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AN OVERVIEW OF THUNDERSTORMS OVER BANGLADESH

M. MOZAMMEL HOQUE[1*], S. JAMAL AHMED[1], M. A. K. MALLIK[2], SM QUAMRUL HASSAN[2]

[1]Department of Physics, Dhaka University of Engineering and Technology (DUET), Bangladesh
[2]Bangladesh Meteorological Department, Agargaon, Dhaka, Bangladesh

**Corresponding author e-mail: mozammelphysics@gmail.com*
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ABSTRACT

An attempt has been made to find out the monthly, seasonal and annual variability, and trend of thunderstorms (TSs) over Bangladesh, specialty the pre-monsoon TSs which are locally known as Nor'westers or Kal-baishakhis. TSs data for the period of 1981-2020, collected from Bangladesh Meteorological Department (BMD), have been analyzed and found that during this period average annual TS days were 66 having maximum in May and minimum in December. Seasonal distribution of TSs shows that highest and lowest number of TSs occurred in the monsoon season and winter season respectively but the pre-monsoon TSs are severe in nature. From the seasonal time series of TSs, it is seen that all the three seasons have increasing trend and the winter season shows decreasing trend. Station-wise distribution of annual average TS days reveals that Sylhet and Srimangal experience the highest number of TS days (136.28 and 116.92 days respectively), while Teknaf experiences the lowest number of TS days (26.15 days) during the study period (1981-2020). Spatial distribution of average annual and seasonal TS days shows that, the North-eastern part of the country is the most TS prone area, followed by northern, mid-western and north-western parts of the country. South-eastern part of the country experienced comparatively lower number of annual average TSs days. Most of the Nor'westers directed from north-west and occurred between 1400- 1600 U.T.C. and least number of Nor'westers occurred between 0400-0600 U.T.C. As the number of observatories of Bangladesh Meteorological Department (BMD) is less considering its area, there is possibilities of unnoticed thunderstorms over Bangladesh.

Keywords: *Thunderstorms (TSs), Nor'westers, Pre-monsoon, Frequency of TSs*

1. INTRODUCTION

Thunderstorms (TSs) are one of the most common mesoscale phenomena in Bangladesh which are accompanied by lightning, thunder, hailstorms and heavy rains causing a considerable loss of properties and lives. The pre-monsoon TSs, generally move from the North West direction (NW'ly) during March to May, are popularly known as Nor'westers or Kalbaishakhi in Bangladesh and West Bengal of India. Several studies have been conducted to understand the formation, propagation and trend of TSs, and the frequency and spatial distribution of Nor'westers [1-9]. It is generally observed that, due to strong heating on warm sunny days, genesis of most of the Nor'westers take place over the Chota Nagpur Plateau area of India and then travel southeastwards and get intensified after meeting with low-level moist air from the Bay of Bengal [6-7]. Outburst conditions of these systems occur when westerly tough superimposes with the low-level moist flow. It is found that, pre-monsoon season (March to May) is the peak period for occurring severe TSs over Bangladesh and the mean seasonal frequency of TSs varies from 40 to 170 having the highest frequency at Sylhet and lowest frequency at Teknaf [6-8]. It is also found that apart from local TSs, some of them move towards Bangladesh from Chota Nagpur, West Bengal and northeastern states of India [7].

Wahiduzzaman et al. [8] studied the seasonal variation of TS days over Bangladesh during 1975–2016 and found the average number of TSs days are 7.96 and 7.95 respectively during monsoon and pre–monsoon seasons, having 65 TS days annually. They also observed that north-eastern zone of the country (Sylhet, Mymensingh) is more TSs prone than the southwestern zone of the country. Regardless of types, all the thunderstorms form by a cycle that has three stages (cumulus stage, mature stage and dissipating stage) which may last between 30 minutes to an hour. As the lifetime of thunderstorms is very short, prediction of these phenomenon is very challenging. But by monitoring the thermodynamic indices related to the formation of TSs in a sequential way and comparing with their threshold values, it is possible to forecast TSs with sufficient lead time [8-11]. In this study the monthly, seasonal and annual variability and trend of TSs have been analyzed.

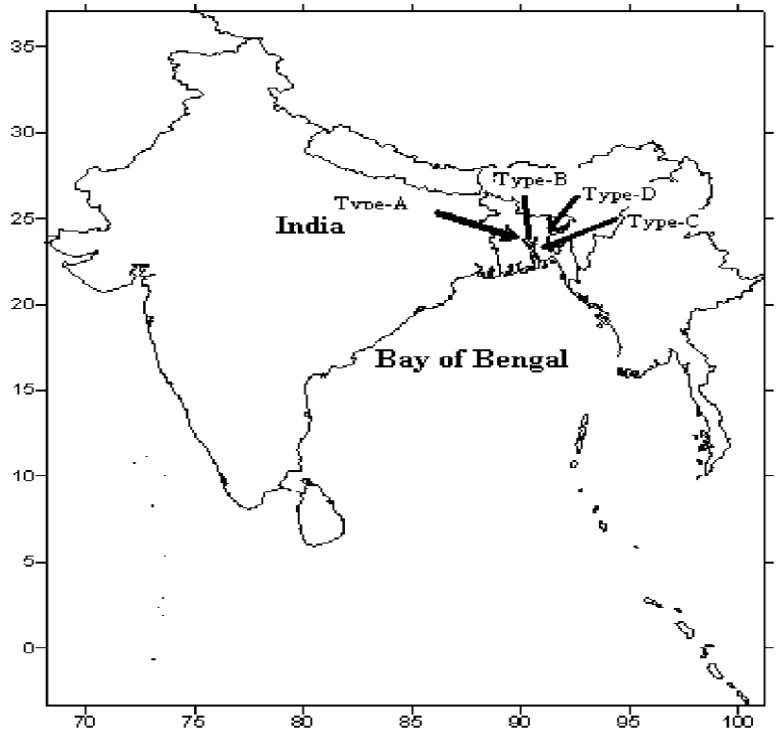

Fig.1: Movement of different types of nor'westers [7]

Although Bangladesh is a small country, it has considerable topographic diversity. Having the Bay of Bengal (BoB) to the south and the Himalayas to the north, Bangladesh possesses a uniquegeographic location and peculiar orographic structure that aid atmospheric instability and strong moisture convergence. All of these are supportive to develop TSs over Bangladesh because for the formation of TSs three factors i.e. moisture, instability and lifting are needed. During the pre-monsoon season a strong westerly jet appears over the country at the upper tropospheric level which generates associated atmospheric instabilities. As the atmosphere is heated unevenly, an imbalance can occur which is balanced by thunderstorm. In fact, the TS activity over Bangladesh is supposed to have

three distinct causes: the southerly/southwesterly surface wind which contains huge amount of moisture, the instabilities produced in the hilly tracts of Bihar and Orissa, adjacent to the western part, and easterly surface wind in the northern and north-eastern parts of the country. On the basis of origin, nor'westers occurring in this region have been classified by India Meteorological Department (IMD) broadly into four types, designated as A, B, C & D. Type-A nor'westers are the most predominant and account for 45% of TSs during April and May. This type of storms usually starts from West Bengal and Chota Nagpur region of India in the afternoon and proceed in the southeasterly direction with a speed of 48-64 km/hr. Fig.1 shows the movement of different types of transboundary nor'westers towards Bangladesh [7].

2. METHODOLOGY

Daily TS's data for the period of 1981-2020 have been collected from 35 meteorological stations (Fig.2) of Bangladesh Meteorological Department (BMD). The number of TSs recorded in one day is assumed as daily frequency of TS. Then monthly, seasonal and annual time series have also been calculated from this daily TS data for every individual station and these data have been used for estimating average monthly, seasonal and annual TS days. Spatial distribution of average TS days has been depicted from station-wise time series data. Seasonal and annual trend of TSs are analyzed. Wind speed, wind direction and occurred time of Nor'westers (Pre-monsoon TSs) are also analyzed.

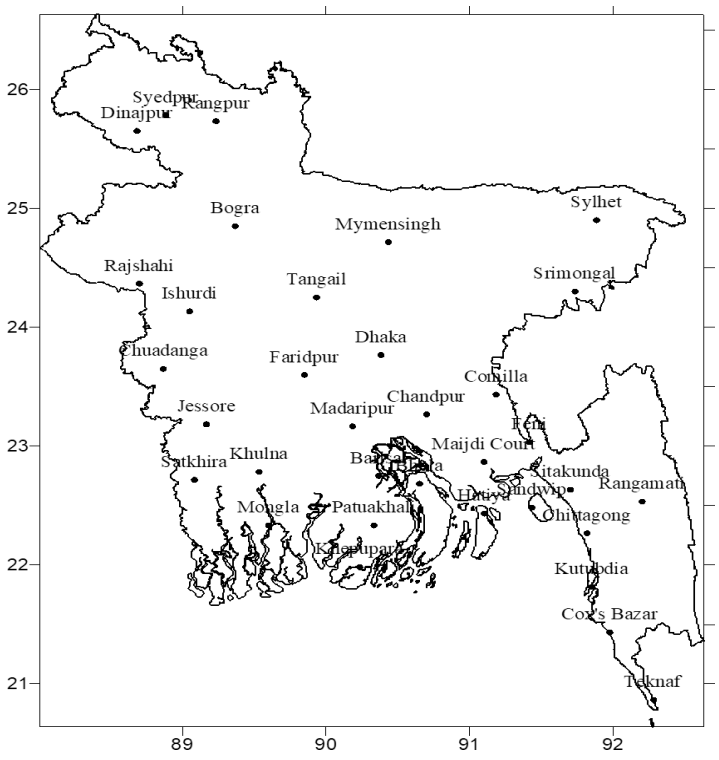

Fig. 2: Location of 35 meteorological stations in Bangladesh [source: BMD].

3. RESULTS AND DISCUSSION

Computational and spatial distribution of monthly and seasonal distribution of TSs and its recent trends in Bangladesh are presented in the following sections.

3.1 Seasonal variability of TS days in Bangladesh

Seasonal variability of TS days in Bangladesh during 1981-2020 is depicted in Fig.3. It is observed that the higher number of monthly TS days belongs to May followed by June, September, August and April. Though several number of thunderstorms occur in monsoon and post-monsoon seasons, the pre-monsoon TSs are more severe in terms of intensity and casualties over Bangladesh and adjoining neighborhood countries.

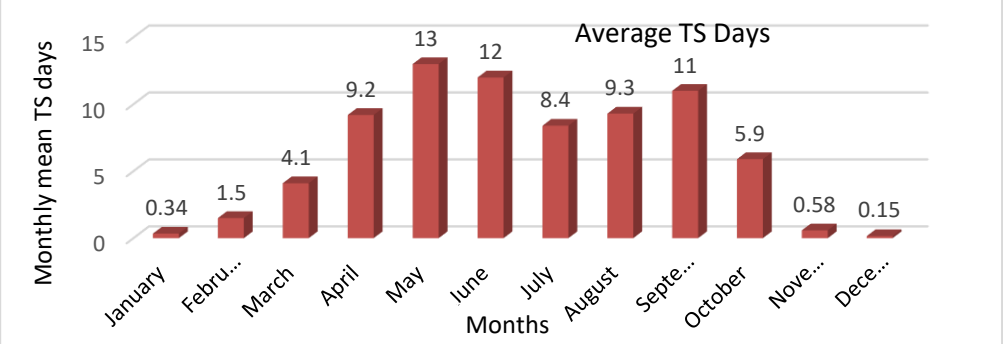

Fig.3: Monthly distribution of average TS days

In pre-monsoon, deep convective clouds form in Bangladesh and highly localized TSs occur and sometimes trans-boundary TSs travel towards Bangladesh from the neighborhood countries from north-westerly or north-easterly direction. Both TSs are severe in nature especially in pre-monsoon when the intensity got like tornadic intensity than that of other seasons in Bangladesh. The lower values of average TS days are observed in the months of November-February with the lowest average value in December (0.15 days).

Table-1 represents the country average seasonal and annual distribution of average TS days over Bangladesh.

Table-1: Seasonal and Annual average TS days in Bangladesh

Season	Average TS days
Pre-monsoon (March-May)	24.54
Monsoon (June- September)	33.90
Post-monsoon (October-November)	5.76
Winter (December-February)	1.85
Annual	66.05

The above table shows that, the monsoon season is facing highest average TS days (33.90 days), then pre-monsoon and post-monsoon having 24.54 days and 5.74 days respectively. The lowest value of average TS days belongs in winter season (1.85 days) and the annual average TS days over Bangladesh is 66.09.

3.2 Spatial distribution of TSs

Based on TSs data for 1981-2020, spatial distribution of TSs over Bangladesh is shown in Fig. 4, which shows that the north-eastern tip i.e. Sylhet and adjoining area of Bangladesh experiences the highest no. of TSs days in pre-monsoon, monsoon and winter season than that of other parts of the country, except Post-monsoon season. On the other hand, the south-eastern part of the country faces the lower no. of TSs days. All other parts of the country record almost moderate TS activity in this season.

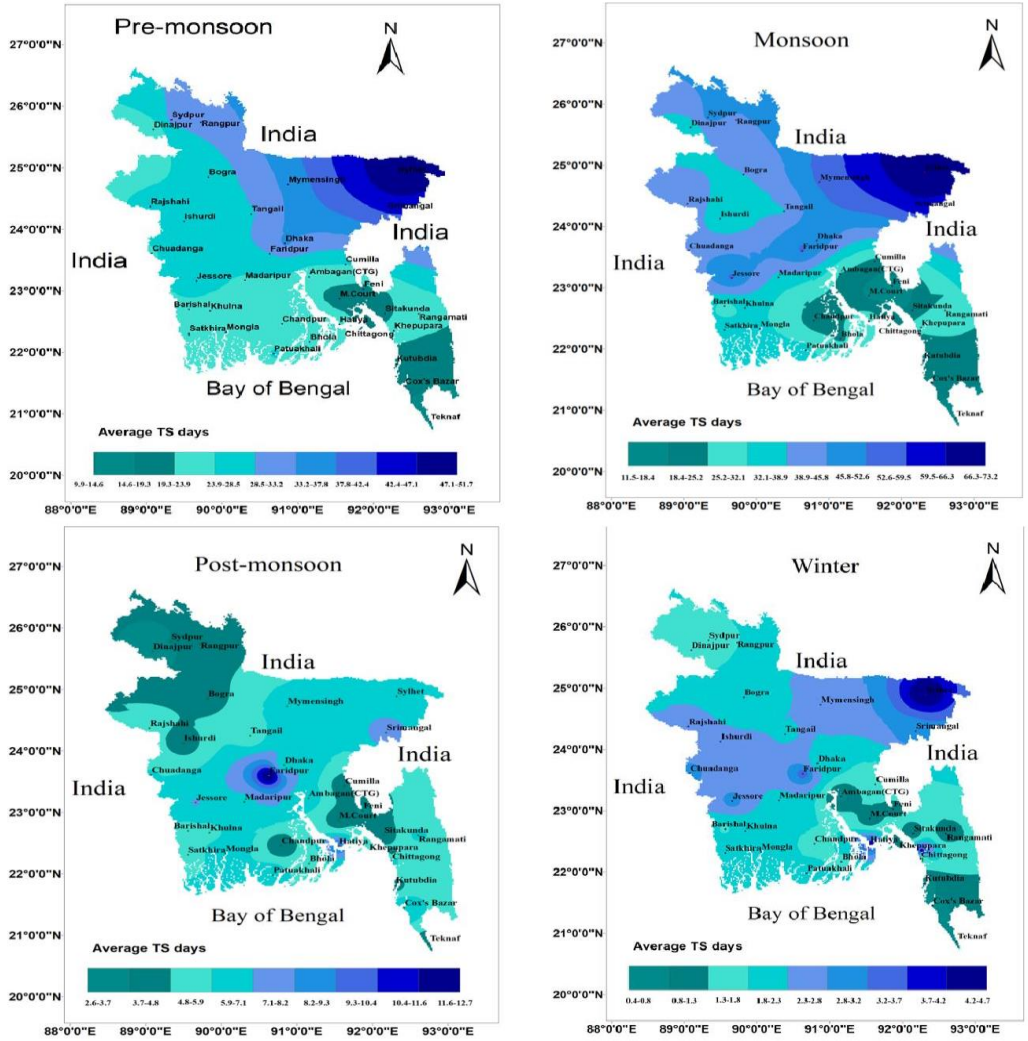

Fig. 4: Spatial distribution of seasonal average TS days in Bangladesh.

Fig. 4 shows that, in monsoon season the highest average TSs days, ranging from 66.3- 73 are occurred over the north- eastern part of Bangladesh. Western and north-western part of Bangladesh also experience high TS activity, ranging from 38.9-52.6 days per year. During monsoon the lowest activities of TSs are observed in the eastern and south-eastern part of Bangladesh having 11.5-25.2 TSs days per year. With the withdrawn of monsoon period, TSs activity and its intensity gradually decreases in the post-monsoon season. During post-monsoon the central part of the country faces the highest TSs activity ranging from 11.6-12.7 days per year, followed by mid-western and North-eastern parts. Whereas the lowest activity is recorded in the North- western, central eastern and mid-southern parts of Bangladesh. Due to the stable thermodynamic atmospheric conditions of the country, winter season experiences the lowest average TSs days per year. The highest value is found on the North-eastern part ranges from 4.2 to 4.7 and upper South-eastern part with the average value of 3.7-4.2. The lowest value is observed in the South-eastern and central eastern part of Bangladesh which ranges from 0.4 to 1.3 days per year.

3.3 Annual distribution of TSs

Annually, the highest average value of TS days was found in the North-eastern part to mid-western part of the country and it ranges from 125 to 72. The south-eastern and mid-eastern experienced the lowest average value of 49 to 53 days per year. North-western and south-western part of the country experienced on average 68-74 TSs days per year as it is shown in the Fig. 5.

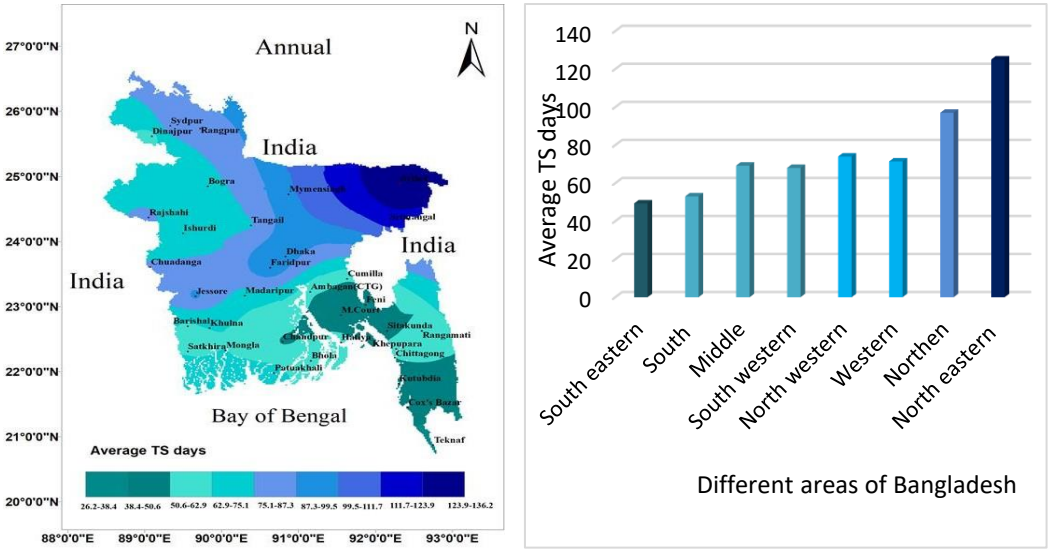

Fig. 5: Annual distribution of Average TS days throughout different parts of Bangladesh.

3.4 Seasonal and annual TS trends

The time series of annual average TSs days shows that it increases gradually from 1981to 1988, after that it's increased sharply and reached at the peak value in 1993 shown in Fig.6. Afterwards the TSs days are decreased rapidly up to 1995 and in 1997 it increases and almost touched the peak again. But during 2000-2009, the variability of TSs days is not too marked.

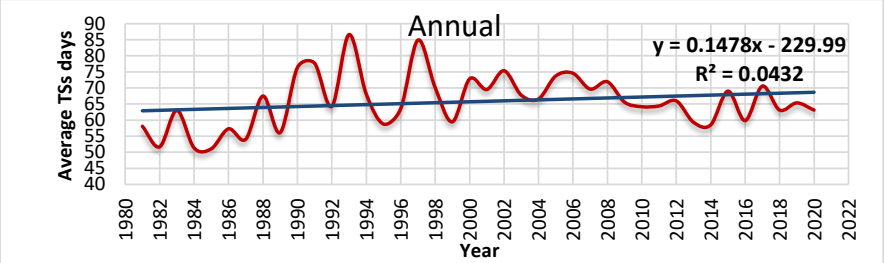

Fig.6: Annual trend of TSs over Bangladesh

Trend analysis shows increasing trend of annual average TS days (0.15 per year). Seasonal trend analysis exhibits increasing TSs trend for all seasons except for winter, shown in Fig. 7 (a)-7(d). Monsoon experiences the highest TSs trend (0.10) value, then pre- monsoon and post-monsoon seasons which belong trend value of 0.08 and 0.04 respectively and the winter season belongs a negative trend as shown in table-2.

Table -2: Seasonal and annual TS Trends during1981-2020

Season/Annual	Trend
Winter	-0.04
Pre-monsoon	0.08
Monsoon	0.10
Post-monsoon	0.04
Annual	0.15

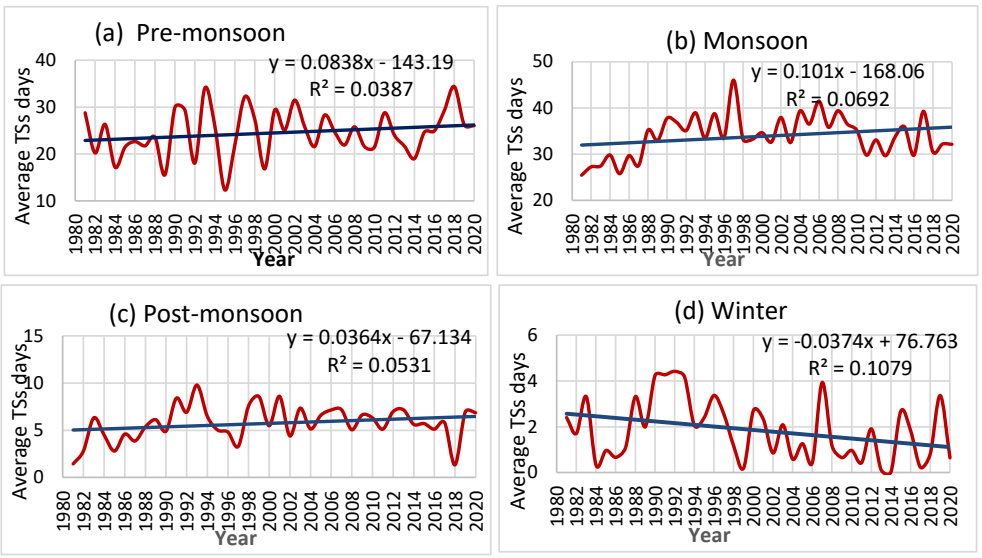

Fig. 7 (a) – (d): Seasonal trend of TSs over Bangladesh

The time series of average TSs days for pre-monsoon season shows that, there is an increasing and decreasing tendency during the study period (1981to 2020) and the variation in average no. of TS days is notable during 1988-2000. Over all there was an increasing tendency which reached at the peak value (34.3 days) in 2018 shown in Fig. 7(a). Fig. 7 (b) and 7 (c) shows time series of average TS days during monsoon and post-monsoon season which indicate positive trends 0.10 and 0.036 respectively. Fig. 7 (d) indicates a negative trend for average TS days during winter season.

Meteorological station-wise distribution of average TS days is presented in Fig.8, which shows that, Sylhet and Srimangal have experienced highest annual average TS days of 136.28 and 116.92 respectively. Teknaf has experienced lowest average TS days (26.15 days) annually and almost 24 stations belong the average value (between 50-100) TS days.

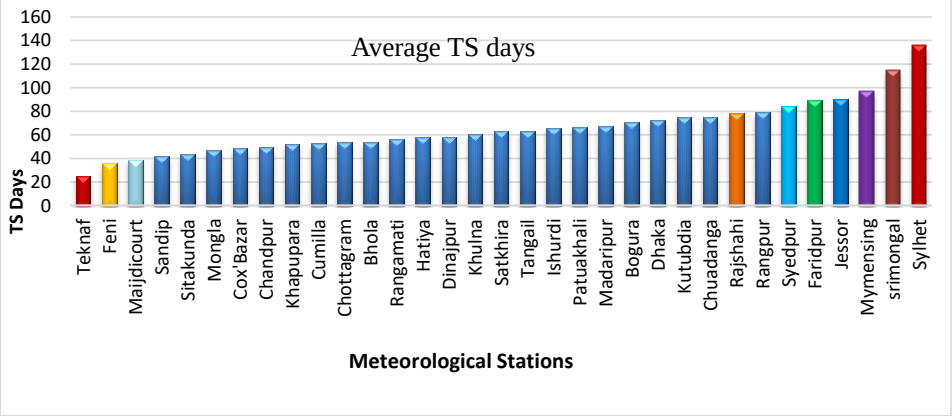

Fig. 8: Station-wise Annual mean TS days

3.5 Frequency of Nor'westers

Nor'westers or Kalbaishakhies are meso-scale severe thunderstorms that occur over Bangladesh during the pre-monsoon season (March-May). In this study only Light (wind speed 61km/h-90km/h), Moderate (wind speed 91km/h-120km/h) and Severe Nor'westers (wind speed 121km/h-149 km/h) over Bangladesh are considered.

Fig.9(a) shows the variation of monthly pre-monsoon TS (Nor'westers) days and events over Bangladesh, which indicates that the average TS days and events increase significantly from March to May. Average monthly pre-monsoon TS days were 3,10 and 10 in the month of March, April and May respectively and the average pre-monsoon seasonal thunderstorm day is 23, whereas, at the same period average monthly pre-monsoon thunderstorm events are 4, 14 and 16 in the month of March, April and May respectively and the average pre-monsoon seasonal thunderstorm event is 34. Fig. 9(b) shows the frequency of the severe thunderstorms (wind speed 121-149 km/h) recorded by different meteorological stations of Bangladesh. It is found that most of the severe Nor'westers took place in Chottagram, Sylhet, Dhaka and Rangpur region in the month of May whereas most of the moderate and light Nor'westers took place in the months of April and May, shown in Fig. 9 (a) and 9 (b).

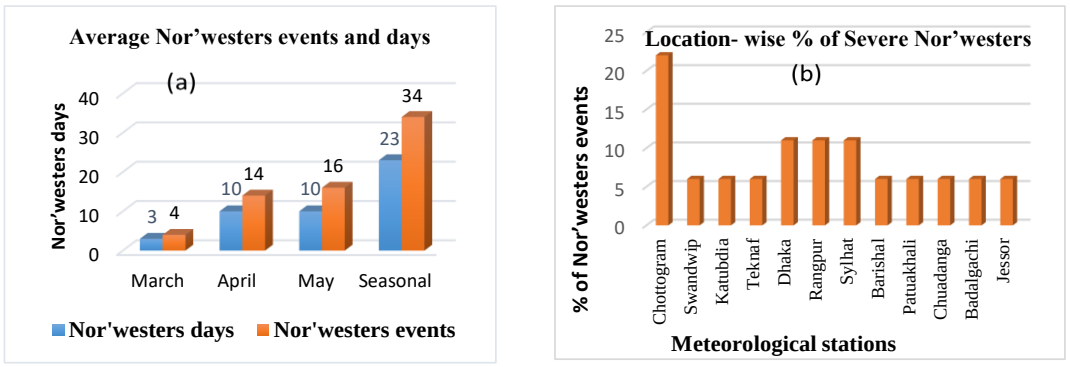

Fig. 9 (a) Month-wise Nor'westers events and days. And **(b)** frequency of severe Nor'westers

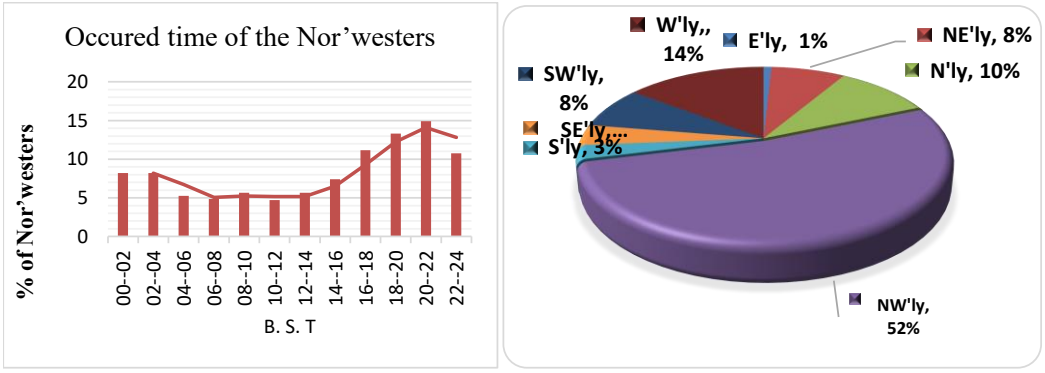

Fig. 10: (a) Frequency of Nor'westers with respect to occurred time (B.S.T.) and **(b)** Percentage of Nor'westers with respect of wind direction.

Fig. 10 (a) shows the frequency of Nor'westers with respect to occurred time (Bangladesh Standard Time-B.S.T.). It is found that most of the Nor'westers occurred in the evening to early night (16.00 B.S.T. to 22.00 B.S.T.) having maximum 15% of the events at 20.00 B.S.T. to 22.00 B.S.T. and least events occurred at 10.00 B.S.T. to 12.00 B.S.T.

In case of wind direction, it is found that most of the Nor'westers took place from north-west direction and the least of the TSs occurred from easterly direction (shown in Fig 10 (b).

4. CONCLUSIONS

Statistical analysis of TSs occurred over Bangladesh during the period 1981-2020 has been narrated in this report. Finally, it may be concluded as follows-

- The time series plot shows that the year 1993 is highly affected by highest no of TS events till now and the monthly distribution plot reveals that, the month of May occupies highest no of TS days (12) per year and the month June and September ranked as second and third position. That means the pre- monsoon and monsoon are the dominant season for TSs.

- From the seasonal time series plot, it is clearly seen that all the three season approaching increasing trend but only winter is showing decreasing trend. Station-wise distribution of annual average TS days reveals that Sylhet and Srimangal experience highest annual mean TS days of 136.28 and 116.92 respectively, while Teknaf is experiencing the lowest mean value of 26.15 TS days annually during the study period (1981-2020).
- Spatial distribution of average annual and seasonal TS days shows that, the North-eastern (Sylhet region) part of the country is the most TS porn area, followed by northern (Mymensing), mid-western (Jessore, Rajshahi, Faridpur) and north-western (Syedpur, Rangpur) parts of the country.
- South-eastern part (Chottagram region) of the country experienced comparatively lower no. of annual average TSs days and the lowest no. of annual average TSs occurred in Teknaf (26.15 TS days).
- Most of the severe Nor'westers (pre-monsoon TSs) occurred in the month of May, whereas most of the moderate Nor'westers TSs occurred in the month of April.
- Most of the Nor'westers occurred between 20-22 B.S.T. and least no. of Nor'westers occurred between 10-12. About 56% of the Nor'westers are directed from north-west and very few (1%) TSs are easterly. As well as local TSs, there are a good number of transboundary TSs move towards Bangladesh from the neighboring states of India.
- As the number of observatories of Bangladesh Meteorological Department (BMD) is less considering its area, there is possibilities of unnoticed thunderstorms over Bangladesh. So the number of Meteorological observatories in Bangladesh need to be increased for better notification of thunderstorms.

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REFERENCES

[1] S. Dementyeva, M. Shatalina, A. Popykina, F. Sarafanov, M. Kulikov and E. Mareev, "Trends and Features of Thunderstorms and Lightning Activity in the Upper Volga Region" *Atmosphere,* vol.14, no. 4, p. 674, 2023.

[2] S. Bhattacharya and H. Chakraborty, "A comparative study of severe thunderstorm among statistical and ANN methodologies" *Sci Rep,* vol.13, p.12038, 2023.

[3] K. Arora, K. Ray, S. Ram, R. Mehajan, "The Role of Instability Indices in Forecasting Thunderstorm and Non-Thunderstorm Days across Six Cities in India", *Climate*, vol.11(1), 2023.

[4] N. Umakanth, G. C. Satyanarayana, N. Navenna, D. Srinivas, D. V. B. Rao, "Statistical and dynamical based thunderstorm prediction over southeast India" *J. Earth Syst. Sci.* vol.130, pp. 71-88, 2021.

[5] B. A. Choudhury, M. Konwar, A. Hazra, G. M. Mohan, P. Pithani, S. D. Ghude, M. C. Barth, "A diagnostic study of cloud physics and lightning flash rates in a severe pre-monsoon thunderstorm over North East India", *Quarterly Journal of the Royal Meteorological Society*. vol. 146, no. 729, pp. 1901-1922, 2020.

[6] T. Akram, F. Akter, M. A. K. Mallik, F. Tabassum S. M. Q. Hassan and M. Omar Faruk, "Recent climatology of Thunderstorm days over Bangladesh", *The Atmosphere,* vol. 9, no.1, pp.116-123, 2022.

[7] S. Karmakar, "Nor'westers over Bangladesh during the pre-monsoon season", *Ph. D. Thesis,* (Khulna University of Engineering & Technology, Bangladesh), 2005.

[8] M. Wahiduzzaman, A. R. M. T. Islam, S. Shahid, M. J. Uddin, S. M. Shimul and M. A. Sattar, "Trends and Variabilities of Thunderstorm Days overBangladesh on the ENSO and IOD Timescales", *Atmosphere,* vol. 11, no. 11, p. 1176, 2020

[9] M. S. H. Bhuiyan, M. A. K. Mallik, M. Rashaduzzaman, M. Omar Faruk, M. R. Kabir and M. Neogi, "Simulation of a thunderstorms over Rajshahi, Syedpur and Rangpur, Bangladesh using WRF-ARW model", *The Atmosphere,* vol. 9, no.1, pp.12-25, 2022.

[10] M. M. Hoque. M. S. U. Afsar, M. R. I. Faruque, S. J. Ahmed, A.T.M. K. Jamil, M.A.K. Mallik, S.M. Q. Hassan, "Sensitivity analysis of cumulus parameterization scheme and data sources to simulate thunderstorms over Bangladesh using WRF model" *Advances in space research, 2024.https://doi.org/10.1016/j.asr.2024.08.013*

[11] A. Vemuri, S. Buckingham, W. Munters, J. Helsen, and J. V. Beeck, "Sensitivity analysis of mesoscale simulations to physics parameterizations over the Belgian North Sea using Weather Research and Forecasting – Advanced Research WRF (WRF-ARW)" *EAWE*, vol. 7, no. 5, pp.1869–1888, 2022.