551.58 : 551.515.4

SOME CLIMATOLOGICAL FEATURES OF THUNDERSTORMS AND SQUALLS OVER PATNA AIRPORT

1. Thunderstorms occur much more frequently in the tropics than in higher latitudes (Atkinson, 1971). Over tropical oceanic regions, almost all the thunderstorms are associated with synoptic disturbances, while over land areas, air mass thunderstorms due to convective heating and orographic lifting are also commonly observed. Most of the hazardous weather such as hailstone; heavy rain and squall are caused by thunderstorms. These cause loss of life, damage to crops and property. Climatological knowledge of thunderstorm and squall may help the forecaster to issue forecast and warnings for safe air navigation and to general public to avoid the loss of life and minimize the loss of property.

Kumar and Mohapatra (2006) studied some climatological aspects of thunderstorms and squalls over Guwahati airport. Manohar and Kesarkar (2003, 2004 and 2005) have produced a comprehensive climatology of thunderstorms over the Indian region bringing out their east-west contrast, spatial distribution and latitudinal and seasonal variation. Viswanathan and Faria (1962) and Krishnamurthy (1965) studied climatology of thunderstorms over Bombay and Pune respectively. The diurnal frequency of incidence and duration of thunderstorms at four international aerodromes of Bombay, Kolkata, Chennai and Delhi were studied by Rao *et al.*, (1971). A similar work on the thunderstorms at the aerodrome stations of Ahmedabad, Bangalore, Agarthala and Hydrabad was done by Philip *et al*., (1974). Various statistical aspects of occurrence of thunderstorms at Lucknow airport were studied by Awadesh Kumar (1992). A similar study of thunderstorms at Mohanbari airport was conducted by Moid (1996) and at Thiruvananthapuram, Kochi and Kozhikode airports by Santhosh *et al*., (2001). As it appears that no study has been done on the climatological aspects of thunderstorms and squalls over Patna airport, an attempt has been made in this study to find out climatological aspects of thunderstorms and squalls in recent years over Patna airport based on 22 years data.

The data on occurrence of thunderstorms and squalls over Patna airport have been collected from Current Weather Registers of India Meteorological Department (IMD) for a period of 22 years (1985-2006). The thunderstorms accounted in this study include all those occasions when thunder was heard and squall was reported as per the criteria of IMD, *viz*., a sudden increase of wind speed by at least 29 kmph (16 knots) to reach a speed of 40 kmph (22 knots) or more and lasting for at least one minute.

TABLE 1(a)

Average monthly frequency of thunderstorm over Patna airport

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Present Study (1985-2006)	0.6	2.1	2.8	3.9	6.8	10.8	13.9	13.7	11.9	3.1	0.5	0.5	70.6
As per Climatological Table (1951-80)	0.9	1.3	2.1	1.9	4.3	8.6	11.0	11.8	9.6	2.9	0.2	0.1	54.7

TABLE 1(b)

Average monthly frequency of squall over Patna airport

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Present Study (1985-2006)	0.0	0.2	0.3	1.2	1.6	0.6	0.0	0.1	0.0	0.1	0.1	0.0	4.2
As per Climatological Table (1951-80)	0.1	0.0	0.1	0.7	1.8	0.9	0.2	0.1	0.1	0.3	0.0	0.0	4.3

The annual and monthly frequency, time of commencement and duration of thunderstorms and squalls have been calculated and analyzed. To analyze the time of commencement of thunderstorms and squalls, a day is divided into 3 hourly periods and the average frequencies of thunderstorms for each of the 3 hourly periods have been worked out. As regards to duration of thunderstorms, frequencies for the period of less than 3 hours, 3-6 hours, 6-9 hours,……..21-24 hours have been calculated and analyzed. The duration of squall has been analyzed in the categories of 1-4 minutes, 4-7 minutes and 7-10 minutes duration. The direction of the squall has been analyzed in 8 points of compass, *viz*., North (N), Northeast (NE), East (E), Southeast (SE), South(S), Southwest (SW), West (W) and Northwest (NW).

3. *Average monthly frequency of thunderstorms and squalls* - Table 1(a&b) shows the average monthly frequency of thunderstorms and squalls respectively for the period 1985-2006 in comparison to the latest climatological tables based on period 1951 to 1980 (IMD, 1995). It is noticed that barring January, there is an increase of number of thunderstorms in all months during 1985-2006 in comparison to the year 1951-1980. It is to be noted that in the present study the highest frequency (13.9) of thunderstorm is found in July while as per climatological table the highest frequency of thunderstorms is found in August. November and December are the months of least number of thunderstorms. Though the thunderstorm activity over Patna airport occurs throughout the year, maximum thunderstorm occurs during monsoon season followed by pre-monsoon season. The frequencies of thunderstorm are very less during winter and post monsoon season. The average annual frequency of squall is almost equal at 4.2. The frequency of squall is found highest in the month of May. In the present study, it is found that no squall had been reported in the months of January, July, September and December whereas as per climatology (1951-1980) no squall was observed in the months of February, November and December.

4. *Season-wise frequency of time of commencement of thunderstorms* – Season-wise distribution of time of commencement of thunderstorms at 3 hourly intervals is shown in Table 2. It is seen that occurrence of thunderstorm is maximum during 0900-1200 UTC and the occurrence is least during 0000-0300 UTC. It is well known that the existence of upper level divergence in combination with moisture incursion of lower levels is favourable for intense and widespread thunderstorm activity. Due to the northward movement of the Sun (from equator during vernal equinox to tropic of cancer during summer solstice), the insolation increases over central and adjoining areas. When temperature exceeds 40° C, a trough of low pressure area generally forms from west Rajasthan to Nagaland, Mizoram, Manipur and Tripura with embedded vortices observed in the lower level either over Uttar Pradesh or Bihar up to 0.9 km above sea level generally. Due to intense heating of land and supply of moisture from the Bay of Bengal thunder activity starts over central India and adjoining areas. The higher frequency of thunderstorm activity during monsoon may be attributed to all India break monsoon condition. During all India break monsoon condition, the monsoon trough shifts to the foothills of the Himalayas leading to maximum low level convergence over Bihar region. The thunderstorm frequency is found

TABLE 2

Frequency distribution of thunderstorms over Patna airport in relation to duration and time of commencement

Season	Duration (Hours)	Time (UTC) of commencement of thunderstorm								
		0000-0300	0300-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2100	2100-2400	Total
Winter	<3	5	1	5	1	8	3	4	6	33
	3-6	1	1	2	2	1	4	2	1	14
	6-9	0	1	1	0	1	2	2	1	8
	9-12	1	1	0	0	0	0	0	1	3
	>12	0	0	0	0	0	1	1	0	2
	Total	**7**	**4**	**8**	**3**	**10**	**10**	**2**	**9**	**60**
Pre-monsoon	<3	30	16	23	38	24	33	28	38	230
	3-6	7	1	4	4	10	15	3	7	51
	6-9	2	0	2	1	2	2	3	0	12
	9-12	0	0	2	0	0	0	0	0	2
	>12	0	0	1	0	0	0	0	0	1
	Total	**39**	**17**	**32**	**43**	**36**	**50**	**34**	**45**	**296**
Monsoon	<3	39	46	156	192	117	78	44	53	725
	3-6	14	28	67	64	36	30	21	24	284
	6-9	2	6	10	10	12	11	8	10	69
	9-12	0	2	2	6	2	2	3	3	20
	>12	0	0	1	3	1	1	1	1	8
	Total	**55**	**82**	**236**	**275**	**168**	**122**	**77**	**91**	**1106**
Post monsoon	<3	3	6	19	13	7	6	7	1	62
	3-6	0	2	8	5	4	1	4	1	25
	6-9	0	0	0	1	0	0	0	0	1
	9-12	0	1	0	0	0	0	0	0	1
	>12	0	0	0	1	0	0	0	0	1
	Total	**3**	**9**	**27**	**20**	**11**	**7**	**11**	**2**	**90**
Annual	<3	77	69	203	244	156	120	83	98	1050
	3-6	22	32	81	75	51	50	30	33	374
	6-9	4	7	13	12	15	15	13	11	90
	9-12	1	4	4	6	2	2	3	4	26
	>12	0	0	2	4	1	2	2	1	12
	Total	**104**	**112**	**303**	**341**	**225**	**189**	**131**	**147**	**1552**

to be maximum during the interval 1200-1800 UTC in the winter and 1500-1800 UTC in the pre-monsoon season. In the monsoon season the frequency of thunderstorm is highest during the interval 0900-1200 UTC and in post monsoon season the thunderstorm frequency is maximum in the interval 0600-0900 UTC.

5. *Average annual and monthly frequency of duration of thunderstorms* - The average monthly and annual frequency of duration of thunderstorm activity at Patna airport have been worked out and found that 67.6% of thunderstorms were of duration less than three hours and 23.9% of cases were of duration 3-6 hours. The occurrence of thunderstorms of duration more than 12 hours was found to be very less, *i.e.*, less than 1%. It is also noticed that while the majority of thunderstorms were confined to duration of less than 3 hours, the highest frequencies of all duration (less than and more than 3 hours) were observed during southwest monsoon season.

TABLE 3

Frequency distribution of squalls over Patna airport in relation to direction

	Frequency distribution of squalls in relation to direction								
Month	N	NE	E	SE	S	SW	W	NW	Total
January	-	-	-	-	-	-	-	-	0
February	-	1	-	-	-	-	2	1	4
March	-	3	-	-	1	3	-	3	10
April	2	3	3	-	1	-	1	16	26
May	7	6	1	-	-	1	-	18	33
June	1	2	-	-	-	-	1	8	12
July	-	-	-	-	-	-	-	-	0
August	-	-	-	-	-	-	1	-	1
September	-	-	-	-	-	-	-	-	0
October	-	-	-	1	-	-	-	1	2
November	-	-	-	-	-	-	-	1	1
December	-	-	-	-	-	-	-	-	0
Total	10	15	4	1	2	4	5	48	89

TABLE 4

Frequency distribution of squalls over Patna airport in relation to duration and time of occurrence

Months	Duration (Minutes)	Time (UTC) of occurrence of squalls								Total
		0000-0300	0300-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2100	2100-2400	
January	1-4	-	-	-	-	-	-	-	-	0
February	1-4	1	-	-	-	-	1	-	2	4
March	1-4	-	-	-	1	3	1	-	-	5
	4-7	-	-	-	-	-	-	1	-	1
April	1-4	1	3	1	4	6	3	2	3	23
	4-7	-	-	-	1	1	1	-	-	3
May	1-4	-	-	5	2	3	7	7	5	29
	4-7	-	-	1	-	2	1	1	-	5
	7-10	-	-	-	-	1	-	-	-	1
June	1-4	1	1	2	5	-	2	1	1	13
	4-7	-	-	1	-	-	-	-	-	1
July	1-4	-	-	-	-	-	-	-	-	0
August	1-4	-	-	-	1	-	-	-	-	1
September	1-4	-	-	-	-	-	-	-	-	0
October	1-4	-	-	-	-	1	-	1	-	2
November	1-4	-	-	-	-	1	-	-	-	1
December	1-4	-	-	-	-	-	-	-	-	0
Total		3	4	10	14	18	16	13	11	89

6. *Frequency distribution of squalls* - The frequency distribution of squalls over Patna airport in relation to direction of squalls is shown in Table 3. On the average 4 - 5 squalls occur in a year over Patna airport. The pre monsoon season is the most favourable season for the squalls over Patna airport as 75% of the squalls have occurred in the period from March to May followed by monsoon season in which 17% of the squalls have occurred. The frequency is maximum in May (39%) followed by April (29%) and June (16%). The months January, July, September and December are free of squalls, while squalls were recorded rarely during February, March, August, October and November. Most of the squalls have wind direction as northwesterly (54%) followed by northeasterly (17%) and northerly (11%). The number of squalls that have wind direction southeasterly and southerly is negligible. The average wind speed associated with the squall over Patna airport is about 37 knots with the highest maximum wind speed being 58 knots.

7. *Time of occurrence and durations of squall* - The frequency distribution of squalls in relation to duration and time of occurrence is shown in Table 4. The maximum frequency of squall is found during 1200-1500 UTC followed by 1500-1800 UTC and 0900-1200 UTC. In the pre-monsoon season, March and April had maximum number of squalls (60% and 26%) during 1200-1500 UTC while the maximum squalls (24%) was during 1500-1800 UTC in May. Most of the squalls have duration of period 1-4 minutes. While squalls of duration 4-7 minutes were noticed, though rarely, during March-June, an extremely long duration of 7-10 minutes squall was observed during 1200-1500 UTC in May.

8. Following conclusions have been drawn from the above study:

(*i*) Average annual frequencies of thunderstorms and squalls over Patna airport are 70.6 and 4.2 respectively.

(*ii*) The thunderstorms mostly occur during monsoon season and the squalls mostly occur in pre-monsoon season. Incidence of thunderstorm is minimum in winter and post-monsoon season. No squall has been reported during January, July, September and December.

(*iii*) The majority of the thunderstorm is of duration less than 3 hours and most of the thunderstorms commence during 0900-1200 UTC.

(*iv*) The squalls occur mostly from Northwesterly direction followed by Northeasterly and Northerly direction. Most of the squalls occur during evening to midnight and are of duration 1-4 minutes.

References

Atkinson, Maj Gary D., 1971, "Forecaster's guide to Tropical Meteorology", USAF, Hq, Air weather service.

India Meteorological Department, 1995, "Climatological Tables of Observatories in India" (1951-80).

Krishnamurthy, V., 1965, "A statistical study of thunderstorms over Poona", *Indian J. Met. & Geophys*.", **16**, 3, 484-487.

Kumar, Awadesh, 1992, "A climatological study of thunderstorms at Lucknow airport", *Mausam*, **43**, 4, 441-444.

Kumar, Gajendra and Mohapatra, M., 2006, "Some climatological aspects of thunderstorms and squalls over Guwahati Airport", *Mausam*, **57**, 2, 231-240.

Manohar, G. K. and Kesarkar, A. P., 2003, "Climatology of thunderstorm activity over the Indian region:I", A study of east-west contrast, *Mausam*, **54**, 4, 819-829

Manohar, G. K. and Kesarkar, A. P., 2004, "Climatology of thunderstorm activity over the Indian region:II", Spatial Distribution, *Mausam*, **55**, 1, 31-40.

Manohar, G. K. and Kesarkar, A. P., 2005, "Climatology of thunderstorm activity over the Indian region:III", Latitudinal and seasonal variation, *Mausam*, **56**, 3, 581-592.

Moid, S. A., 1996, "A climatological study of thunderstorms at Mohanbari airport", *Mausam*, **47**, 2, 200-204.

Philip, N. M., Deniel, C. E. J. and Punjabi, K. G., 1974, "A study on the diurnal frequency and duration of thunderstorms at four aerodrome stations", PPSR No.203 of IMD.

Rao, K. N., Deniel, C. E. J. and Punjabi, K. G., 1971, "A study on the diurnal frequency and duration of thunderstorms at four aerodrome stations" PPSR No. 154 of IMD.

Santhosh, K., Sarasakumari, R., Gangadharan, V. K. and Sasidharan, N. V., 2001, "Some climatological features of thunderstorms at Thiruvananthapuram, Kochi and Kozhikode airports" *Mausam*, **52**, 2, 357-364.

Viswanathan, T. R. and Faria, S. F., 1962, "A climatological study of thunderstorms at Bombay airport", *Indian J. Met. & Geophys*., **13**, 3, 377-383.

S. I. LASKAR

Meteorological Centre, Civil Aerodrome, Patna, India
(*23 October 2008, Modified 12 May 2009*)
e mail : sebul@sify.com