6·3	0·2	4	25·0	0·9	5	31·3	1·1	16	6·7
SM	31	15·4	5·1	14	7·0	2·3	66	32·8	10·8	90	44·8	14·7	201	84·5
PM	0	0	0	3	100·0	0·7	0	0	0	0	0	0	3	1·3
T	43	18·1	2·3	22	9·2	1·2	74	31·1	4·0	99	41·6	5·4	238	
						ALJAL								
W	4	19·0	1·3	6	28·6	2·0	6	28·6	2·0	5	23·8	1·7	21	5·5
H	21	11·7	4·6	44	24·6	9·6	81	45·3	17·6	33	18·4	7·2	179	46·5
SM	9	5·2	1·5	17	9·8	2·8	120	69·4	19·7	27	15·6	4·4	173	44·9
PM	1	8·3	0·2	0	0	0	7	58·3	1·5	4	33·3	0·9	12	3·1
T	35	9·1	1·9	67	17·6	3·7	214	55·6	11·7	69	17·9	3·8	385	
						BOGRA								
W	6	27·3	2·0	2	9·1	0·7	6	27·3	2·0	8	36·4	2·6	22	1·3
H	94	20·8	20·4	80	17·7	17·4	176	38·8	38·3	103	22·7	22·4	453	27·8
SM	178	16·8	29·2	238	22·5	39·0	402	37·9	65·9	242	22·8	39·7	1060	65·0
PM	21	21·9	4·6	15	15·6	3·3	39	40·6	8·5	21	21·9	4·6	96	5·9
T	299	18·3	16·3	335	20·5	18·3	623	38·2	34·0	374	22·9	20·4	1631	

TABLE 1 (*contd*)

	03-0900 IST			09-1500 IST			15-2100 IST			21-0300 IST			ΣN	Seasonal (%N)
	N	F (%)	P (%)	N	F (%)	P (%)	N	F (%)	P (%)	N	F (%)	P (%)		
						BAREILLY								
W	15	22·1	5·0	14	20·6	4·7	25	36·8	8·3	14	20·6	4·7	68	12·4
H	23	16·9	5·0	21	15·4	4·6	42	30·9	9·1	50	36·8	10·9	136	24·8
SM	48	15·3	7·9	82	26·2	13·4	109	34·8	17·9	74	23·6	12·1	313	57·0
PM	2	6·3	0·4	12	37·5	2·6	15	46·9	3·3	3	9·4	0·7	32	5·8
T	88	16·0	4·8	129	23·5	7·0	191	34·8	10·4	141	25·7	7·7	549	
						BIKANER								
W	2	18·2	0·7	1	9·1	0·3	6	54·5	2·0	2	18·2	0·7	11	42·8
H	8	9·0	1·7	6	6·7	1·3	37	41·6	8·0	38	42·7	8·3	89	34·6
SM	23	14·7	3·8	9	5·8	1·5	78	50·0	12·8	46	29·5	7·5	156	60·7
PM	0	0	0	0	0	0	0	0	0	1	100·0	0·2	1	0·4
T	33	12·8	1·8	16	6·2	0·9	121	47·1	6·6	87	33·9	4·7	257	
						BHOPAL								
W	28	29·2	9·3	5	5·2	1·7	25	26·0	8·3	38	39·6	12·7	96	20·0
H	7	12·5	1·5	0	0	0	28	50·0	6·1	21	37·5	4·6	56	11·6
SM	48	15·2	7·9	28	8·9	4·6	155	49·1	25·4	85	26·9	13·9	316	65·7
PM	0	0	0	2	15·4	0·4	9	69·2	2·0	2	15·4	0·4	13	2·7
T	83	17·3	4·5	35	7·3	1·9	217	45·1	11·9	146	30·4	8·0	481	
						BEGUMPET								
W	0	0	0	0	0	0	5	10·0	1·7	0	0	0	5	1·3
H	22	12·0	4·8	20	10·9	4·3	91	49·7	19·8	50	27·3	10·9	183	48·0
SM	13	8·1	2·1	22	13·7	3·6	74	46·3	12·1	51	31·9	8·4	160	42·0
PM	2	6·1	0·4	3	9·1	0·7	17	51·5	3·7	11	33·3	2·4	33	8·7
T	37	9·7	2·0	45	11·8	2·5	187	49·1	10·2	112	29·4	6·1	381	
						BANGALORE								
W	0	0	0	0	0	0	2	50·0	0·7	2	50·0	0·7	4	0·6
H	17	4·0	3·7	17	4·0	3·7	287	68·0	62·4	101	23·9	21·9	422	60·8
SM	14	8·3	2·3	5	3·0	0·8	95	56·5	15·6	54	32·1	8·9	168	24·2
PM	2	2·0	0·4	6	6·0	1·3	65	65·0	14·1	27	27·0	5·9	100	14·4
T	33	4·8	1·8	28	4·0	1·5	449	64·7	24·5	184	26·5	10·1	694	
						COLABA								
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H	11	44·0	2·4	1	4·0	0·2	1	4·0	0·2	12	48·0	2·6	25	24·5
SM	15	27·8	2·5	2	3·7	0·3	19	35·2	3·1	18	33·3	2·9	54	52·9
PM	1	4·3	0·2	0	0	0	20	87·0	4·3	2	8·7	0·4	23	22·5
T	27	26·5	1·5	3	2·9	0·2	40	39·2	2·2	32	31·4	1·7	102	

TABLE 1 (*contd*)

	03-0900 IST			09-1500 IST			15-2100 IST			21-0300 IST				
	N	*F* (%)	*P* (%)	*N*	*F* (%)	*P* (%)	*N*	*F* (%)	*P* (%)	*N*	*F* (%)	*P* (%)	ΣN	Seasonal (%*N*)
							DIBRUGARH							
W	5	1·3	1·7	125	33·4	41·7	229	61·2	76·3	15	4·0	5·0	374	35·4
H	4	2·9	0·9	74	53·2	16·1	47	33·8	10·0	14	10·1	3·0	139	13·2
SM	18	6·6	2·9	144	53·1	23·6	105	38·7	17·2	4	1·5	0·7	271	25·6
PM	0	0	0	139	50·9	30·2	120	44·0	26·1	14	5·1	3·0	273	25·8
T	27	2·6	1·5	482	45·6	26·3	501	47·4	27·4	47	4·4	2·6	1057	
							DARJEELING							
W	0	0	0	2	16·7	0·6	9	75·0	3·0	1	8·3	0·3	12	2·0
H	29	7·0	6·3	96	23·0	20·9	253	60·7	55·0	39	9·4	8·5	417	68·1
SM	17	10·2	2·8	26	15·7	4·3	80	48·2	13·1	43	25·9	7·0	166	27·1
PM	0	0	0	7	41·2	1·5	9	52·9	1·9	1	5·9	0·2	17	2·8
T	46	7·5	2·5	131	21·4	7·1	351	57·4	19·2	84	13·7	4·6	612	
							GAUHATI							
W	2	18·2	0·6	1	9·1	0·3	3	27·3	1·0	5	45·5	1·7	11	1·0
H	160	24·4	34·8	106	16·1	23·0	188	28·6	40·9	203	30·9	44·1	657	60·5
SM	66	16·3	10·8	141	34·7	23·1	125	30·8	20·5	74	18·2	12·1	406	37·4
PM	2	16·7	0·4	1	8·3	0·2	6	50·0	1·3	3	25·0	0·7	12	1·1
T	230	21·2	12·6	249	22·9	13·6	322	29·7	17·6	285	26·2	15·6	1086	
							GOPALPUR							
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H	13	13·5	2·8	13	13·5	2·8	54	56·3	11·7	16	16·7	3·5	96	44·4
SM	6	6·8	1·0	13	14·8	2·1	50	56·8	8·2	19	21·6	3·1	88	40·7
PM	8	25·0	1·7	5	15·6	1·1	15	46·9	3·3	4	12·5	0·9	32	14·8
T	27	12·5	1·5	31	14·4	1·7	119	55·1	6·5	39	18·1	2·1	216	
							GORAKHPUR							
W	4	20·0	1·3	9	45·0	3·0	2	10·0	0·7	5	25·0	1·7	20	13·5
H	12	33·3	2·7	5	13·9	1·1	10	27·7	2·2	9	25·0	2·0	36	24·3
SM	11	12·2	1·8	34	37·8	5·6	39	43·3	6·4	6	6·7	1·0	90	60·8
PM	0	0	0	0	0	0	2	100·0	0·4	0	0	0	2	1·4
T	27	18·2	1·5	48	32·4	2·6	53	35·8	2·9	20	13·5	1·1	148	
							GWALIOR							
W	3	13·0	1·0	5	21·7	1·7	12	52·2	4·0	3	13·0	1·0	23	4·4
H	15	11·0	3·3	15	11·0	3·3	88	64·7	19·1	18	13·2	3·9	136	25·8
SM	44	12·3	7·2	82	22·8	13·4	212	59·1	34·7	21	5·8	3·6	359	68·1
PM	1	11·1	0·2	3	33·3	0·7	1	11·1	0·2	4	44·4	0·9	9	1·7
T	63	12·0	3·4	105	19·9	5·7	313	59·4	17·1	46	8·7	2·5	527	

TABLE 1 (*contd*)

	03-0900 IST			09-1500 IST			15-2100 IST			21-0300 IST			ΣN	Seasonal (%N)
	N	F (%)	P (%)	N	F (%)	P (%)	N	F (%)	P (%)	N	F (%)	P (%)		
							GUNA							
W	11	12·9	3·7	22	25·9	7·3	39	45·9	13·0	13	15·3	4·3	85	18·8
H	5	4·9	1·1	9	7·2	1·9	78	62·4	16·9	33	26·4	7·2	125	27·6
SM	9	3·8	1·5	45	18·8	7·4	148	61·9	24·3	37	15·5	6·1	239	52·8
PM	0	0	0	1	25·0	0·2	3	75·0	0·7	0	0	0	4	0·9
T	25	5·5	1·4	77	17·0	4·2	268	59·2	14·6	83	18·3	4·5	453	
							GADAG							
W	0	0	0	0	0	0	6	75·0	2·0	2	25·0	0·7	8	1·4
H	2	0·6	0·4	11	3·5	2·4	247	78·9	53·7	53	16·9	11·5	313	56·3
SM	4	2·9	0·7	15	10·9	2·5	105	76·1	17·2	14	10·1	2·3	138	24·8
PM	1	1·0	0·2	13	13·4	2·8	63	64·9	13·7	20	20·6	4·3	97	17·4
T	7	1·3	0·4	39	7·0	2·1	421	75·7	23·0	89	16·0	4·9	556	
							HAZARIBAGH							
W	13	14·3	4·3	22	24·2	7·3	45	49·5	15·0	11	12·1	3·7	91	5·5
H	33	12·2	7·2	105	38·9	22·8	101	37·4	21·9	31	11·5	6·7	270	16·2
SM	66	5·4	10·8	366	29·8	60·0	667	54·4	109·3	128	10·4	21·0	1227	73·6
PM	2	2·6	0·4	20	25·6	4·3	51	66·4	11·1	5	6·4	1·1	78	4·7
T	114	6·8	6·2	513	30·8	28·0	864	51·9	47·2	175	10·5	9·6	1666	
							INDORE							
W	9	22·0	2·0	13	31·7	4·3	7	17·1	2·3	12	29·3	4·0	41	10·7
H	1	1·3	0·2	8	10·5	1·7	39	51·3	8·5	28	36·8	6·1	76	19·9
SM	11	4·2	1·8	23	8·8	3·8	167	64·2	27·4	59	22·7	9·7	260	68·1
PM	0	0	0	0	0	0	4	80·0	0·9	1	20·0	0·2	5	1·3
T	21	5·5	1·1	44	11·5	2·4	217	56·8	11·9	100	26·2	5·5	382	
							JHARSUGUDA							
W	21	26·9	7·0	9	11·5	3·0	28	35·9	9·3	20	25·6	6·7	78	4·9
H	32	10·6	6·9	19	6·3	4·1	154	51·2	33·5	96	31·9	20·9	301	19·1
SM	58	5·3	9·5	176	16·0	28·9	618	56·1	101·3	250	22·7	41·0	1102	69·9
PM	7	7·4	1·5	19	20·0	4·1	55	57·9	11·9	14	14·7	3·0	95	6·6
T	118	7·4	6·4	223	14·1	12·2	855	54·3	46·7	380	24·1	20·8	1576	
							JAIPUR							
W	5	8·1	1·7	17	27·4	5·7	31	50·0	10·3	9	14·5	3·0	62	5·9
H	32	12·9	6·9	33	13·3	7·2	141	56·6	30·7	43	17·3	9·3	249	23·6
SM	82	11·8	13·4	161	23·1	26·4	344	49·4	56·4	109	15·7	17·9	696	66·1
PM	9	19·6	1·9	10	21·7	2·2	18	39·1	3·9	9	19·6	1·9	46	4·4
T	128	12·2	7·0	221	21·0	12·1	534	50·7	29·2	170	16·1	9·3	1053	

TABLE 1 (*contd*)

	03-0900 IST			09-1500 IST			15-2100 IST			21-0300 IST			ΣN	Seasonal (%N)
	N	F (%)	P (%)	N	F (%)	P (%)	N	F (%)	P (%)	N	F (%)	P (%)		
						JABALPUR								
W	27	19·3	9·0	14	10·0	4·7	50	35·7	16·7	49	35·0	16·3	140	17·0
H	17	10·3	3·7	18	10·9	3·9	88	53·3	19·1	42	25·5	9·1	165	20·0
SM	24	4·8	3·9	69	13·7	11·3	295	58·5	48·4	116	23·0	19·0	504	61·2
PM	0	0	0	3	20·0	0·7	4	26·7	0·9	8	53·3	1·7	15	1·8
T	68	8·3	3·7	104	12·6	5·7	437	53·0	23·9	215	26·1	11·7	824	
						JAGDALPUR								
W	0	0	0	3	30·0	1·0	7	70·0	2·3	0	0	0	10	4·8
H	2	1·6	0·4	6	4·8	1·3	88	71·0	19·1	28	22·6	6·1	124	59·6
SM	5	7·1	0·8	5	7·1	0·8	52	74·3	8·5	8	11·4	1·3	70	33·7
PM	0	0	0	0	0	0	3	75·0	0·7	1	25·0	0·2	4	1·9
T	7	3·4	0·4	14	6·7	0·8	150	72·1	8·2	37	17·8	2·0	208	
						KODAIKANAL								
W	0	0	0	2	8·3	0·6	13	54·2	4·3	9	37·5	3·0	24	2·0
H	15	2·7	3·3	93	16·7	20·2	358	64·4	77·8	90	16·2	19·6	556	47·4
SM	4	1·2	0·7	81	25·2	13·3	221	68·8	36·2	15	4·7	2·5	321	27·3
PM	8	2·9	1·7	27	9·9	5·9	187	68·5	40·7	51	18·7	11·1	273	23·3
T	27	2·3	1·5	203	17·3	11·1	779	66·3	42·6	165	14·1	9·0	1174	
						JALGAON								
W	0	0	0	0	0	0	6	46·1	2·0	7	53·8	2·3	13	16·5
H	0	0	0	0	0	0	7	46·7	1·5	8	53·3	1·7	15	19·0
SM	1	2·0	0·2	11	21·6	1·8	16	31·4	2·6	23	45·1	3·8	51	64·6
PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T	1	1·3	0	11	13·9	0·6	29	36·7	1·6	38	48·1	2·1	79	
						MANGALORE								
W	5	62·5	1·7	1	12·5	0·3	2	25·0	0·6	0	0	0	8	1·2
H	57	25·1	12·4	22	9·7	4·8	56	24·7	12·2	92	40·6	20·0	227	34·0
SM	21	22·3	3·6	22	23·4	3·6	23	24·5	3·8	28	29·8	4·6	94	14·1
PM	38	11·2	8·3	21	6·2	4·6	154	45·4	33·5	126	37·2	27·4	339	50·7
T	121	18·1	6·6	66	9·9	3·6	235	35·2	12·8	246	36·8	13·4	668	
						MASULIPATAM								
W	0	0	0	1	100·0	0·3	0	0	0	0	0	0	1	0·8
H	5	27·8	1·1	2	11·1	0·4	7	38·9	1·5	4	22·2	0·9	18	15·0
SM	14	27·5	2·3	5	9·8	0·8	19	37·2	3·1	13	25·5	2·1	51	42·5
PM	14	28·0	3·0	18	36·0	3·9	8	16·0	1·7	10	20·0	2·2	50	41·7
T	33	27·5	1·8	26	21·7	1·4	34	28·3	1·9	27	22·5	1·5	120	

TABLE 1 (*contd*)

	03-0900 IST			09-1500 IST			15-2100 IST			21-0300 IST			ΣN	Seasonal (%N)
	N	F (%)	P (%)	N	F (%)	P (%)	N	F (%)	P (%)	N	F (%)	P (%)		
							MT. ABU							
W	0	0	0	0	0	0	2	100·0	0·6	0	0	0	2	3·4
H	0	0	0	0	0	0	1	100·0	0·2	0	0	0	1	1·7
SM	17	30·4	2·8	7	12·5	1·1	18	32·1	2·9	14	25·0	2·3	56	94·9
PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T	17	28·8	0·9	7	11·9	0·4	21	35·6	1·1	14	23·7	0·8	59	
							MADRAS							
W	1	4·8	0·3	2	9·5	0·6	17	81·0	5·7	1	4·8	0·3	21	3·1
H	29	31·9	6·3	17	18·7	3·7	27	29·7	5·9	18	19·8	3·9	91	13·2
SM	46	13·2	7·5	41	11·7	6·7	160	45·8	26·2	102	29·2	16·7	349	50·7
PM	69	30·4	15·0	44	19·4	9·6	45	19·8	9·8	69	30·4	15·0	227	33·0
T	145	21·1	7·9	104	15·1	5·7	249	36·2	13·6	190	27·6	10·4	688	
							NEW DELHI							
W	11	24·4	3·7	7	15·6	2·3	12	26·7	4·0	15	33·3	5·0	45	8·9
H	24	20·2	5·2	18	15·1	3·9	54	45·4	11·7	23	19·3	5·0	119	23·6
SM	74	24·3	12·1	60	19·7	9·8	109	35·9	17·9	61	20·1	10·0	304	60·3
PM	6	16·7	1·3	6	16·7	1·3	13	36·1	2·8	11	30·6	2·4	36	7·1
T	115	22·8	6·3	91	18·1	5·0	188	37·3	10·3	110	21·8	6·0	504	
							NAGPUR							
W	1	2·1	0·3	6	12·8	2·0	16	34·0	5·3	24	51·1	8·0	47	12·1
H	14	10·1	3·0	10	7·2	2·2	56	40·3	12·2	59	42·4	12·8	139	35·7
SM	8	4·4	1·3	31	16·9	5·1	112	61·2	18·4	32	17·5	5·2	183	47·0
PM	0	0	0	3	15·0	0·7	11	55·0	2·4	6	30·0	1·3	20	5·1
T	23	5·9	1·3	50	12·9	2·7	195	50·1	10·7	121	31·1	6·6	389	
							PATNA							
W	5	20·0	1·7	1	4·0	0·3	6	24·0	2·0	13	52·0	4·3	25	8·8
H	12	17·6	2·6	12	17·6	2·6	25	36·8	5·4	19	27·9	4·1	68	24·0
SM	37	20·4	6·1	52	28·7	8·5	59	32·6	9·7	33	18·2	5·4	181	64·0
PM	0	0	0	2	22·2	0·4	6	66·7	1·3	1	11·1	0·2	9	3·2
T	54	19·1	2·9	67	23·7	3·7	96	33·9	5·2	66	23·3	3·6	283	
							PENDRA							
W	5	9·8	1·7	5	9·8	1·7	26	51·0	8·7	15	29·4	5·0	51	16·2
H	5	4·8	1·1	36	34·3	7·8	59	56·2	12·8	5	4·8	1·1	105	33·3
SM	5	3·2	0·8	46	29·7	7·5	77	49·7	12·6	27	17·4	4·6	155	49·2
PM	0	0	0	3	75·0	0·7	1	25·0	0·2	0	0	0	4	1·3
T	15	4·8	0·8	90	28·6	4·9	163	51·7	8·9	47	14·9	2·6	315	

TABLE 1 (*contd*)

	03-0900 IST			09-1500 IST			15-2100 IST			21-0300 IST			ΣN	Seasonal (%N)
	N	F (%)	P (%)	N	F (%)	P (%)	N	F (%)	P (%)	N	F (%)	P (%)		
						PRABHANI								
W	0	0	0	2	40·0	0·6	3	60·0	1·0	0	0	0	5	3·1
H	3	11·1	0·7	0	0	0	17	63·0	3·7	7	25·9	1·5	27	17·0
SM	2	2·0	0·3	9	9·1	1·5	47	47·5	7·7	41	41·4	6·7	9	62·3
PM	2	7·1	0·4	2	7·1	0·4	18	64·3	3·9	6	21·4	1·3	28	17·6
T	7	4·4	0·4	13	8·2	0·7	85	53·5	4·6	54	34·0	2·9	159	
						POONA								
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H	4	3·7	0·9	5	4·6	1·1	81	75·0	17·6	18	16·7	3·9	108	50·0
SM	1	1·1	0·2	10	11·4	1·6	63	71·6	10·3	14	15·9	2·3	88	32·6
PM	1	1·4	0·2	8	10·8	1·7	55	74·3	11·9	10	13·5	2·2	74	27·4
T	6	2·2	0·3	23	8·5	1·3	199	73·7	10·9	42	15·6	2·3	270	
						RAIPUR								
W	15	33·3	5·0	1	2·2	0·3	2	4·4	0·6	27	60·0	9·0	45	13·8
H	18	15·1	3·9	5	4·2	1·1	53	44·5	11·5	43	36·1	9·3	119	36·6
SM	7	4·4	1·1	23	14·5	3·8	96	60·4	15·7	33	20·8	5·4	159	48·9
PM	0	0	0	0	0	0	2	100·0	0·4	0	0	0	2	0·6
T	40	12·3	2·2	29	8·9	1·6	153	47·1	8·4	103	31·7	5·6	325	
						SHILLONG								
W	6	10·5	2·0	19	33·3	6·3	26	45·6	8·7	6	10·5	2·0	57	3·3
H	206	23·0	4·8	299	33·3	65·0	236	26·3	51·3	156	17·3	33·9	897	52·6
SM	58	9·0	9·5	211	32·7	34·6	290	45·0	47·5	86	13·3	14·1	645	37·8
PM	5	4·7	1·1	36	33·6	7·8	62	57·9	13·5	4	3·7	0·9	107	6·3
T	275	16·1	15·0	565	33·1	30·9	614	36·0	33·5	252	14·8	13·8	1706	
						SABOUR								
W	2	4·5	0·6	10	22·7	3·3	14	31·8	4·7	18	40·9	6·0	44	2·3
H	30	8·8	6·5	82	24·2	17·8	141	41·6	30·7	86	25·4	18·7	339	17·4
SM	202	13·5	33·1	556	37·3	91·1	514	34·5	84·3	220	14·7	36·1	1492	76·6
PM	8	10·8	1·7	28	37·8	6·1	20	27·0	4·3	18	24·3	3·9	74	3·8
T	242	12·4	13·2	676	34·7	36·9	689	35·4	37·7	342	17·5	18·7	1949	
						SANDHEADS								
W	1	50·0	0·3	0	0	0	1	50·0	0·3	0	0	0	2	2·0
H	6	40·0	1·3	0	0	0	4	26·7	0·9	5	33·3	1·1	15	14·7
SM	24	43·6	3·9	5	9·1	0·8	8	14·5	1·3	18	32·7	2·9	55	53·9
PM	14	46·7	3·0	7	23·3	1·5	4	13·3	0·9	5	16·7	1·1	30	29·4
T	45	44·1	2·5	12	11·8	0·7	17	16·7	0·9	28	27·5	1·5	102	

TABLE 1 *(contd)*

	03-0900 IST			09-1500 IST			15-2100 IST			21-0300 IST			ΣN	Seasonal (%N)
	N	F (%)	P (%)	N	F (%)	P (%)	N	F (%)	P (%)	N	F (%)	P (%)		
							SATNA							
W	25	19·2	8·3	17	13·1	5·7	55	42·3	18·3	33	25·4	11·0	130	17·5
H	29	19·7	6·3	16	10·9	3·5	68	46·3	14·8	34	23·1	7·4	147	19·8
SM	61	14·0	10·0	87	20·0	14·3	217	49·8	35·6	71	16·3	11·6	436	58·8
PM	11	37·9	2·4	2	6·9	0·4	7	24·1	1·5	9	31·0	1·9	29	3·9
T	126	17·0	6·9	122	16·4	6·7	347	46·8	19·0	147	19·8	8·0	742	
							TIRUCHIRAPALLY							
W	0	0	0	1	20·0	0·3	2	40·0	0·6	2	40·0	0·6	5	0·6
H	21	7·5	4·6	26	9·3	5·7	156	55·7	33·9	77	27·5	16·7	280	32·2
SM	4	1·1	0·7	11	3·0	1·8	235	63·7	38·5	119	32·2	19·5	369	42·5
PM	9	4·7	1·9	28	13·0	6·1	119	55·3	25·9	59	27·4	12·8	215	24·7
T	34	3·9	1·9	66	7·6	3·6	512	58·9	28·0	257	29·6	14·0	869	
							TRIVANDRUM							
W	0	0	0	5	8·9	1·7	41	73·2	13·7	10	17·9	3·3	56	5·1
H	60	10·2	13·0	113	19·1	24·6	334	56·5	72·6	84	14·2	18·3	591	54·1
SM	20	26·3	3·3	28	36·8	4·6	17	22·4	2·8	11	14·5	1·8	76	7·0
PM	12	3·2	2·6	51	13·8	11·1	230	62·2	50·0	77	20·8	16·7	370	33·9
T	92	8·4	5·0	197	18·0	10·8	622	56·9	34·0	182	16·7	9·9	1093	
							TEZPUR							
W	1	20·0	0·3	0	0	0	3	60·0	1·0	1	20·0	0·3	5	1·6
H	35	26·3	7·6	21	15·8	4·6	34	25·6	7·4	43	32·3	9·3	133	42·9
SM	44	27·3	7·2	30	18·6	4·9	38	23·6	6·2	49	30·4	8·0	161	51·9
PM	6	54·5	1·3	0	0	0	4	36·4	0·9	1	9·1	0·2	11	3·5
T	86	27·7	4·7	51	16·5	2·8	79	25·5	4·3	94	30·3	5·1	310	
							VERAVAL							
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H	6	46·2	1·3	4	30·8	0·9	0	0	0	3	23·1	0·7	13	44·8
SM	2	16·7	0·3	4	33·3	0·7	4	33·3	0·7	2	16·7	0·3	12	41·4
PM	0	0	0	2	50·0	0·4	2	50·0	0·4	0	0	0	4	13·8
T	8	27·6	0·4	10	34·5	0·5	6	20·7	0·3	5	17·2	0·3	29	

W—Winter, H—Hot weather, SM—Southwest Monsoon, PM—Post-Monsoon. T—Annual Total

$\%F = (N/\Sigma N) \times 100$ $\%P = (N/\text{periods}) \times 100$

Periods during seasons—

W=300, H=460, SM=610, PM=460 and T=1830

$\%N = \Sigma N/(\text{annual total occurrences}) \times 100$