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Thunderstorm climatology over northeast and adjoining east India

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सार – इस शोध पत्र में 1981–2008 के अप्रैल और मई माह के दौरान भारत मौसम विज्ञान विभाग (आई.एम.डी.) की 26 वेधशालाओं के लिए आँकड़ों के आधार पर पूर्वोत्तर और उसके समीपवर्ती पूर्वी भारत के क्षेत्रों में गर्ज के तूफान, ओला और चंडवात की जलवायविकी विकसित करने का प्रयास किया गया है। इन क्षेत्रों में स्थित भारतीय वायु सेना (आई.ए.एफ.) की 08 वेधशालाओं से लिए गए 1991–2008 तक की अवधि के आँकड़ों का भी उपयोग किया गया है। गर्ज के साथ तूफान की अंतर वार्षिक व अंतरामौसमी विविधता, जलवायु पविर्तन के पहलुओं और दैनिक विविधता का विश्लेषण तथा विवेचना की गई है।

इस क्षेत्र में गर्ज के साथ तूफान, ओला और चंडवात के दिनों की आवृति और समय से बड़े पैमाने पर होने वाली स्थानिक विविधता का पता चला है। पर्वतीय क्षेत्रों और तटीय क्षेत्रों ऐसी गतिविधियाँ अधिक होती है। हाल ही के वर्षों में उड़ीसा के दक्षिण तटीय क्षेत्र और तटीय पश्चिम बंगाल के कुछ भागों में गर्ज के साथ तूफान के दिनों की संख्या में बढ़ोतरी देखी गई है तथा उत्तरी तटीय उड़ीसा, मणिपुर, मिजोरम और त्रिपुरा के कुछ भागों में कमी की प्रवृति देखी गई है।

ABSTRACT. In this study an attempt has been made to develop climatology of thunderstorm, hail and squall over the northeast and adjoining east India region based on data of 26 India Meteorological Department (IMD) observatories for the months of April and May during 1981-2008. The data of 8 Indian Air Force (IAF) observatories in these regions which are available for the period of 1991-2008 have also been considered. The interannual & intraseasonal variation, climate change aspects and diurnal variation of occurrence of thunderstorms have been analysed and discussed.

The frequency and time of occurrence of thunderstorm, hail and squall days over the region show large spatial variation. The orographically dominant regions as well as the coastal areas are more prone for such activity. There is increasing trend in number of thunderstorm days over some parts of south coastal Orissa and coastal West Bengal and decreasing trend over some parts of north coastal Orissa, Manipur, Mizoram and Tripura in recent years.

Key words – Thunderstorm, Hail, Squall, Climatology, Frequency, Trend.

1. Introduction

The climatology of thunderstorms depends on definition of thunderstorm and the observation tools. According to past climatology based on the data of 1951-1980 (Tyagi, 2007), the thunderstorms are more frequent (>40 days/year) over northeastern states, adjoining east India and pockets of extreme south peninsula. They are more dangerous over northeastern states and adjoining east India over eastern and northeastern India. They are also known as nor'wester as most of them move from northwest to southeast over this region. A knowledge of the thunderstorm climatology with respect to its frequency & time of occurrence, severity, diurnal variation and duration is essential particularly for nowcasting of thunderstorm and issue of warnings for different users.

2. Brief review of past studies

The first ever recorded study on thunderstorm in India was carried out by Dallas (1900) who took only 10 observatories data during 1897. The first series of published charts of monthly frequency of thunderstorm days in India and neighbouring countries based on data for a short period were published in the Climatological Atlas for Airmen (IMD, 1943). The average monthly and annual frequency of days of thunderstorm for all India and neighbouring observatories are then published as Climatological Tables of Observatories (IMD, 1953). Later on climatological tables have also been prepared by IMD based on data of 1931-60 (IMD, 1969) and 1951-80 (IMD, 1995).

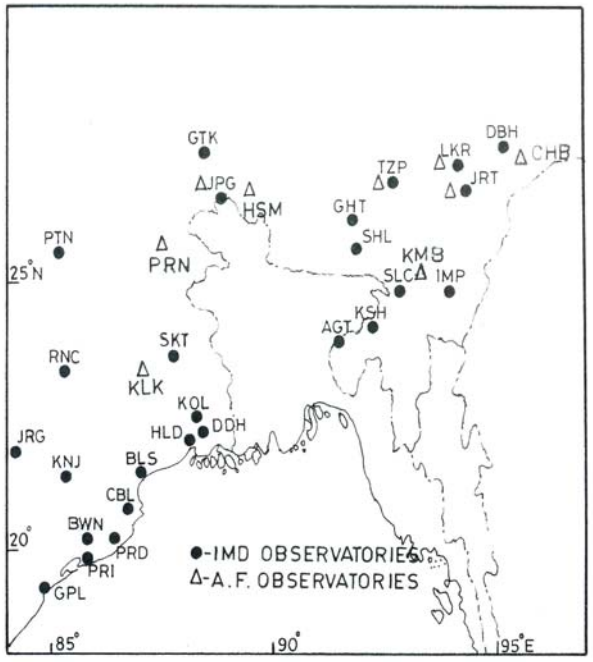
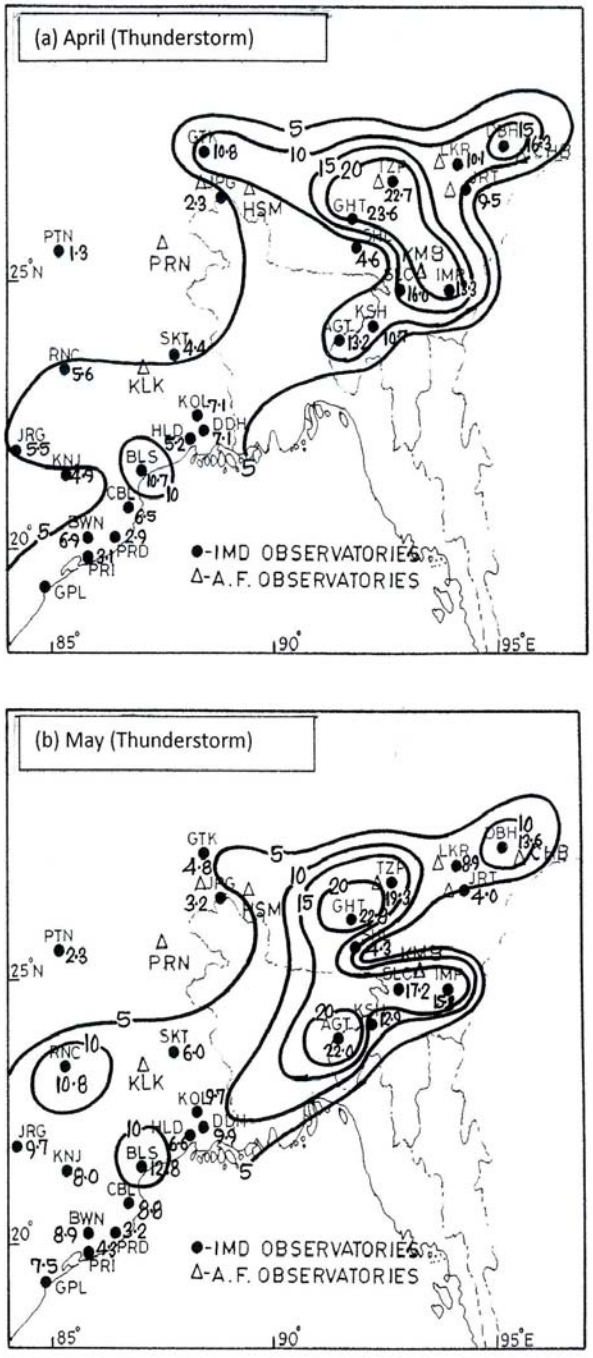


Fig. 1. Region of study including selected 26 IMD and 9 IAF stations are shown

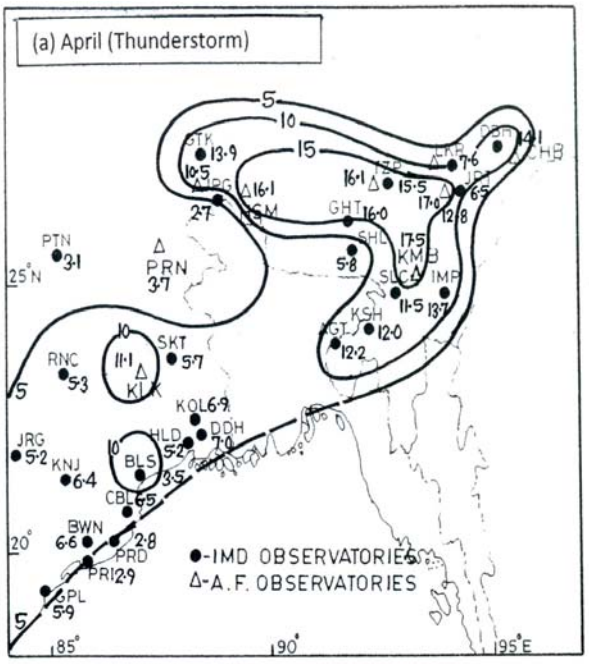


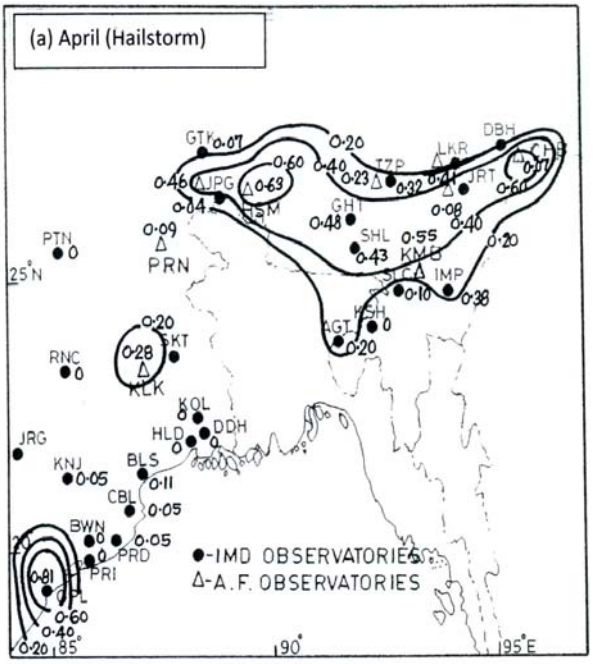
Figs. 2(a&b). Average number of thunderstorm events during (a) April and (b) May over the period of 1981-2008

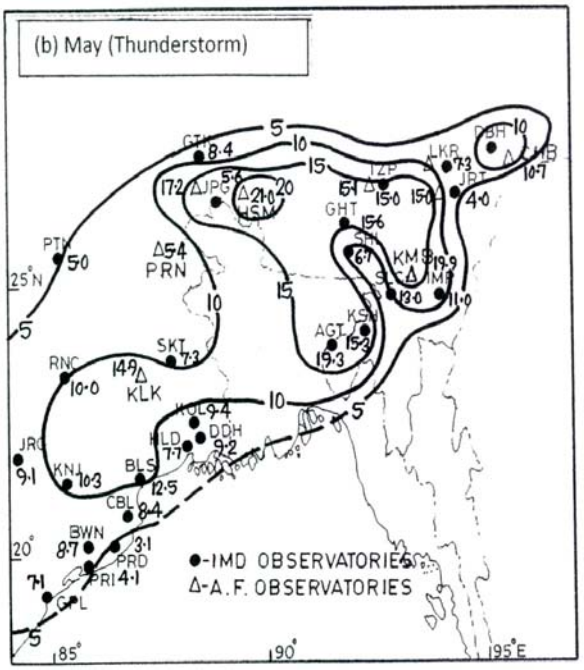
Rao and Raman (1961) based on data of 20 years extensively studied monthly and annual frequency of thunderstorm in India and found the highest thunderstorm activity occurs over Assam, West Bengal, Jharkhand and Orissa states of India. The annual average of these areas exceeds 75 days/year.

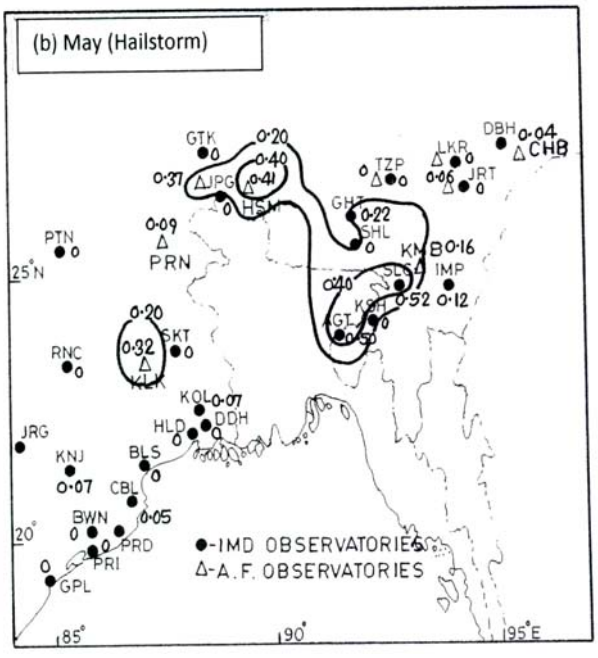
Tyagi (2007) has studied thunderstorm in detail by considering all possible data of IMD, IAF and neighbouring countries. He found that the highest annual frequency (100-120 days/year) is observed over Assam and Sub-Himalayan West Bengal and Jammu region of Jammu & Kashmir. The lowest frequency (≤5 days/year) is observed over Ladakh region. With the onset of summer conditions over most parts of the country during the month of April, there is significant increase in thunderstorm days over the east and northeast India. The significant areas of most frequent (more than 15 days) thunderstorms are observed over Assam, Meghalaya, adjoining Bangladesh, Sub-Himalayan West Bengal in the northeast and Kerala and adjoining Tamilnadu in the month of April.

Raman and Raghavan (1961) for the first time systematically studied the diurnal variation of thunderstorm occurrence over India. Alvi and Punjabi (1966) examined diurnal variation in squalls which usually accompany thunderstorms. They also worked out the annual frequency of thunderstorms as 75 days/year over northeast India, Bangladesh, West Bengal and adjoining Orissa. However, the northeast Assam is the most thundery area in India with an average exceeding 100 days/years.









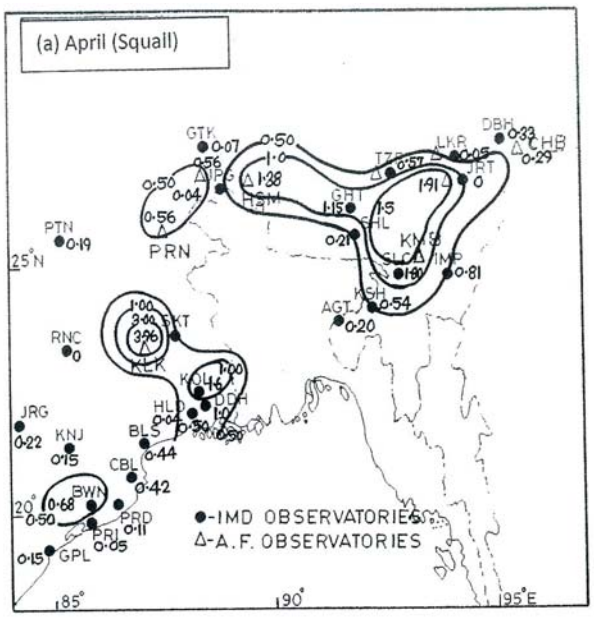
Figs. 3(a&b). Average number of thunderstorm days during (a) April & (b) May over the period of 1981-2008

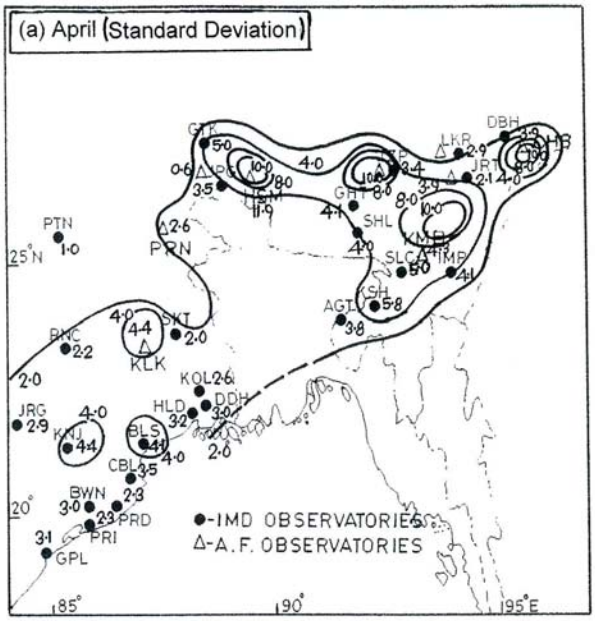
Figs. 4(a&b). Average number of hailstorm days during (a) April & (b) May over the period of 1981-2008

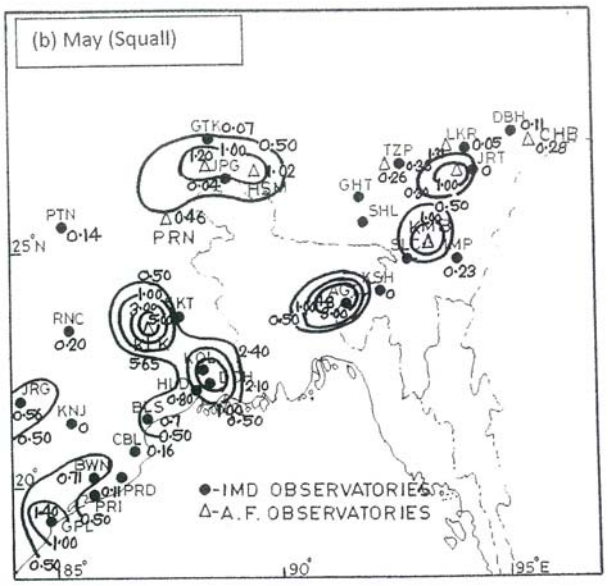
Mukherjee and Sen (1983) studied the diurnal variation of thunderstorm for some selected observatories *viz*., observatories at plain areas, hill observatories, coastal observatories and island observatories etc to understand the influence of different physical features.

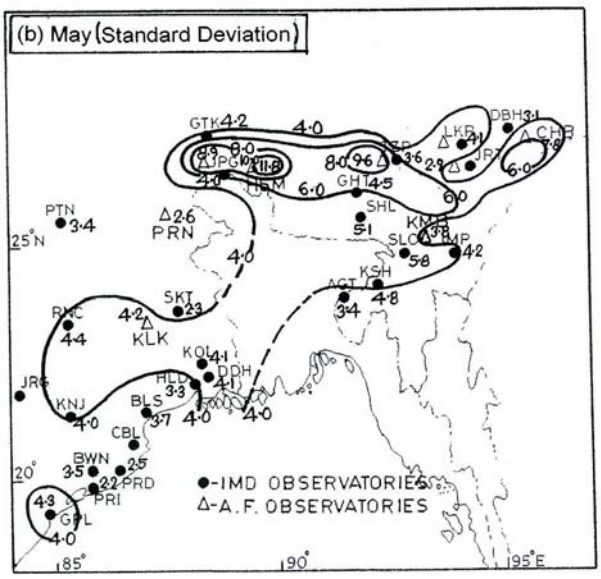
3. Data and Methodology

The area which is more vulnerable to thunderstorm in east and northeast India *i.e*., Lat. 17.0° N to 30.0° N and Long. 84.0° to 97.0° E (Fig. 1) has been selected for study.









Figs. 5(a&b). Average number of squally days during (a) April & (b) May over the period of 1981-2008

Figs. 6(a&b). Standard Deviation (SD) of number of thunderstorm days during (a) April and (b) May over the period of 1981-2008

Twenty six IMD and 8 IAF observatories data on thunderstorms during April and May have been considered for the study over the period of 1981-2008 and 1991-2008 respectively. The selected 26 of IMD and 8 of IAF observatories are also shown in (Fig. 1). It happens to be the regions under detailed study of the Severe Thunderstorm Observation and Regional Modeling (STORM) project under taken by Ministry of Earth Sciences. The physiography of the region is bound by the Bay of Bengal to the south and eastern Himalayas to the north. It has varied physiography with coastal and Gangetic plains, upland over north interior Orissa and Jharkhand and hilly region in northeastern states. The major hill ranges of the region include eastern Himalayas, Garo-Khasi-Jaintia hills and north-south oriented northeast hill range, Myanmar hills from Arunachal Pradesh to Myanmar across Nagaland and Mizoram (Fig. 2).

Thunderstorms accounted in the study includes all these occasions when at least thunder heard is reported. The occurrence of squall is reported as per the criteria of IMD forecasting manual. Average events of thunderstorms, hails and squalls are found out and analysed for all the observatories. Here events mean the number of thunderstorms which occur once and more than once a day. Average thunderstorm, hail and squall days are also calculated and analysed for all the 26 IMD and 8 IAF observatories. In the present study hail and squall are included in the thunderstorms. The Standard Deviation (SD), Coefficient of Variance (CV) and linear trend (LT) also have been calculated and discussed.

4.1. *Frequency of thunderstorm events*

During the month of April, the monthly average of the thunderstorm events is more than 20 over Guwahati, Shillong, Imphal and Tezpur stations. It varies from 10-20 over remaining stations of northeastern states, pockets of north Orissa and Gangtok (Fig. 3). In May, station with more than 20 thunderstorm events extend a little to the south of its location during April as the station Agartala is included. The frequencies vary between 10-20 over remaining parts of northeastern states except North Lakhimpur. It is also relatively higher over pockets of north Orissa and over Ranchi. It is less than 10 over the remaining stations.

4.2. *Average number of thunderstorm days*

The spatial distribution of average number of thunderstorm days during April and May are presented in Fig. 3. The spatial distribution of average hailstorm is similar to the distribution of thunderstorm events as shown in Fig. 4. Compared to thunderstorm days, the number of hail days is significantly less. However, hail days are more along the foothills extending from Sub-Himalayan West Bengal to Arunachal Pradesh across Assam. Maximum number of squall days is recorded at Guwahati and Kolkata. They are more than 0.5 over most parts of northeastern states, coastal West Bengal and over Bhubaneswar in south coastal Orissa (Fig. 5).

Based on the data presented in Figs. 3, 4, 5 and 6, the following information stands out;

(*i*) Thunderstorm along Sub-Himalayan West Bengal & Sikkim to Arunachal Pradesh across Assam.

(*ii*) Thunderstorm along Sub-Himalayan West Bengal to Tripura across Assam, Meghalaya and Bangladesh.

(*iii*) Thunderstorm over north coastal Orissa and adjoining West Bengal (Balasore to Kolaikunda).

(*iv*) Thunderstorm over south coastal Orissa (near Gopalpur).

(*v*) Isolated thunderstorm over interior region of Orissa, Jharkhand, Bihar and West Bengal.

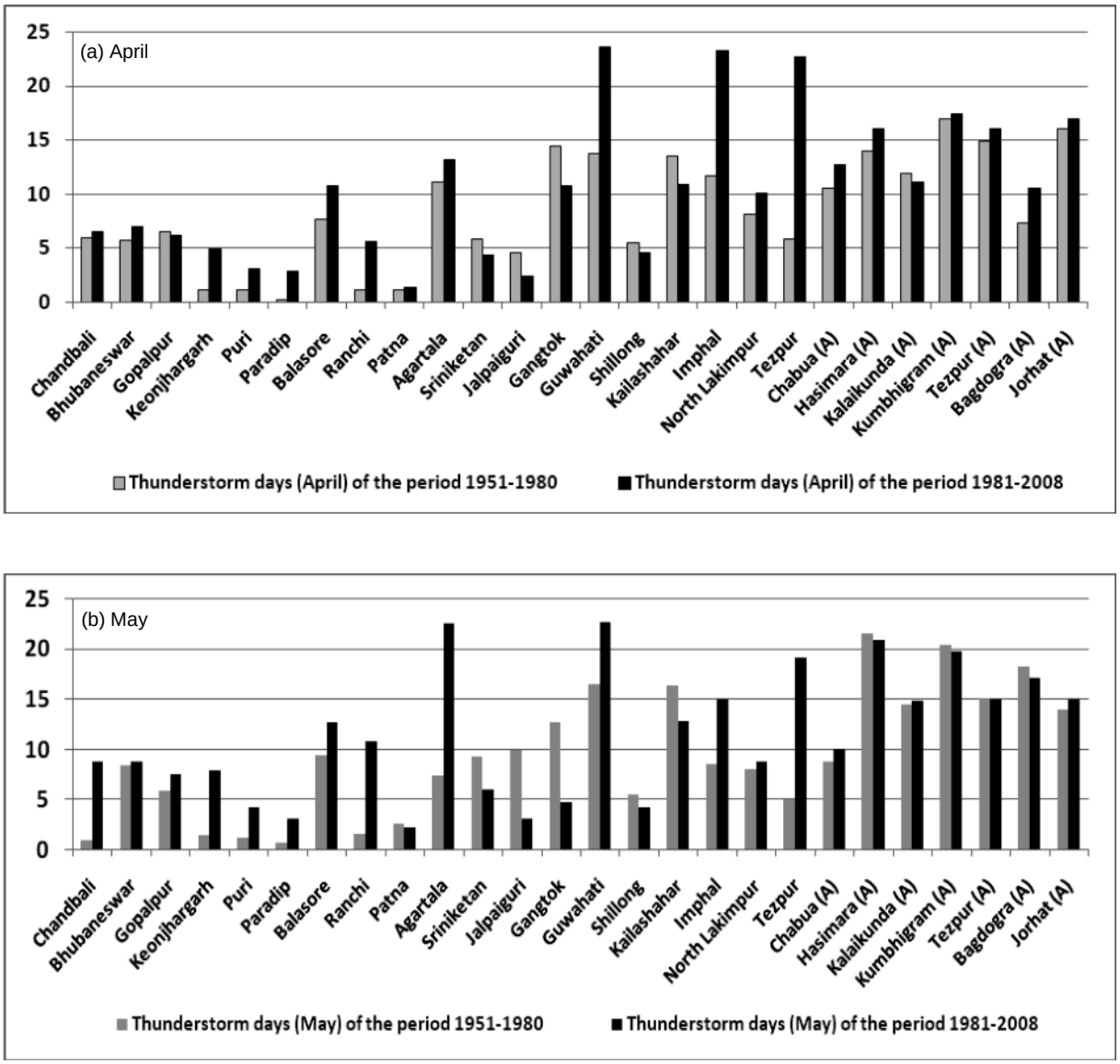
The thunderstorms that occur in West Bengal and the adjoining areas have been classified as A, B, C, and D type (Srinivasan *et al*., 1973) depending upon place and time of occurrence and direction of movement. Type-A thunderstorms develop over Jharkhand and the adjoining areas, mainly in the afternoon, and subsequently move in a southeasterly direction, Type-B thunderstorms originate in the submontane districts of north Bengal and move southwards. They generally originate during night and early morning, Type-C thunderstorms originate in the hills of Nagaland, Manipur and Mizoram and travel westwards. They are very rare. Type D thunderstorm is very similar to type B, but the place of origin is near the Khasi hills and not the Himalayas. The direction of movement is also from north to south.

4.3. *Diurnal variation*

It is seen that there is variation in the preferred time of occurrence of thunderstorms with respect to region and month. Thunderstorm sets in early in Jharkhand and Bihar during May compared to April as most of them occur during late evening/night in April and during afternoon/early evening during May. It occurs in the afternoon/early evening for most parts of Gangetic West Bengal and Orissa in both the months. Maximum occurrence takes place during early hours/early morning for southern Assam during both the months. It is maximum during late evening/night over rest Assam, Arunachal Pradesh and Nagaland in both the months. Over Manipur, Mizoram & Tripura they occur during early hours/early morning in April and during afternoon/early evening in May. The above results endorse the earlier findings (Srinivasan *et al*., 1973), but with more detailed regional characteristics and some new findings with respect to stations like Puri & Keonjhargarh in Orissa and Barakpore in Gangetic West Bengal. The favourable time of occurrence of thunderstorms is night over Puri, afternoon over Keonjhargarh and evening over Barakpore.

4.4. *Interannual variation of thunderstorm, hail and squall days*

The standard deviation (SD) for occurrence of thunderstorms is higher over Meghalaya, south Assam and adjoining Tripura, Mizoram, Manipur and Hasimara in Sub-Himalayan West Bengal during both April and May. Comparing the SD in April and May, SD is higher in May with higher mean frequency (Fig. 6).



Figs. 7(a&b). Average number of thunderstorm days during the month of (a) April and (b) May over the period of 1951-1980 and 1981-2008

Increasing trend in frequency of thunderstorm days is observed over most of the study area except some parts of Orissa and northeastern states during April and May. It is found that there is significant increasing trend at 95% level of confidence in thunderstorm days over the stations Haldia, Jharsuguda, Gopalpur, Gangtok and Sriniketan (5 stations) and decreasing trend over Kailashahar, Balasore, Puri, Imphal and Paradip (5 stations) for the month of April. Similarly, for the month of May, the rising trend is significant for Gopalpur, Haldia, Alipore, Paradip and Jharsuguda (5 stations) and decreasing trend is significant for Kailashahar, Balasore, Imphal, Guwahati and Tezpur (5 stations). Hence, there is decreasing trend in both the months over Kailashahar, Balasore and Imphal (3 stations) and increasing trend over Gopalpur and Haldia (2 stations).

4.5. *Comparison with climatology based on 1951-1980*

Data for the period 1981-2008 from total 28 observatories under consideration, including 19 IMD and

9 IAF observatories for which climatological data are available, have been compared with the climatology based on the period of 1951-1980. There has been significant rise in thunderstorm days over Guwahati, Tezpur, Imphal, Keonjhargarh, Puri, Paradip & Ranchi (7 stations) and fall over Gangtok and Jalpaiguri (2 stations) in the month of April [Fig. 7(a)] in recent years. During the month of May, significant rise in event is observed at Chandbali, Keonjhargarh, Puri, Paradip, Balasore, Ranchi, Agartala, Guwahati, Tezpur and Imphal (10 stations) and fall in event is noticed over Jalpaiguri, Gangtok and Kailashahar (3 stations) [Fig. 7(b)]. Considering hailstorm days, significant rise is noticed at Gopalpur and fall over most parts of northeastern states in the month of April and significant fall at Agartala for the month of May in recent years. The number of squall days has also significantly fallen over northeastern states except Agartala in the month of April and May. It has increased at Agartala during the month of May. Air Force data are not compared for hail and squall, due to non availability of these data.

Comparing station wise frequency of thunderstorms during the period 1951-1980 and 1981-2008 there is significant rise in the month of April at Tezpur from 5.9 to 22.6, Imphal 11.7 to 23.3, Guwahati 13.8 to 23.6 and Ranchi 1.2 to 5.6. There is significant rise during May over Tezpur from 5.0 to 19.2, Imphal 8.6 to 15.0, Agartala 7.5 to 22.6, Ranchi 1.7 to 10.8 and Chandbali 1.0 to 8.8. There is significant fall in average thunderstorms during May over Sriniketan from 9.3 to 6.0, Jalpaiguri 10.0 to 3.2, Gangtok 12.7 to 4.8 and Kailashahar 16.4 to 12.8. The causes for such significant changes (increase or decrease) have not been explored. It would be interesting to club the stations with significant changes for finding physical causes for the changes, if any. For this purpose statistical tests have to be employed.

5. Limitations and future scope

Existing synoptic network of observatories have limitations in recording all the occurrences of thunderstorms at the observatory and adjoining areas. As thunderstorm is primarily shortly lived meso-scale weather phenomena, it becomes difficult to keep records of observations with limited watch hours. As there are just a few full time observatories in most of the sub-divisions, the study is not able to bring out spatial distribution of thunderstorm activity within the area with desired resolution. The limitation, due to lack of surface observations can be taken care of with the advanced observational systems like weather radar and compritive gradur data. The study is also limited as it does not bring out the time of commencement; duration and time of dispersal with more precision.

6. Conclusions

(a) There are two different regions of occurrence of thunderstorms, including the region of maxima *viz*., (*i*) east-west oriented region along the foothills of the Himalayas and (*ii*) northwest to southeast oriented region from Sub-Himalayan West Bengal to Tripura. The number of thunderstorm days in May is higher than that in April by about 5 days.

(b) Considering the region and time of occurrence, there are six types of thunderstorm over the region. The results endorse the earlier findings of Srinivasan *et al*., (1973) it establishes two other categories of thunderstorms region *viz*., south coastal Orissa and north coastal Orissa and coastal Gangetic West Bengal.

(c) There is increasing trend in frequency of thunderstorms over some parts of south coastal Orissa and coastal West Bengal and decreasing trend over some parts of north coastal Orissa, Manipur, Mizoram and Tripura in recent years.

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