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# Some climatological aspects of thunderstorms and squalls over Guwahati Airport

GAJENDRA KUMAR and M. MOHAPATRA*

*Regional Meteorological Centre, Guwahati, India*

**India Meteorological Department, New Delhi – 110 003, India*

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**सार** – गुवाहाटी हवाई अड्डे पर आए चंडवात से जुड़े वार्षिक और मासिक बारम्बारता का वितरण, गर्ज के साथ आए तूफानों और चंडवातों के आरम्भ होने का समय और उनकी अवधि तथा पर्यावरणीय परिवर्तनों का विश्लेषण किया गया है। तूफान और चंडवात सबसे ज्यादा मई के महीनें में आते हैं और उसके बाद अप्रैल के महीने में आते हैं। तूफानों और चंडवातों की आवृतियाँ सबसे ज्यादा मई के महीनें में होती हैं और उसके बाद अप्रैल के महीने में होती हैं। अधिकाँश तूफान मानसून ऋतु से पूर्व और मानसून ऋतु के दौरान आते हैं तथा चंडवात फरवरी से मई के महीनों के दौरान आते हैं। मानसून ऋतु से पूर्व आने वाले अधिकाँश तूफान मध्य रात्रि से लेकर तड़के सुबह के समय में आते हैं जबकि मानसून ऋतु के दौरान आने वाले तूफान 0600–1200 यू. टी. सी. के बीच आया करते हैं अधिकाँश तूफानों की अवधि तीन घंटों से भी कम की होती है। अधिकाँश चंडवातों की अवधि चार मिनटों से भी कम की होती है, दिशा उत्तर पश्चिम और ये 0900–2100 यू. टी. सी. के समय आते हैं। गुवाहाटी हवाई अड्डे पर चंडवात के आने से पर्यावरणीय तापमान औसतन 2.2° सें. तक गिर जाता है, सापेक्षिक आर्द्रता 8.5 प्रतिशत तक बढ़ जाती है और दाब 1.6 हैक्टापास्कल तक बढ़ जाता है। गुवाहाटी हवाई अड्डे पर चंडवात के आने से अधिकतम पवन गति औसतन लगभग 39 नॉट्स होती है। पिछले अध्ययनों से तुलना करने पर यह पता चलता है कि पिछले कुछ वर्षों में तफानों और चंडवातों के लक्षणों में विशेष परिवर्तन नहीं आया है।

**ABSTRACT.** The annual and monthly frequency distribution, time of commencement and duration of thunderstorms & squalls and environmental changes associated with occurrence of squall at Guwahati Airport have been analyzed. The frequencies of thunderstorms and squalls are maximum in the month of May followed by April. Most of the thunderstorms occur during premonsoon and monsoon season and squalls occur during Feb-May. Most of the premonsoon thunderstorms commence during midnight to early morning while the thunderstorms during monsoon season have preference to commence between 0600-1200 UTC. Majority of thunderstorms is of the duration of less than three hours. Majority of squalls have the duration of less than four minutes, direction as northwesterly and occur during 0900-2100 UTC. On the average, environmental temperature falls by 2.2° C, the relative humidity rises by 8.5%, and the pressure increases by 1.6 hPa due to squall over Guwahati Airport. The average maximum wind speed associated with a squall over Guwahati Airport is about 39 knots. Comparison with the past studies indicates that characteristics of thunderstorms and squalls have not changed significantly over the years.

**Key words** – Thunderstorm, Squall, Climatology, Frequency.

## 1. Introduction

The thunderstorms & squalls are the important hazards to the aviation activities. The statistical knowledge of their time of occurrence is helpful to issue forecast and warnings. There have been many studies on climatological aspects of thunderstorms & squalls activity over different parts of India. The frequency of thunderstorms in different months over India has been extensively discussed by Rao & Raman (1961). According to them, highest thunderstorm activity occurs over Assam, Bengal, Jharkhand and Orissa. The annual average of these areas exceeds 75 days. The northeast Assam, the most thundery area in India has an average exceeding 100 days. Mukherjee *et al*. (1964) have analyzed the occurrence of thunderstorm over Guwahati Airport based on the data of 1955-61 and found that Guwahati Airport gets thunder on 119 days in a year. According to them the frequency is maximum in May (19) followed by June, July & August (17 each), September (16) and April (12). According to Climatological Tables, India Meteorological Department (1966 & 1999), the thunderstorms and squalls occur over Guwahati Airport mostly during pre-monsoon and monsoon season. Guwahati Airport is situated in the Brahmaputra valley and at the foothills of Garo-khasi-Jaintia range on the southern bank of Brahmaputra river. The great Himalayan range lies to the north with high average height and many snow covered peaks. The valley has a gentle slope from east to west.

The thunderstorm activity over northeast India though occurs throughout the year, the intensity of thunderstorm is significantly higher and hazardous during pre-monsoon season (March–May) and the thunderstorm activity in this season over northeast India is popularly known as Nor'westers. The thunderstorm activity over

northeastern India is characteristically different from the thunderstorms over other parts of the country considering its genesis, time of occurrence and intensity etc. According to Sen & Basu (1961) and Mukherjee *et al.* (1964), the chief synoptic features during pre-monsoon months are the existence of a high pressure area south of 20° N extending vertically upto middle troposphere and a low pressure area north of 25° N in the lower troposphere. The wind at lower levels upto 850 hPa remains normally southerly or southwesterly over northeast India. The large scale flow in the upper troposphere remains westerly. Often western disturbances in the form of low pressure area and/or trough embedded in the westerlies pass over the region in an eastward direction. Localized convection many times is induced by low level cyclonic circulations extending vertically upto 2.1 km. There exists a trough of low pressure over Uttar Pradesh and Bihar with its axis or trough running in a WNW-ESE direction. Around this trough, WSW/Wly current normally blows over Assam in the lower levels with the passage of western disturbance or otherwise, the seasonal trough often gets accentuated and extends southeastwards into Gangetic West Bengal or eastwards to North Bengal, causing incursion of moist SW/S-ly air from Bay of Bengal into Assam. ENE/E-ly current which is relatively dry and cooler blows westwards across the foot of the Himalayas. The existence of dry and cold ENE/E-ly over north Assam and warm moist SW/S-ly over the southern latitude results in a E-W line of wind discontinuity which is also a favourable though not essential factor for thunderstorm. The existence of upper level divergence when associated with moisture incursion in lower levels appears to be very favourable for intense and widespread thunderstorm activity. According to Chaudhary (1961), the strong solar insolation and orographic lifting helps to form local convergence leading to deep convection. Srinivasan *et al.* (1973) has reviewed the work done on the Nor'westers upto early 1970. Chaudhary & Majumdar (1983) have reviewed subsequent work to qualitatively explain the variations in Nor'westers activity observed with the advance of the season from early March to late May. According to them, with the progress of season, Nor'westers activities extend northwards and westwards. They have found that according to synoptic climatology of the northeast India (*i*) the intensity of the seasonal trough over Gangetic plain increases (*ii*) horizontal extent and vertical depth of moist maritime air increases northwards and westwards (*iii*) the liquid water content of the atmosphere also increases with lowering of cloud condensation level, increase of buoyancy energy and hence greater penetrations of convective clouds into the lower stratosphere with progress of the season. The vertical wind shear also decreases with the decrease in wind speed in middle and upper troposphere with advance of the season. The thunderstorms also occur during monsoon season due to interaction of basic monsoon flow with the orography of the region. According to Mukherjee *et al*. (1964), Cumulonimbus clouds are found to be present during almost all days in monsoon season over Guwahati Airport. The frequency of thunderstorms is significantly less during post monsoon and winter seasons. Considering the climatological studies of thunderstorms and squalls over northeast India, Sen and Basu (1961) over different stations in Assam, Mukherjee, *et al*. (1983) over Calcutta, Sivaramakrishnan (1987) over Mohanbari and Moid (1996) over Mohanbari have studied the climatic characteristics. The works on the climatological aspects of thunderstorms and squalls over Guwahati Airport during recent years are limited. In this study, an attempt has been made to find out different climatological aspects of thunderstorms and squalls in recent years over the Guwahati Airport based on 10 years data. The basic objective of the study is to understand the temporal (both diurnal and intra-annual) variations in the occurrence of thunderstorms and squalls over the Guwahati Airport.

## 2. Data and methodology

The data on occurrence of thunderstorms and squalls over Guwahati Airport have been collected from Current Weather Registers of India Meteorological Department (IMD) for a period of 10 years (1991-2000). The thunderstorms accounted in this study include all those occasions when “thunder heard” is reported. A thunder is seldom heard beyond the distance of 25 km, 40 km may be considered as the upper limit for the distance to which thunder can be heard from the source of lightning. Hence the climatology obtained in this study represents the characteristics of thunderstorm activity over an area centered on Guwahati Airport within the radius of 40 km. The occurrence of squall is reported as per the criteria of IMD. A sudden increase of wind speed by atleast 3 stages on the Beaufort scale, the speed rising to force 6 or more, and lasting for atleast one minute is called squall. The wind force of 6 on Beaufort scale corresponds to minimum wind speed of 39 km per hour.

The annual and monthly frequency, time of commencement and duration of thunderstorms and squalls are 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 3 hourly period have been worked out. As regards duration of thunderstorms, frequencies for the period of less than 3 hours, 3-6 hours, 6-9 hours, 9-12 hours, 12-15 hours and more than 15 hours are calculated and analyzed. The duration of squall has been analyzed in the categories of 1-4 minutes, 4-7 minutes, 7-10 minutes and more than 10 minutes duration. The direction of the squall has been analyzed in 8 degrees

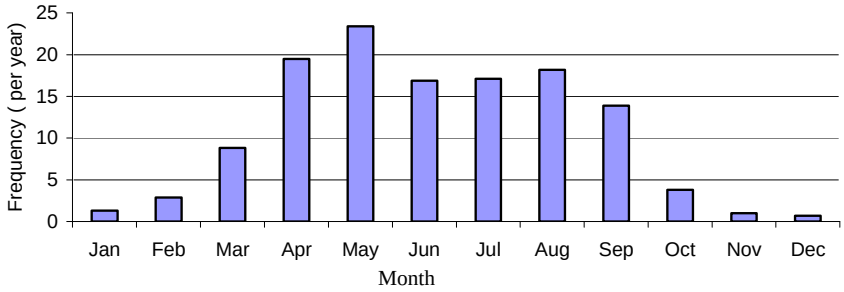


**Fig. 1.** Average monthly frequency distribution of thunderstorms over Guwahati Airport

of compass, *viz*., north (N), northeast (NE), east (E), southeast (SE), south (S), southwest (SW), west (W) and northwest (NW). Also the environmental changes associated with the occurrence of squalls are calculated and analyzed by finding out changes in environmental temperature, relative humidity, mean sea level pressure and maximum wind speed associated with the squall.

## 3. Results & discussion

### 3.1. *Frequency distribution of thunderstorms*

On the average, there have been 127.5 thunderstorms per year over Guwahati Airport. The frequency ranges from 172 in 1994 to 94 in 1999 during 10 years period of 1991-2000. Average monthly distribution of thunderstorms is shown in Fig. 1. The occurrence of the thunderstorms is maximum in the month of May followed by April. In monsoon season, the frequency is maximum in the month of August. Incidence of thunderstorms in post-monsoon and winter season is very insignificant. Majority (92.4%) of total thunderstorms have occurred in pre-monsoon and monsoon seasons. Comparing with the results obtained by Mukherjee *et al*. (1964) and IMD (1966, 1999), the frequency of occurrence and seasonal distribution of thunderstorms do not show any significant variations from the climatological pattern. The higher frequency of thunderstorm activity during pre-monsoon season may be attributed to the favourable synoptic conditions as discussed in Sec. 1. The higher frequency of thunderstorm activity during August may be attributed to the fact that, all India break monsoon condition mostly occurs in August. During all India break monsoon condition the monsoon trough shifts to the foothills of the Himalayas leading to maximum low level convergence over Assam region and hence more frequent thunderstorm activity. Also during this condition, a north-south trough develops over the region which is further helpful for thunderstorm activity.

### 3.2. *Time of commencement of thunderstorms*

Considering year as a whole, about 20.6% of the total thunderstorms have started during 0900-1200 UTC followed by 18.5% during 1200-1500 UTC & 17.6% during 0600-0900 UTC. The monthly frequency distribution of time of commencement of thunderstorms over Guwahati Airport is shown in Fig. 2. During pre-monsoon season, the thunderstorms have mostly occurred during late night/early morning hours, which is same as climatological pattern of the thunderstorm over this region. Mukherjee *et al*. (1964) have found that most of the thunderstorms during pre-monsoon season occur during late night/early morning. During monsoon season specially in August, when the frequency is maximum, most of the thunderstorms commence during 0600-1200 UTC. According to Mukherjee *et al*. (1964), most of thunderstorms during monsoon season also commence during the same period. Thus there is a characteristic difference in the nature of the thunderstorms over Guwahati Airport, during pre-monsoon and monsoon seasons as there is difference in causative synoptic conditions for thunderstorm during these two seasons. During post monsoon and winter seasons, though frequencies are less, maximum number of thunderstorms has commenced during 1200-1500 UTC followed by 0900-1200 UTC. Comparison with the results obtained by Mukherjee *et al*. (1964) indicates that characteristic pattern like the time of commencement of thunderstorms during different seasons has not changed over years.

### 3.3. *Duration of thunderstorms*

The frequency distribution of duration of thunderstorms in different months is shown in Fig. 3. It is found that during 10 years period, 69.3% of the thunderstorms are of the duration of less than 3 hours and 22.4% are of the duration of 3-6 hours. Considering the frequency of thunderstorms with duration of 3-6 hours, about 29 thunderstorms occur per year with this duration

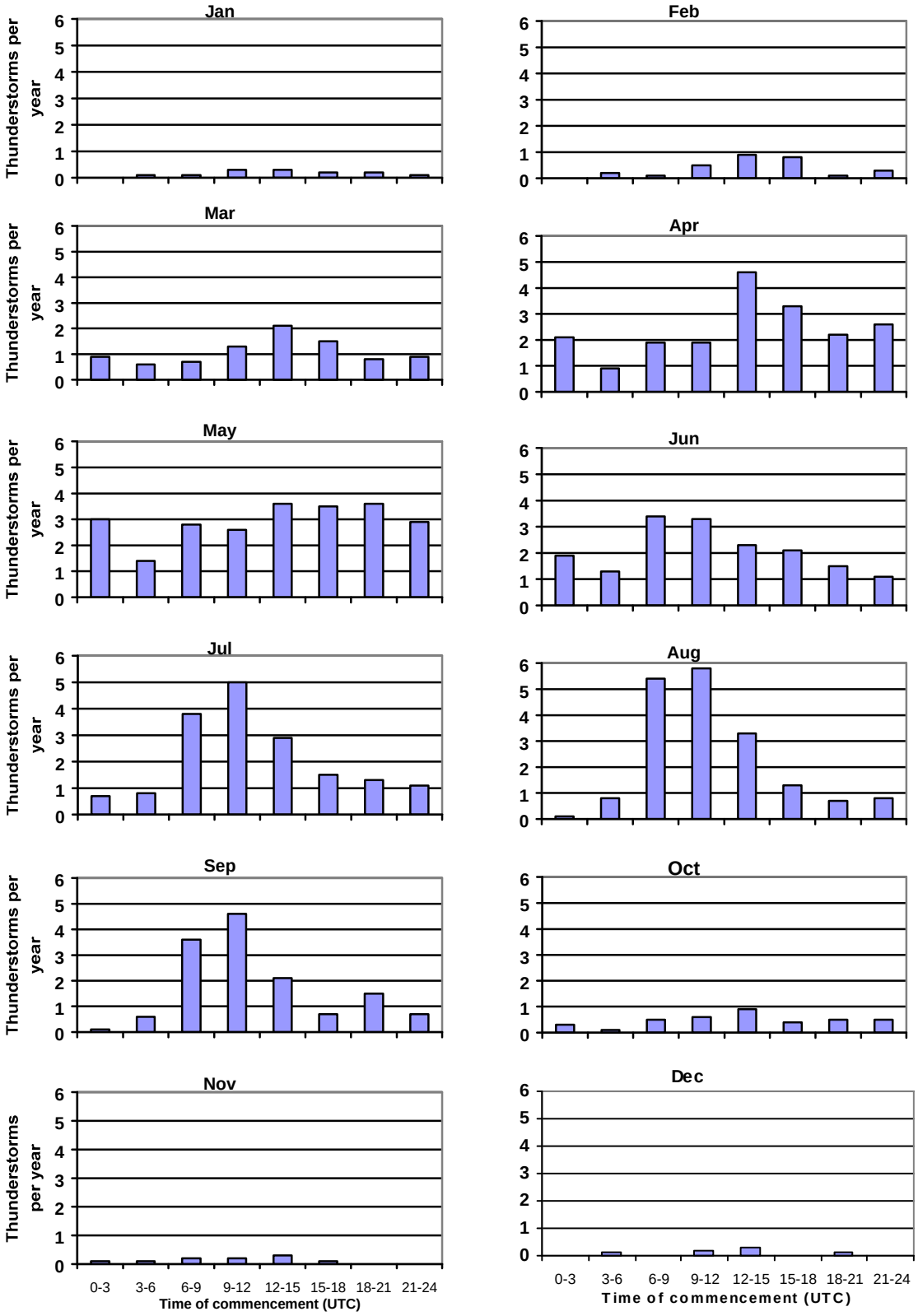


**Fig. 2.** Time of commencement of thunderstorms over Guwahati Airport

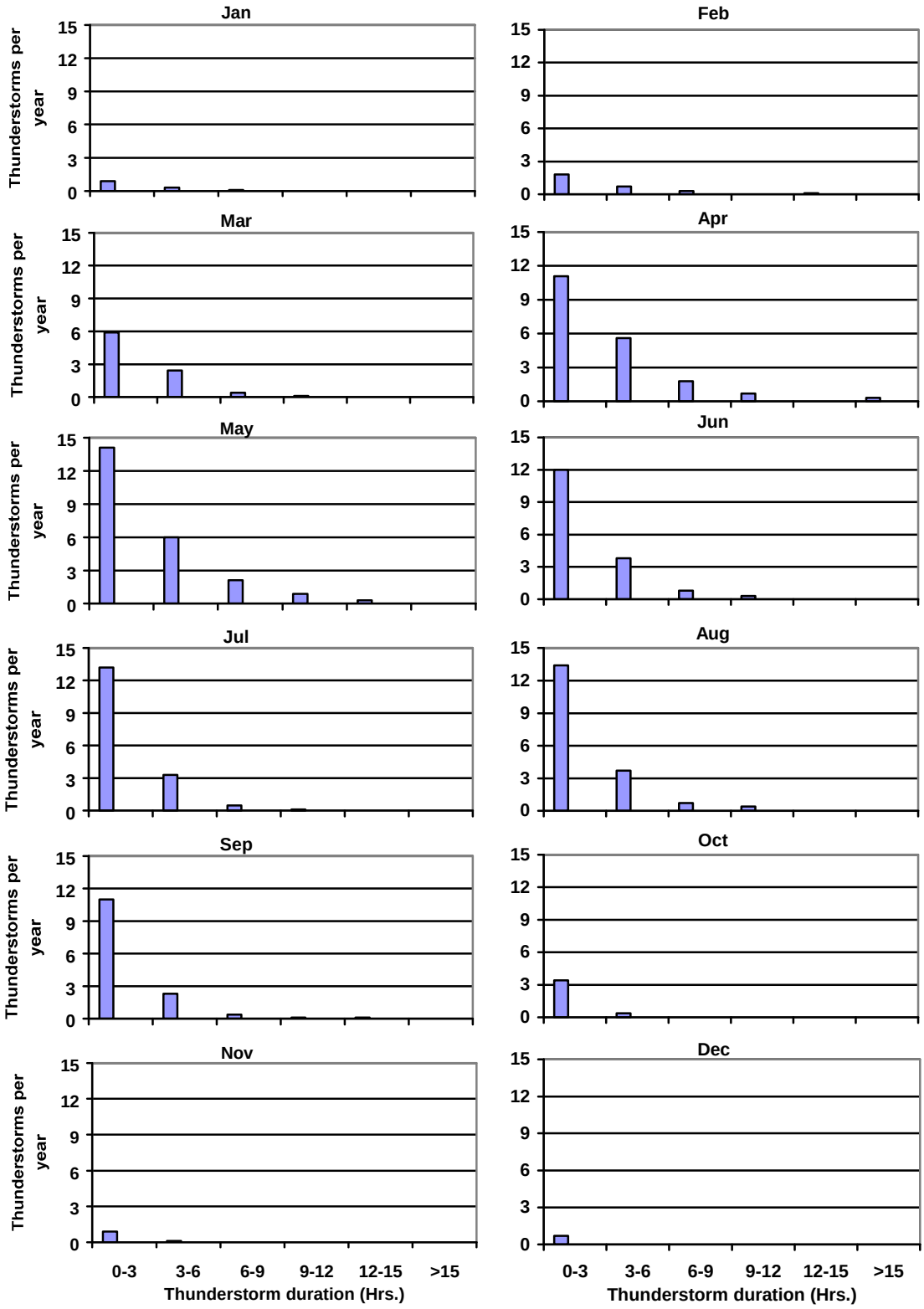


**Fig. 3.** Duration of thunderstorm over Guwahati Airport

**TABLE 1(a)**

**Frequency distribution of thunderstorms over Guwahati Airport in relation to duration and time of commencement during 10 years period (1991-2000)**

| Month | Duration (Hours) | Time (UTC) of commencement of thunderstorm activity | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0000-0300 | 0300-0600 | 0600-0900 | 0900-1200 | 1200-1500 | 1500-1800 | 1800-2100 | 2100-2400 | |
| Jan | 0-3 | 0 | 1 | 0 | 2 | 1 | 2 | 2 | 1 | 9 |
| | 3-6 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 3 |
| | 6-9 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Feb | 0-3 | 0 | 2 | 1 | 4 | 5 | 2 | 1 | 3 | 18 |
| | 3-6 | 0 | 0 | 0 | 1 | 2 | 4 | 0 | 0 | 7 |
| | 6-9 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 3 |
| | 9-12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 12-15 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Mar | 0-3 | 5 | 5 | 7 | 12 | 11 | 8 | 6 | 5 | 59 |
| | 3-6 | 4 | 1 | 0 | 0 | 8 | 6 | 1 | 4 | 24 |
| | 6-9 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 4 |
| | 9-12 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Apr | 0-3 | 15 | 7 | 16 | 13 | 24 | 11 | 9 | 16 | 111 |
| | 3-6 | 6 | 2 | 3 | 3 | 10 | 14 | 9 | 9 | 56 |
| | 6-9 | 0 | 0 | 0 | 2 | 7 | 5 | 4 | 0 | 18 |
| | 9-12 | 0 | 0 | 0 | 1 | 4 | 1 | 0 | 1 | 7 |
| | 12-15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | >15 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 3 |
| May | 0-3 | 21 | 11 | 21 | 21 | 20 | 15 | 12 | 20 | 141 |
| | 3-6 | 6 | 2 | 3 | 3 | 10 | 12 | 16 | 8 | 60 |
| | 6-9 | 3 | 0 | 3 | 0 | 2 | 8 | 5 | 0 | 21 |
| | 9-12 | 0 | 1 | 1 | 0 | 3 | 0 | 3 | 1 | 9 |
| | 12-15 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 3 |
| Jun | 0-3 | 16 | 8 | 30 | 24 | 17 | 8 | 9 | 8 | 120 |
| | 3-6 | 3 | 5 | 4 | 9 | 6 | 4 | 5 | 2 | 38 |
| | 6-9 | 0 | 0 | 0 | 0 | 0 | 6 | 1 | 1 | 8 |
| | 9-12 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 3 |
| Jul | 0-3 | 7 | 7 | 32 | 41 | 22 | 6 | 7 | 10 | 132 |
| | 3-6 | 0 | 1 | 6 | 6 | 4 | 9 | 6 | 1 | 33 |
| | 6-9 | 0 | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 5 |
| | 9-12 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Aug | 0-3 | 1 | 4 | 45 | 45 | 23 | 6 | 3 | 7 | 134 |
| | 3-6 | 0 | 3 | 8 | 11 | 5 | 6 | 3 | 1 | 37 |
| | 6-9 | 0 | 1 | 0 | 1 | 3 | 1 | 1 | 0 | 7 |
| | 9-12 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 4 |
| Sep | 0-3 | 1 | 5 | 32 | 39 | 15 | 4 | 9 | 5 | 110 |
| | 3-6 | 0 | 1 | 4 | 7 | 3 | 2 | 5 | 1 | 23 |
| | 6-9 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 4 |
| | 9-12 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| | 12-15 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Oct | 0-3 | 2 | 1 | 5 | 6 | 9 | 3 | 3 | 5 | 34 |
| | 3-6 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 4 |
| Nov | 0-3 | 1 | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 9 |
| | 3-6 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Dec | 0-3 | 0 | 1 | 0 | 2 | 3 | 0 | 1 | 0 | 7 |

**TABLE 1(b)**

**Frequency distribution of thunderstorms over Guwahati Airport in different seasons in relation to duration and time of commencement during 10 years period (1991-2000)**

| Month | Duration (Hours) | Time (UTC) of commencement of thunderstorm activity | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0000-0300 | 0300-0600 | 0600-0900 | 0900-1200 | 1200-1500 | 1500-1800 | 1800-2100 | 2100-2400 | |
| Pre-monsoon | 0-3 | 41 | 23 | 44 | 46 | 55 | 34 | 27 | 41 | 311 |
| | 3-6 | 16 | 5 | 6 | 6 | 28 | 32 | 26 | 21 | 140 |
| | 6-9 | 3 | 0 | 3 | 3 | 10 | 14 | 10 | 0 | 43 |
| | 9-12 | 0 | 1 | 1 | 1 | 8 | 1 | 3 | 2 | 17 |
| | 12-15 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 3 |
| | >15 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 3 |
| Monsoon | 0-3 | 25 | 24 | 139 | 149 | 77 | 24 | 28 | 30 | 496 |
| | 3-6 | 3 | 10 | 22 | 33 | 18 | 21 | 19 | 5 | 131 |
| | 6-9 | 0 | 1 | 0 | 3 | 7 | 8 | 3 | 2 | 24 |
| | 9-12 | 0 | 0 | 1 | 2 | 3 | 3 | 0 | 0 | 9 |
| | 12-15 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| | >15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Post monsoon | 0-3 | 3 | 3 | 7 | 10 | 14 | 4 | 4 | 5 | 50 |
| | 3-6 | 1 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 5 |
| | 6-9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 9-12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 12-15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | >15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Winter | 0-3 | 0 | 3 | 1 | 6 | 6 | 4 | 3 | 4 | 27 |
| | 3-6 | 0 | 0 | 0 | 2 | 4 | 4 | 0 | 0 | 10 |
| | 6-9 | 0 | 0 | 1 | 0 | 1 | 2 | 0 | 0 | 4 |
| | 9-12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 12-15 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| | >15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

and highest frequency is found to be in the month of May (6.0) followed by April (5.6). In 6-9 hour duration category, there have been about 7.1 per year and in 9-12 hours duration category, it has been 2.6 per year. Average frequency of thunderstorm with duration of more than 12-hours period is less than one and most of them have occurred during pre-monsoon season. It indicates that thunderstorms during pre-monsoon season are more durable. In Tables 1(a & b), the frequency distribution of thunderstorms in relation to duration and time of commencement has been shown. It is seen that the thunderstorms with 6-9 hours duration have mostly commenced during 1500-1800 UTC followed by 1800-2100 UTC during May & June, 1200-1500 UTC followed by 0900-1200 UTC during July, August, 1200-1500 UTC followed by 1500-1800 UTC and 1800-2100 UTC during April. The frequency of thunderstorm with 6-9 hrs or more duration is nil during post monsoon season and negligible during January to March. Similarly thunderstorms with duration of 9-12 hours or more have the tendency to commence mostly during 1200-1500 UTC followed by 1500-1800 UTC and 1800-2100 UTC respectively during April and May. Thunderstorms of the duration more than 12 hours are very rare and mostly found in the month of April & May and have the tendency to commence during 0900-1200/1200-1500 UTC. Hence thunderstorms commencing during evening in pre-monsoon months are found to be more durable.

### 3.4. *Frequency distribution of squalls*

The frequency distribution of squalls over Guwahati Airport in relation to direction of squalls is shown in

**TABLE 2**

**Frequency distribution of squalls over Guwahati Airport in relation to direction during 10 years period (1991-2000)**

| Month | Frequency distribution of squalls in relation to direction | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | N | NE | E | SE | S | SW | W | NW | |
| Jan | - | - | - | - | 1 | - | - | - | 1 |
| Feb | - | - | - | - | - | - | 1 | 4 | 5 |
| Mar | - | - | - | - | 1 | 1 | 1 | 1 | 4 |
| Apr | - | 1 | 1 | - | - | 2 | 3 | 11 | 18 |
| May | - | 1 | - | 1 | - | 3 | 3 | 17 | 25 |
| Jun | - | - | - | - | - | - | - | - | 0 |
| Jul | - | - | - | - | - | - | - | - | 0 |
| Aug | - | - | - | - | - | - | - | - | 0 |
| Sep | - | - | - | - | 1 | - | - | - | 1 |
| Oct | - | - | - | - | - | - | - | - | 0 |
| Nov | - | - | - | - | - | - | - | - | 0 |
| Dec | - | - | - | - | - | - | - | - | 0 |
| Total | 0 | 2 | 1 | 1 | 3 | 6 | 8 | 33 | 54 |

Table 2. On the average, 5-6 squalls occur in a year over Guwahati Airport. According to Mukherjee *et al*. (1964), about 6 squalls per year have occurred over Guwahati Airport during 1955-61. The pre-monsoon season is the most favoured season for the squalls over Guwahati, as 87% of the squalls have occurred in the period from March to May. The frequency is maximum in May (about 50%) followed by April. It endorses the results obtained by Mukherjee *et al*. (1964). Statistics shows that majority of the squalls have wind direction as northwesterly (60%), followed by westerly (15%) and southwesterly (11%). According to Sen and Basu (1961), large majority (over 90%) of the squalls during pre-monsoon season over Guwahati Airport have come from northwest with only few from west and rarely from southwest during 5 years period of 1955-59. According to present study, about 66% of the total squalls during pre-monsoon season have been associated with northwesterly direction. Monsoon and post monsoon seasons are almost free of squalls.

### 3.5. *Time of occurrence and durations of squall*

The frequency distribution of squalls in relation to duration and time of occurrence is shown in Table 3. Considering the total frequencies of squalls, most of them have occurred during 1200-1500 UTC followed by 0900-1200/1500-1800/1800-2100 UTC. About 76% of the total squalls have occurred during 0900-2100 UTC. Considering the individual pre-monsoon months of April and May, when the frequencies of squalls are significantly higher, maximum number of squalls have occurred (4 each) during 0000-0300, 0900-1200, 1200-1500, 1500-1800 and 1800-2100 UTC in the month of May and during 1200-1500 UTC followed by 1500-1800 and 1800-2100 UTC in the month of April. The frequencies of squalls during above mentioned periods have been about 87% and 80% respectively in April and May.

Most of the squalls have duration of period 1-4 followed by 4-7 minutes. The squalls are more durable in pre-monsoon season as all the squalls with the duration of 7 minutes or more (3 out of total 54) have occurred during pre-monsoon season only. However the most durable squall of the duration greater than 10 minutes have occurred once during March originating between 0900-1200 UTC.

### 3.6. *Environmental changes with the occurrence of squall*

The changes in environmental temperature, relative humidity, mean sea level pressure and wind speed have been examined for the squalls occurring in the pre-monsoon season as those are most frequent and more

**TABLE 3**

**Duration of squalls over Guwahati Airport**

| Month | Duration (Minutes) | Time (UTC) of occurrence of Squall | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0000-0300 | 0300-0600 | 0600-0900 | 0900-1200 | 1200-1500 | 1500-1800 | 1800-2100 | 2100-2400 | |
| Jan | 1-4 | - | - | - | - | 1 | - | - | - | 1 |
| Feb | 1-4 | - | 1 | - | - | 2 | - | 1 | - | 4 |
| | 4-7 | - | - | - | 1 | - | - | - | - | 1 |
| | 7-10 | - | - | - | - | - | - | - | - | 0 |
| Mar | 1-4 | - | - | - | - | 1 | - | 1 | - | 2 |
| | 4-7 | - | - | - | - | - | - | - | - | 0 |
| | 7-10 | - | - | - | 1 | - | - | - | - | 1 |
| | >10 | - | - | - | 1 | - | - | - | - | 1 |
| Apr | 1-4 | 1 | - | - | 2 | 5 | 4 | 3 | 1 | 16 |
| | 4-7 | - | - | - | - | - | 1 | - | - | 1 |
| | 7-10 | - | - | - | - | 1 | - | - | - | 1 |
| May | 1-4 | 3 | - | 1 | 4 | 2 | 4 | 3 | 1 | 18 |
| | 4-7 | 1 | 2 | - | - | 2 | - | 1 | 1 | 7 |
| | 7-10 | - | - | - | - | - | - | - | - | 0 |
| Jun | 1-4 | - | - | - | - | - | - | - | - | 0 |
| Jul | 1-4 | - | - | - | - | - | - | - | - | 0 |
| Aug | 1-4 | - | - | - | - | - | - | - | - | 0 |
| Sep | 4-7 | - | - | 1 | - | - | - | - | - | 1 |
| Oct | 1-4 | - | - | - | - | - | - | - | - | 0 |
| Nov | 1-4 | - | - | - | - | - | - | - | - | 0 |
| Dec | 1-4 | - | - | - | - | - | - | - | - | 0 |
| Total | | 5 | 3 | 2 | 9 | 14 | 9 | 9 | 3 | 54 |

disastrous in nature. The results are shown in Table 4. In association with the squall, the environmental temperature falls but relative humidity, mean sea level pressure and wind speed increases. The highest fall of temperature associated with the squall over Guwahati Airport during the period under study has been 7.6° C, while average fall of temperature due to squall is found to be 2.2° C. The maximum rise in mean sea level pressure has been 4 hPa and average rise in pressure is found be 1.6 hPa. The rise in humidity has been as high as 31% while average rise in humidity has been 8.8% with the occurrence of squall. The highest maximum wind speed due to squall has been 70 knots, while the average maximum wind speed has been 39 knots. Sen and Basu (1961), while analyzing squalls during pre-monsoon season over period of 1955-59, have found that the speed of squalls on most

**TABLE 4**

**Environmental changes during squall over Guwahati Airport**

| Date | Temp fall ( °C) | Humidity rise (%) | Pressure change (hPa) | Peak wind (knots) |
|---|---|---|---|---|
| Average | 2.2 | 8.8 | 1.6 | 39 |
| Maximum | 7.6 | 31 | 4.0 | 70 |
| Minimum | 0.0 | 0.0 | -0.7 | 25 |

occasion is 35-40 knots, the highest recorded during that period being 75 knots. It indicates that the characteristics of squall like associated maximum wind speed of the squall have not changed significantly over the years.

## 4. Conclusions

Following conclusions emerge out of study.

(*i*) Average frequency of thunderstorm and squalls over Guwahati Airport is 127.5 and 5.4 per year respectively. The thunderstorm and squall activity is maximum in the month of May followed by April. While the thunderstorms mostly occur during pre-monsoon and monsoon season, the squalls mostly occur during Feb-May.

(*ii*) The majority of the thunderstorms have the tendency to commence during midnight to early morning in pre-monsoon season and during 0600-1200 UTC in monsoon season. Thunderstorms of the duration of more than 6 hours mostly commence between 1200-1800 UTC hours. Very long duration thunderstorms with the duration of more than 12 hours are very rare and they mostly occur during pre-monsoon season.

(*iii*) The squalls occur mostly from NWly direction followed by Wly and SWly direction. Most of the squalls occur during 0900-2100 UTC. More durable squalls occur during pre-monsoon season.

(*iv*) On the average, the environmental temp falls by 2.2° C, the relative humidity rises by 8.8%, Mean sea level pressure increases by 1.6 hPa due to occurrence of squall over Guwahati Airport. The average maximum wind speed associated with squall over Guwahati Airport is about 39 knots with the highest maximum wind speed being 70 knots.

(*v*) Comparison with the past studies indicates that the characteristics of thunderstorms and squalls over Guwahati Airport have not changed significantly over the years.

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