

Climatological and synoptic aspect of hailstorm and squall over Guwahati Airport during pre-monsoon season

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सार – उत्तर-पूर्वी भारत मानसून पूर्व ऋतु में गर्ज के साथ तूफान और उसके साथ सामान्य से भारी वर्षा, झोंके साथ पवन, चंडवात और कभी-कभी ओलावृष्टि के लिए जाना जाता है। इस शोधपत्र में मानसून पूर्व ऋतु के दौरान गुवाहाटी हवाई अड्डे (26.18°उ. 91.75°पू.) में ओलावृष्टि और चंडवात के जलवायविक और सिनॉप्टिक पहलुओं का पता लगाने का प्रयास किया गया है। 1987 से 2006 तक के 20 वर्षों के आँकड़ों का विश्लेषण किया गया है। मानसून पूर्व ऋतु के दौरान ओले और चंडवात के आवृत्ति क्रमशः 1.35 और 3.65 रही। गुवाहाटी हवाई अड्डे में ओलावृष्टि का सबसे अनुकूल समय दोपहर से देर शाम तक और चंडवात का शाम से तड़के सुबह तक होता है। पूर्वी उत्तर प्रदेश/बिहार से उत्तर पूर्वी भारत तक समुद्र स्तर द्रोणी तथा बिहार और उसके निकटवर्ती क्षेत्रों में निम्न सतह साइसिर ओले की घटना से संबंधित महत्वपूर्ण सिनॉप्टिक स्थितियाँ हैं।

ABSTRACT. Premonsoon season in north-east India is known for thunderstorm activity with moderate to heavy rain, gusty wind, squall and sometimes with the occurrences of hail fall. In this paper an attempt has been made to find out the climatological and synoptical aspects of hailstorms as well as squall over Guwahati Airport (26.18° N, 91.75° E) during Premonsoon season. 20 years data from 1987 to 2006 have been analyzed. The frequency of hail and squall during premonsoon season is observed to be 1.35 and 3.65 respectively. The most favourable time of occurrence of hail is during afternoon to late evening and that for the occurrence of squall is during evening to early morning over Guwahati Airport. The significant synoptic situations associated with occurrence of hail are Sea level trough from East Uttar Pradesh/Bihar to North-East India and low level cycir over Bihar and neighbourhood.

Key words – Climatology, Hail, Squall, Synoptic situation, CAPE, CINE.

1. Introduction

Intensity of thunderstorm over NE India is significantly higher and hazardous during pre-monsoon season (March-May) than the other seasons. Thunderstorm activity in the pre-monsoon season in northeast India is popularly known as Nor'wester. Hail and squall are generally found to occur with severe thunderstorm during this season. There had been many studies on climatological aspect of thunderstorms over different parts of India. The frequency of thunderstorm in different months over India has been extensively discussed by Rao and Raman (1961). The study showed

that highest thunderstorm activity occurs over Assam, Bengal, Jharkhand and Orissa. The annual average of these activities over these areas exceed 75 days. Many authors, for examples Koteswaram and Srinivasan (1958), Sen and Basu (1961), Chaudhury (1961), Mukherjee (1983) had explored the favourable condition for the occurrences of thunderstorm activity. Mukherjee (1964) has studied thunderstorm activity around Guwahati Airport and concluded that its frequency has been maximum in May and it approached the station from west. A synoptic and radar study on severe hailstorm of 27th May 1959 near Sikar (Rajasthan) has been done by Mull and Kulshrestha (1962). Suresh and Bhatnagar (2004)

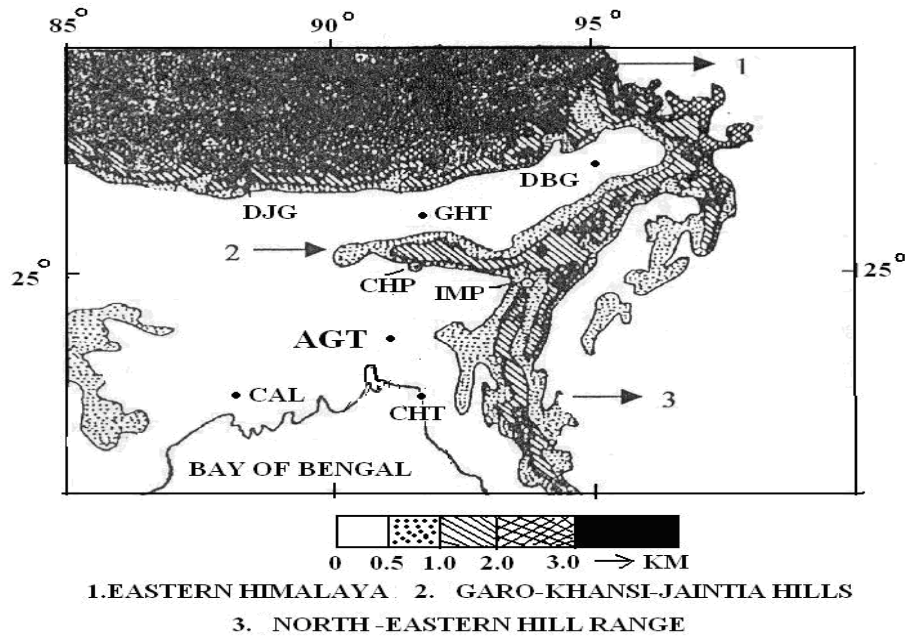
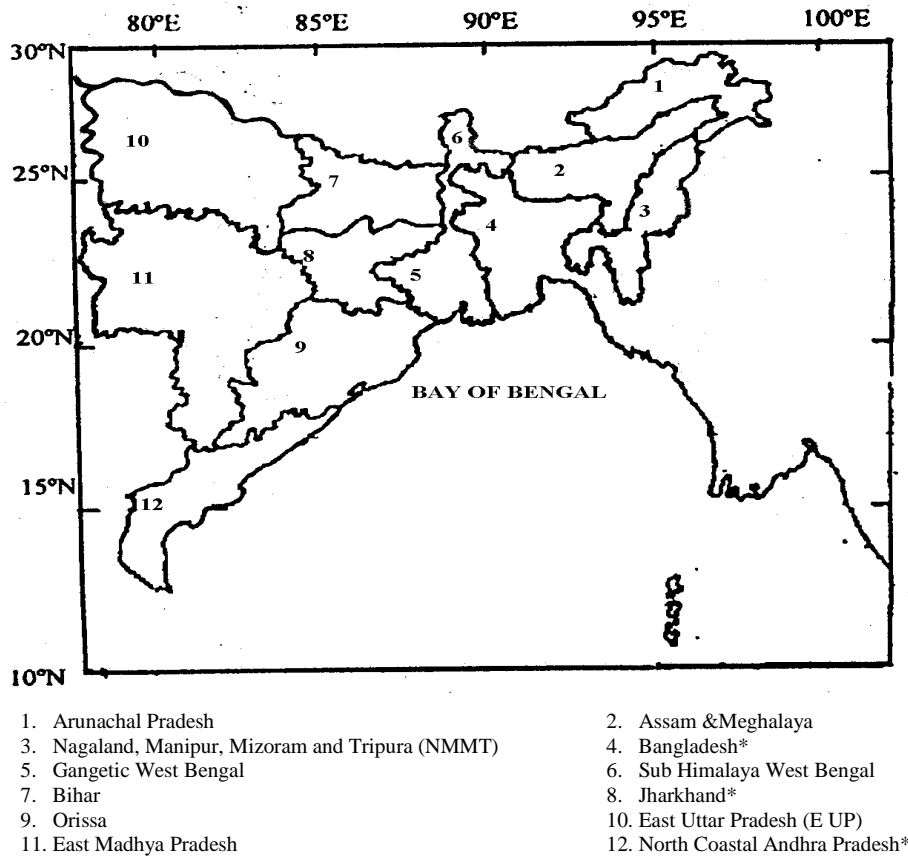


Fig. 1. Physiographic map of northeast India



Note : * are not Met sub-divisions

Fig. 2. Geographical regions considered in the study for synoptic analysis

TABLE 1

Frequency of Hailstorms at Guwahati Airport

| Month | Total during 20 Years | Mean | % Distribution | SD | CV |
|----------|-----------------------|------|----------------|------|-----|
| March | 09 | 0.45 | 33 | 0.69 | 153 |
| April | 14 | 0.70 | 52 | 0.86 | 124 |
| May | 04 | 0.20 | 15 | 0.41 | 205 |
| Seasonal | 27 | 1.35 | 100 | 1.45 | 88 |

TABLE 2

Frequency of Squall

| Month | Total during 20 Years | Mean | % Distribution | SD | CV |
|----------|-----------------------|------|----------------|------|-----|
| March | 11 | 0.55 | 15 | 0.94 | 172 |
| April | 35 | 1.75 | 48 | 1.37 | 78 |
| May | 27 | 1.35 | 37 | 1.57 | 116 |
| Seasonal | 73 | 3.65 | 100 | 2.62 | 72 |

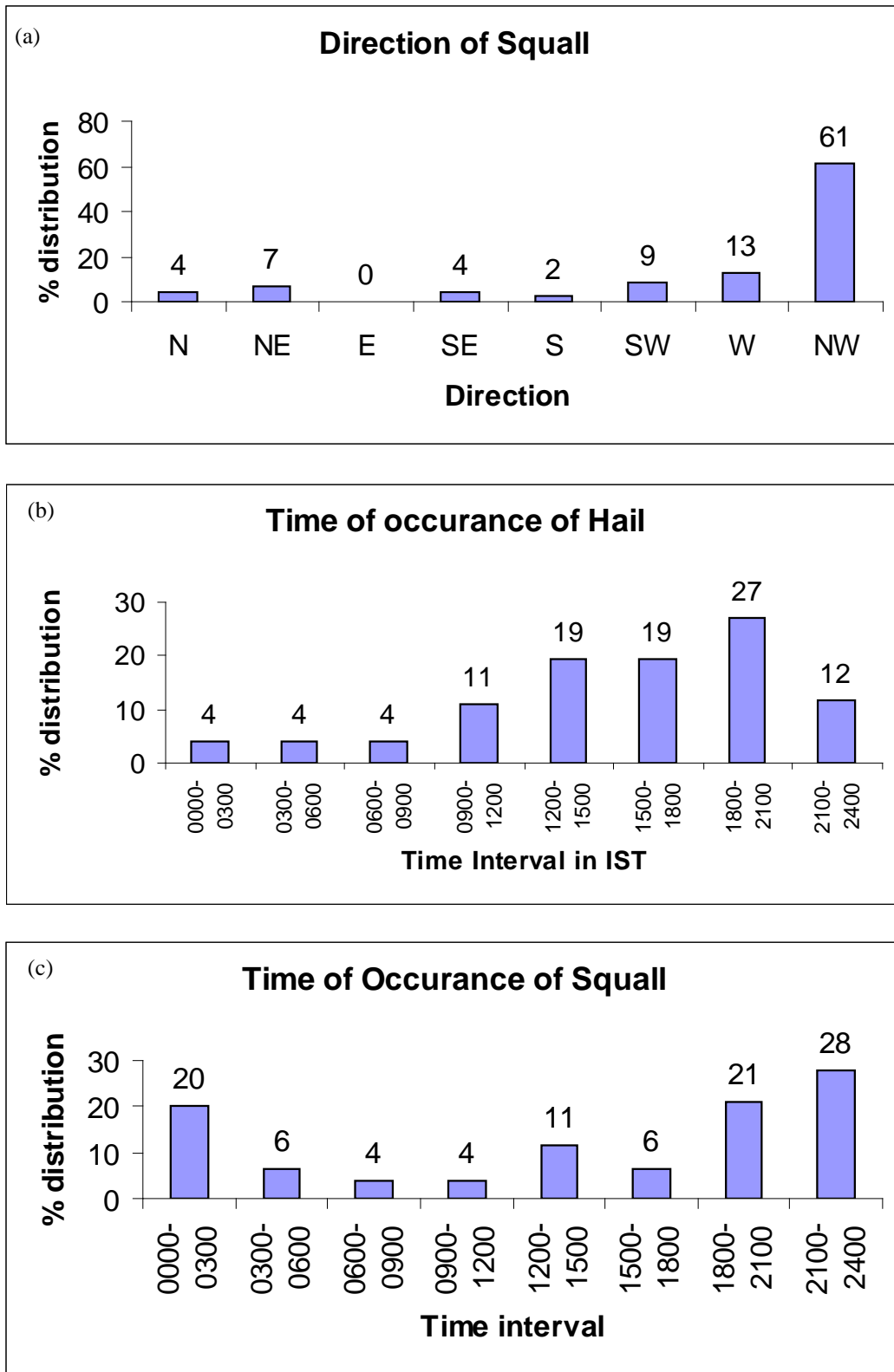
have analyzed unusual hailstorm over Chennai by using data from a single Doppler weather radar. Rao and Mukherjee (1958) described a method for forecasting hailstorms using 24 hrs vectorial wind change at 1.5 km level from the previous day. Influence of wind shear on the growth of hail have analyzed by Das (1962). A radar study has been done by Sharma (1965) on hailstorm over Guwahati and concluded that LOW over Nepal/North Bengal and its movement towards Guwahati was responsible for occurrence of hook shaped perturbation. Mukherjee *et al.* (1962) had studied the structure of hailstorm and prevailing meteorological situation on an unusual hailstorm event over Guwahati on 18th March 1961. They opined that sufficient amount of moisture, local orographic features and latent instability in the atmosphere appear to have given rise to the hailstorm. They also observed that hailstorms were in association with strong vertical wind. Convective Inhibition Energy (CINE) has been studied in relation to pre-monsoon convective activity over West Bengal by Chaudhury and Chattopadhyay (2001). A climatological study of thunderstorm at Mohanbari Airport has been done by Moid (1966). Sivaramakrishnan (1987) has studied squalls over Mohanbari. Recently Gajendra Kumar & Mohapatra (2006) studied climatology of thunderstorm over Guwahati Airport along with impact on environmental temperature, relative humidity and pressure due to squall over Guwahati Airport. An extended study of the climatological and synoptical aspect of squall and hail over Guwahati Airport has been attempted in this paper.

2. Data and methodology

Guwahati Airport is situated in the Brahmaputra valley and at the foothills of Garo-Khasi-Jaintia hills range of average height 1.5 km on the south bank of Brahmaputra River. The great Himalayas range lies to the north with high average height and many snow covered peaks. The valley has a gentle slope from east to west (Fig. 1). Fig. 2 shows the geographical regions from where the synoptic system may affect Guwahati.

Information pertaining to date and time of occurrences of hail and squall over Guwahati Airport have been collected from current weather register of India Meteorological Department (IMD) for pre-monsoon season (March-May) for a period of 20 years (1987-2006).

The seasonal and monthly frequencies, time of commencement of hail and squall are analysed. To determine the time of commencement of hails and squalls, a day is divided into 3 hourly periods and average frequencies of hail and squall for each 3 hourly period have been worked out. The direction of squall has been analyzed in 8 degrees of compass North (N), Northeast (NE), East (E), Southeast (SE), South (S), Southwest (SW), West (W) and Northwest (NW). The data on synoptic systems associated with hail and squall has been collected from daily weather report of RMC Guwahati. RS/RW data of Guwahati and Agartala have been



Figs. 3 (a-e). Direction of Squall and time of occurrences of hail & squall over Guwahati Airport

TABLE 3
Favourable Synoptic Situation for Hail and Squall Occurrences

| S. No. | Synoptic Situation | % Distribution for Hail | % Distribution for Squall |
|--------|--|-------------------------|---------------------------|
| 1 | LOW/ Cyclonic circulation over Bihar in Lower Level | 24 | 34 |
| 2 | LOW/ Cyclonic circulation over GWB/BD in Lower Level | 4 | 11 |
| 3 | LOW/ Cyclonic circulation over SHWB in Lower Level | 12 | 10 |
| 4 | Sea level trough from E UP/Bihar to NE India | 44 | 30 |
| 5 | LOW/ Cyclonic circulation over E UP in Lower Level | 0 | 6 |
| 6 | LOW/ Cyclonic circulation over West/Central Assam in Lower Level | 8 | 4 |
| 7 | Upper Air North-South Trough/Trough in westerly roughly along 88°E | 8 | 5 |
| Total | | 100 | 100 |

Note : E UP : East Uttar Pradesh, GWB : Gangetic West Bengal, BD: Bangladesh, SHWB : Sub Himalayan and West Bengal

obtained from National Data Centre, IMD, Pune and analysed. Time series analysis has been carried out to identify the tendency if any on the occurrence of hail and squall using Mann-Kendall rank statistic (WMO, 1966).

CAPE and CINE value of Guwahati Airport have been calculated and analysed. Whereas 0530 hrs (IST) RS/RW data has been used for the occurrence of hail/squall from 0600 & 1759 hrs (IST) and 1730 hrs (IST) RS/RW data has been used for their occurrences from 1800 to 0559 hrs (IST).

3. Results and discussions

3.1. Frequency distribution of hail

The frequency distribution of hail over Guwahati Airport is shown in the Table 1. According to Sharma (1965) on an average 2 hailstorm occurred over Guwahati Airport during pre-monsoon season, 1955-61 with highest in April (57%) followed by March (36%) and May (7%). In the present study it is found that there have been 1.35 hailstorm occurred during pre-monsoon season with maximum in the month of April (52%) followed by March (33%) and May (15%). Moreover the coefficient of variation (CV) shows that the occurrence of hail is highly variable in the month of May and least variable in April during the pre-monsoon season.

3.2. Frequency distribution of squall

The frequency distribution of squall over Guwahati Airport in relation with direction of squall is shown in Table 2 and Fig. 3(a) respectively. According to Gajendra Kumar and Mohapatra (2006), out of 5-6 squalls that were

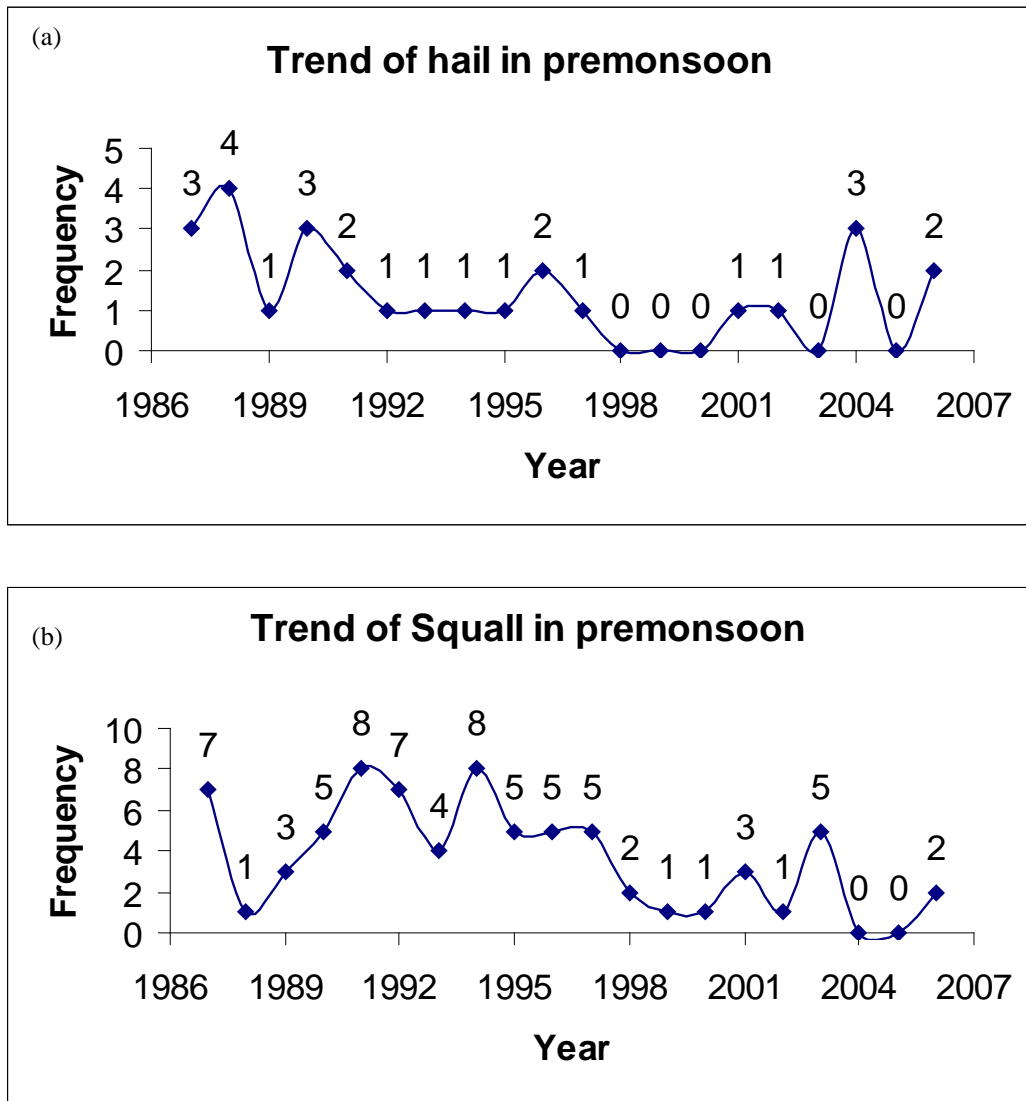
reported per year over Guwahati Airport during 1991-2000, 4-5 were observed during pre-monsoon season. However, this study shows that on an average, 3.65 squalls occurred during pre-monsoon season. Maximum frequency is observed in April (48%) followed by May (37%) and March (15%). The CV shows that the occurrence of squall in the pre-monsoon season is highly variable, maximum in March and minimum in April. According to Sen and Basu (1961), a majority (over 90%) of the squall during pre-monsoon season affected Guwahati Airport from northwest (NW) direction with only a few from west and rarely from southwest (SW) direction during the five years period of their study, *viz.*, 1955-1959. The present study re-confirms that the majority of squalls are from NW (61%) with an exception that squalls from west (13%) and SW directions (9%) were also significant. The average wind speed associated with squall in this study is 37 knots with maximum of 75 knots on 22 April 1992 with direction NW.

3.3. Time of occurrence of hail

The frequency distribution of hails in relation to the time of occurrence is shown in Fig. 3(b). During the season, most of the hails have been occurred during 1800-2100 hrs (IST) (27%) followed by 1200-1500 hrs (IST) (19%) and 1500-1800 IST (19%). In other words the most favourable time of occurrence of hail is during afternoon to late evening accounting for 65% of the total frequency.

3.4. Time of occurrence of squall

The frequency distribution of squalls in relation to the time of occurrence is shown in the Fig. 3(c). During the season, most of the squalls have occurred during



Figs. 4 (a&b). Time series analysis of Hail and Squall

2100-2400 hrs (IST) (28%) followed by 1800-2100 hrs (IST) (21%) and 0000-0300 hrs (IST) (20%). The most favourable time of occurrence of squall is during evening to early morning accounting for 69% of the total frequency.

3.5. Synoptic situation associated with hail and squall

The synoptic situation associated with hail and squall is shown in Table 3. The trough at sea level from East Uttar Pradesh/Bihar to northeast India seem to be the most significant synoptic situation associated with occurrence of hail (44%) followed by LOW (Low

Pressure Area)/Cyclonic circulation in lower level over Bihar and neighbourhood and its eastward movement (24%). It is also observed that strong southwesterly wind in lower level over the region plays a significant role along with the above synoptic situation in the occurrence of hail as shown by the mean wind at Agartala at 850 hPa (250°/17 knots).

The synoptic situation associated with hail is presented in Table 3. The LOW/Cyclonic circulation in lower level over Bihar and neighbourhood and its eastward movement is the most significant synoptic situation associated with occurrence of squall (34%)

TABLE 4(a)

CAPE value and its frequency at Guwahati for Hail

| Range of CAPE (J/kg) | Frequency | % of the Total |
|----------------------|-----------|----------------|
| 0-100 | 3 | 12.5 |
| 100-200 | 3 | 12.5 |
| 200-300 | 1 | 4.16 |
| 300-400 | 0 | 0 |
| 400-500 | 4 | 16.67 |
| >500 | 13 | 54.17 |
| Total | 24 | 100 |

TABLE 4(b)

CAPE value and its frequency at Guwahati for Squall

| Range of CAPE (J/kg) | Frequency | % of the Total |
|----------------------|-----------|----------------|
| 0-250 | 12 | 19.05 |
| 250-500 | 2 | 3.17 |
| 500-750 | 5 | 7.94 |
| 750-1000 | 14 | 22.22 |
| >1000 | 30 | 47.62 |
| Total | 63 | 100 |

TABLE 4(c)

CINE value and its frequency at Guwahati for Hail

| Range of CINE (J/kg) | Frequency | % of the Total |
|----------------------|-----------|----------------|
| 0-(-50) | 3 | 12.50 |
| (-50)-(-100) | 6 | 25.00 |
| (-100)-(-150) | 2 | 8.33 |
| (-150)-(-200) | 3 | 12.50 |
| <-200 | 10 | 41.67 |
| Total | 24 | 100 |

TABLE 4(d)

CINE value and its frequency at Guwahati for Squall

| Range of CINE (J/kg) | Frequency | % of the Total |
|----------------------|-----------|----------------|
| 0-(-50) | 11 | 17.46 |
| (-50)-(-100) | 10 | 15.87 |
| (-100)-(-150) | 18 | 28.57 |
| (-150)-(-200) | 5 | 7.94 |
| <-200 | 19 | 30.16 |
| Total | 63 | 100 |

followed by the trough at sea level from East Uttar Pradesh/Bihar to northeast India (30%). Here again, it is observed that strong southwesterly wind in lower level over the region plays a significant role along with the above synoptic situation in the occurrence of squall as shown by the mean wind at Agartala at 850 hPa (245°/14 knots).

3.6. Tendency of hail and squall

The total frequency of hail storm and squall during premonsoon season 1987-2006 have been depicted in Figs. 4(a&b) respectively. It can be seen that the hail frequency was more than the average frequency in 6 years and the squall frequency was more than the average frequency in 10 years out of the 20 years considered in this study. No clear out trend could be fixed. However, decreasing tendency has been observed using Mann-Kendall rank statistic for hail and squall.

3.7. CAPE and CINE value for hail and squall at Guwahati

CAPE and CINE values are tabulated in Tables 4(a) to Table 4 (d) for hailstorms and squall events. About 71% of hailstorms were associated with CAPE values exceeding 400 J/kg and nearly 70 % of squalls with CAPE exceeding 750 J/kg. While CINE of less than 50 J/kg is associated with 87.5 % of hailstorm, squalls of 67 % are associated with CINE of less than 150 J/kg.

4. Conclusions

The following conclusions are drawn on the basis of the results and analysis made in this study.

(i) The average frequency of hail in pre-monsoon is 1.35 per season with maximum in April (0.70) followed by March (0.45) and May (0.20). High variability is observed in this season.

(ii) The average frequency of squall in pre-monsoon season is 3.65 with maximum in April (1.75) followed by May (1.35) and March (0.55). High variability is seen in all the month as well as season. The majority of squalls was associated with wind from northwesterly (61%) followed by westerly (13%) and southwesterly (9%).

(iii) While the most favourable time of occurrence of hail is between afternoon and late evening, it is during late evening/early morning in respect of squall.

(iv) The most significant synoptic situation associated with the occurrence of hail are the trough at sea level from East Uttar Pradesh/Bihar to northeast India and

Low/Cyclonic circulation in lower level over Bihar and neighbourhood and its eastward movement.

(v) The most significant synoptic situation associated with the occurrence of squall are Low/Cyclonic circulation in lower level over Bihar and neighbourhood and its eastward movement and the trough at sea level from East Uttar Pradesh/Bihar to northeast India.

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