

Analysis of Decadal Variability of Thunderstorm's Intensity over Bangladesh for the Period from 1993 to 2022

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Abstract

The present study investigates the intensity and frequency patterns of thunderstorms over Bangladesh spanning the period from 1993 to 2022. The months of March, April, and May are recognized as the nor'wester period when thunderstorms manifest more frequently than in other periods throughout the year. The study involves the computation of thunderstorm (TS) frequencies at three-hour intervals to identify the most intensified occurrences among eight designated observation times at 00 UTC, 03 UTC, 06 UTC, 09 UTC, 12 UTC, 15 UTC, 18 UTC, and 21 UTC. The highest occurrence of thunderstorms is found at 18 UTC and the lowest occurrence is found at 03 UTC. Utilizing the Geographic Information System (GIS) software, the authors have endeavored to identify the geographical regions with the highest TS frequencies across the country, utilizing data from 35 observatories under the purview of the Bangladesh Meteorological Department. The results from all these analyses show that Srimangal and Sylhet are experienced more thunderstorms than the other parts of Bangladesh. The lowest frequency is found in Teknaf, Kutubdia. Furthermore, a decadal analysis has been conducted employing the Mann-Kendall test to ascertain potential trends of increase or decrease in thunderstorm frequency over time. Both increasing and decreasing trends are found in different UTC.

Keywords: Thunderstorm, Frequency, Intensity, GIS.

1. INTRODUCTION

Bangladesh is mainly a low-lying riverine country. The northeastern part of the country is situated at the foothills of Meghalaya. The northwestern part is bounded by the landmass of India. In the Southern part, the longest coastline of the Bay of Bengal. In the southeast, there lie mountain ranges of Myanmar which are north-south oriented. This country is the contribution of the accumulated sediment of the Padma, Meghna, Jamuna and their tributary [6]. The thunderstorm is one of the most devastating natural calamities in Bangladesh. March, April and May are considered as nor'wester period. Thunderstorms are short-lived weather phenomena that occur very frequently in Bangladesh, especially during the pre-monsoon season. It is associated with rain and lightning. Thunderclouds are known as cumulonimbus clouds form vertically by water vapors forced by powerful air currents. Bangladesh is densely populated and every year number of people are victims of thundering. Thunderstorm is a consequence of Collision between updrafts and downdrafts cumulonimbus clouds which produces thunder and lightning. Basically, updrafts and downdrafts of air mass create cumulonimbus clouds which is the ultimate result of convection. Most of the places on the earth's surface experience this dangerous convective weather events [1]. Thunderstorm is a severe hazardous weather phenomenon that causes a number of death and tremendous loss of agriculture, livestock and also in infrastructure during the pre-monsoon and monsoon period [2]. The Comprehensive Disaster Management Program under the Ministry of Disaster Management and Relief reported 180 deaths by TS only in 2016 [2]. The Government of Bangladesh declared TS as a natural disaster on 17 May 2016 by considering its significant impacts on human life and economy [2]. People in developing countries are the victim of the casualties of TS because of their lack of knowledge about the safety of TS. Their inadequate knowledge and superstition lead them to the way of death and huge loss of property [3]. Bangladesh has the highest lightning death among all South Asian Association for Regional Cooperation (SAARC) countries [3]. When the atmospheric condition is unstable and the variability of time distance, this situation is considered as atmospheric instability which is favorable for occurring of TS [4]. Lightning strikes the earth more than 100 times each second, totaling 8 million times every day. An estimated 50,000 thunderstorms occur each day, causing fires and injuries [5]. Worldwide, mortality from lightning is estimated at between 0.2 and 1.7 deaths/1,000,000 people, affecting mainly the young and people who work outdoors [5]. According to geographical location, Bangladesh is situated in a tropical monsoon region which is characterized by high humidity, temperature and extensive variation with rainfall [6].

2. DATA AND STUDY AREA

Fig.1 represents 35 observatories of the Bangladesh Meteorological Department (BMD). (Dhaka, Tangail, Mymensingh, Faridpur, Madaripur, Srimangal, Sylhet, Bogura, Dinajpur, Ishurdi, Rajshahi, Rangpur, Sayedpur, Chuadanga, Jessore, Khulna, Mongla, Satkhira, Barishal, Bhola, Khepupara, Patuakhali, Chandpur, Ambagan, Patanga, Cumilla, Cox's Bazar, Feni, Hatia, Kutubdia, Maijdi Court, Rangamati, Sandwip, Sitakunda, Teknaf). Thunderstorm (TS) frequency data were collected for every three hours from 35 observatories of BMD for the period of 1993 to 2022.

3. METHODOLOGY

In this paper, the authors intend to find out the vulnerability of thunderstorms based on temporal and spatial differences throughout the country. To identify the intensified areas, authors considered Thunderstorm and lightning data from 35 observatories of Bangladesh Meteorological Department (BMD) throughout 1993 to 2022. Every three hourly data were collected for the pre-monsoon period which corresponds to the months of March, April and May. Processing of the three-hour data was accomplished using the FORTRAN programming language. Additionally, MS Excel played a significant role in computing the station-wise frequency data, yearly and three-hourly. The computed data were further divided into two segments based on UTC. The first segment considered the cumulative frequency of the initial four daily observations at 03 UTC, 06 UTC, 09 UTC and 12 UTC. In contrast, the second segment accounted for the cumulative frequency of the later four observations at 15 UTC, 18 UTC, 21 UTC and 00 UTC. For enhanced insight, GIS software was employed to determine the zones and times with the highest and lowest intensification of thunderstorms. Moreover, the Mann-Kendall test was applied to identify the level of significance in the observed trends.

4. RESULTS AND DISCUSSION

The data collected at three-hour intervals were calculated for each specific three-hour segment and also for individual months within the pre-monsoon period. Using these calculated values, the authors intend to identify the most intensified month and time during the pre-monsoon period from 1993 to 2022. The result is illustrated in Fig.2, indicating that May is the most intensified month among the three months of the pre-monsoon period when the country received the highest number of TS. Furthermore, the authors computed the total frequency for each three-hour interval, visually presenting the results in a graph. 18 UTC is found as the most prominent time for thunderstorm occurrences, while 03 UTC displays relatively less prominence in terms of thunderstorm frequency among the eight daily observation times.

In this step, the authors considered TS frequency for the month of March across 35 observatories throughout the country. This analysis was conducted at every three-hour interval for the mentioned period which is graphically illustrated in Fig.3. Analyzing the data and graphical output, it can be explained that the Sylhet region along with Srimangal received the highest frequency of TS and the number of occurrences were very infrequent mainly in Teknaf and then Dinajpur, Kutubdia, Sandwip and Chattogram.

Similar analysis was also done for the month of April and visualized in the graph which is represented in Fig.4. It has been revealed from the analysis that the highest frequency was observed in Sylhet then Srimangal but TS occurred the lowest times in Teknaf during the mentioned period. Additionally, number of TS frequency was also very less in Kutubdia and Cox's Bazar.

Authors also tried to examine the scenario for the month of May. For better understanding total number of TS also calculated for the month of May. The total TS frequency of 35 observatories for the mentioned period also have graphically represented in Fig.5. Similarly, as observed in the other two months of the pre-monsoon period, it was

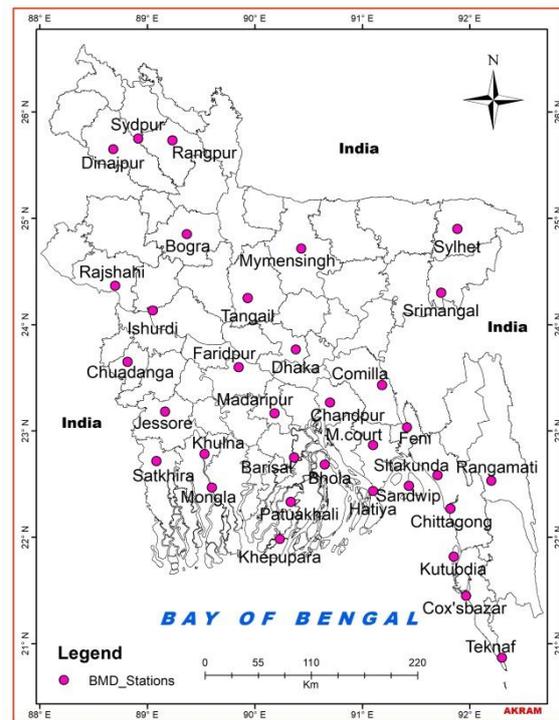


Fig. 1: Location of all observatories of BMD across Bangladesh

revealed that TS occurred maximum times in Sylhet and then the neighboring region Srimangal. This weather phenomenon occurred the lowest times in Kutubdia, with similarly infrequent occurrences observed in Teknaf and Chattogram.

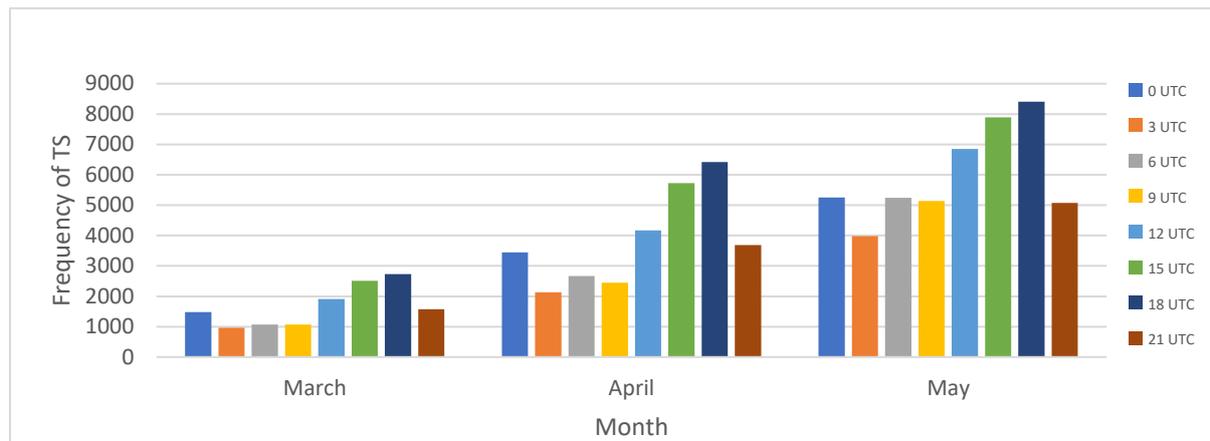


Fig.2: Every three hourly TS for the period from 1993 to 2022

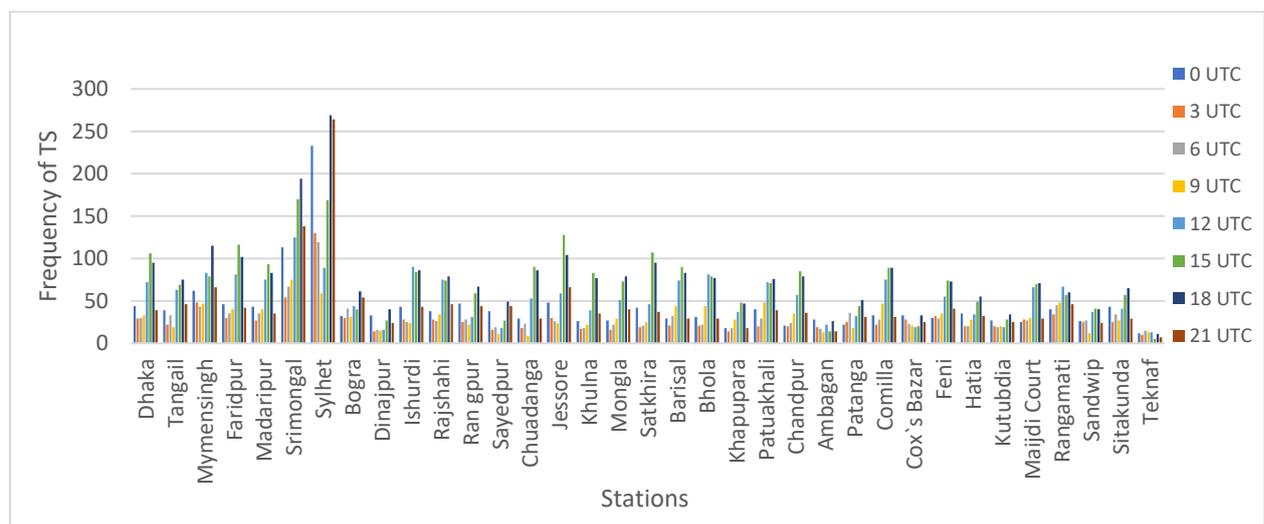


Fig.3: Every three hourly frequency of TS for 35 observatories for the month of March

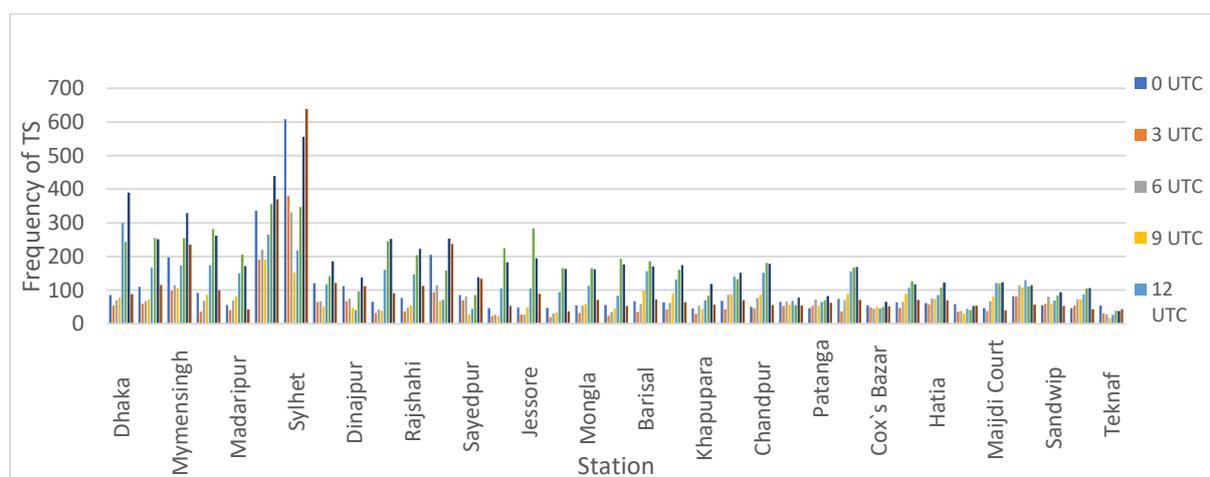


Fig.4 Every three hourly frequency for 35 observatories for the of April

The authors were interested to find out the significant levels for every individual UTC and months of the pre-monsoon period for the frequency of TS. Mann Kendall test was also done for three selected decades in Table-1 and for the whole period (1993-2022) in Table-2 to satisfy their requirement. Some significant levels are mentionable such as for the first decade for 00 and 09 UTC in the month of May, which was found to be

significantly increasing. For the third decade, levels were found to be significantly decreasing in March at 12 UTC and in May at 15 UTC, 18 UTC and 21 UTC. When testing the trends for the whole period, a number of significant levels were found. Those are for March 12 UTC, 15 UTC, 18 UTC and 21 UTC for April 15 UTC, 18 UTC, 21 UTC and for May 15 UTC, 18 UTC and 21 UTC are mentioning the decreasing trends of different significant levels.

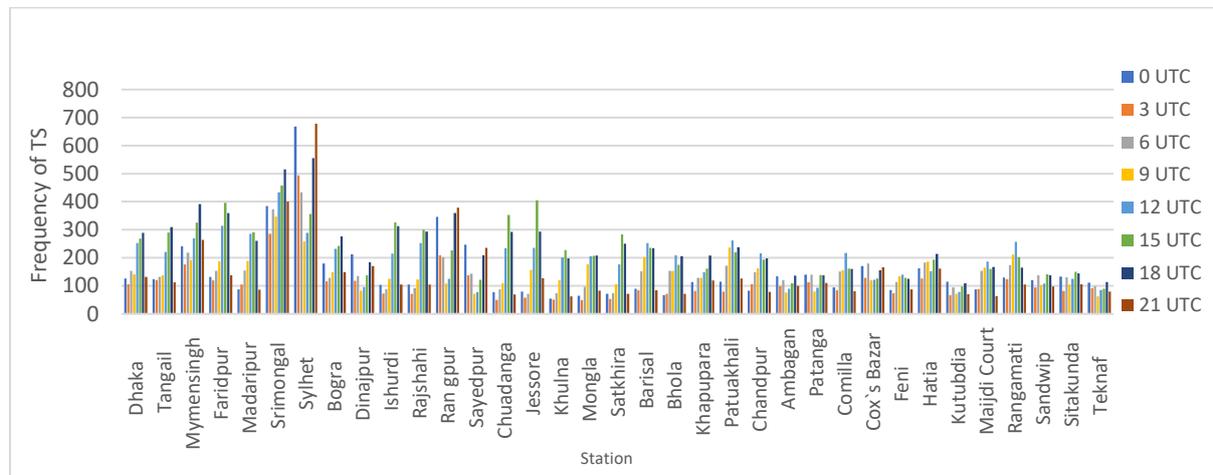


Fig.5: Three hourly frequency of 35 observatories for the month of May

Table-1: The significant level of different categories of thunderstorm trends for selected three decades by Mann Kendall test.

Period (1993-2002)				Period (2003-2012)			Period (2013-2022)		
March				April			May		
UTC	Tau	P_Value	Sig level	Tau	P_Value	Sig level	Tau	P_Value	Sig level
0	-0.333	0.1052		-0.044	0.4642		0.467	0.0368	Significant
3	-0.2	0.2371		0.066	0.4290		0.511	0.0245	Highly Significant
6	-0.2	0.2371		0.089	0.3938		0.556	0.0159	
9	-0.289	0.1415		-0.066	0.4290		0.467	0.0368	Significant
12	-0.289	0.1415		-0.244	0.1855		0.156	0.2957	
15	-0.289	0.1415		-0.422	0.0537	On the edge of Significant	-0.022	0.5	
18	-0.315	0.1215		-0.18	0.2648		0.022	0.5	
21	-0.315	0.1215		-0.066	0.4290		0.2	0.2371	
0	-0.156	0.2957		-0.022	0.5		0.36	0.0889	
3	-0.066	0.4290		-0.044	0.4642		0.289	0.1415	
6	-0.066	0.4290		0.022	0.5		0.333	0.1052	
9	-0.089	0.3938		-0.022	0.5		0.18	0.2648	
12	-0.089	0.3938		-0.111	0.3602		0.2	0.2371	
15	-0.044	0.4642		-0.2	0.2371		-0.066	0.4290	
18	-0.066	0.4290		-0.244	0.1855		-0.022	0.5	
21	-0.111	0.3602		-0.156	0.2957		0.089	0.3938	
0	-0.18	0.2648		-0.2	0.2371		-0.36	0.0889	
3	-0.089	0.3938		-0.25	0.1836		-0.27	0.1616	
6	-0.2	0.2371		-0.022	0.5		-0.244	0.1855	
9	-0.089	0.3938		0.089	0.3938		-0.244	0.1855	
12	-0.467	0.0368	Significant	0.066	0.4290		-0.111	0.3602	
15	-0.405	0.0634		-0.244	0.1855		-0.467	0.0368	Significant
18	-0.422	0.0537		-0.2	0.2371		-0.467	0.0368	Significant
21	-0.27	0.1616		-0.289	0.1415		-0.467	0.0368	Significant

Table-2: The significant level of different categories of thunderstorm trends for the period (1993-2022) by Mann Kendall test.

Period (1993-2022)								
March			April			May		
Tau	P_Value	Sig level	Tau	P_Value	Sig level	Tau	P_Value	Sig level
-0.358	0.002986		-0.036	0.39448		0.00693	0.4857	
-0.229	0.040035		-0.023	0.43616		-0.0461	0.3672	
-0.181	0.0845		0.034	0.40135		-0.0414	0.3808	
-0.231	0.038558		-0.078	0.27798		-0.0967	0.2322	
-0.302	0.010168	Highly Significant	-0.136	0.15031		-0.133	0.1545	
-0.339	0.004585	Highly Significant	-0.377	0.0018	Highly Significant	-0.426	0.0005	Highly Significant
-0.314	0.007983	Highly Significant	-0.214	0.0503	On the edge of Significant	-0.327	0.0059	Highly Significant
-0.347	0.003898	Highly Significant	-0.274	0.0176	Highly Significant	-0.262	0.0218	Highly Significant

In this step, the authors intended to identify the specific regions that are intensified for the frequent occurrence of TS. Three hourly data of the pre-monsoon period for every month of March, April and May were calculated for individual 35 stations. To make it more specific, the authors decided to divide the considered 30-year data into three decades 1993-2002, 2003-2012 and 2013 to 2022 and also divided these three decades into two segments based on daytime and nighttime. Spatial distribution was done to point out the most intensified and less intensified zones over the country using Inverse Distance Weighting (IDW) interpolation technique. Initially considered the month March, the first month of the pre-monsoon period. When the authors analyzed the three decades and also the segments of day times and night times, they found that the country received the highest number of TS in Sylhet, Srimangal and the situation extended up to the total Northeastern part of the country in respect of daytimes for the first decade (1993-2002). Rest of the country experienced a low number of TS except in some scattered places.

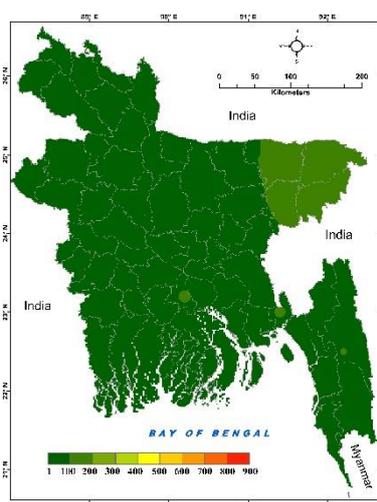


Fig.6a: Spatial distribution for daytime TS during the month of March from 1993 to 2002

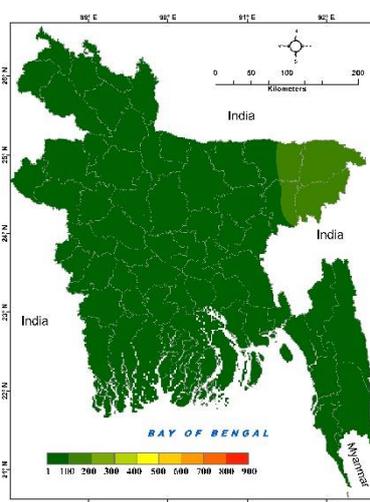


Fig.6b: Spatial distribution for daytime TS during the month of March from 2003-2012

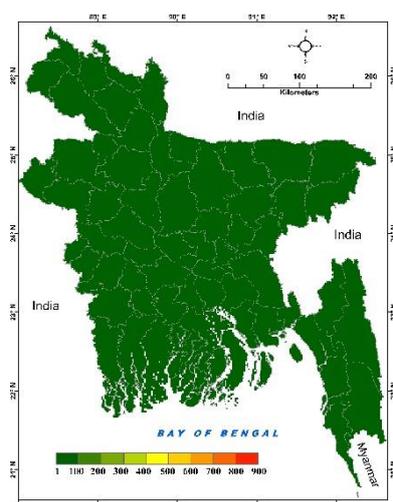
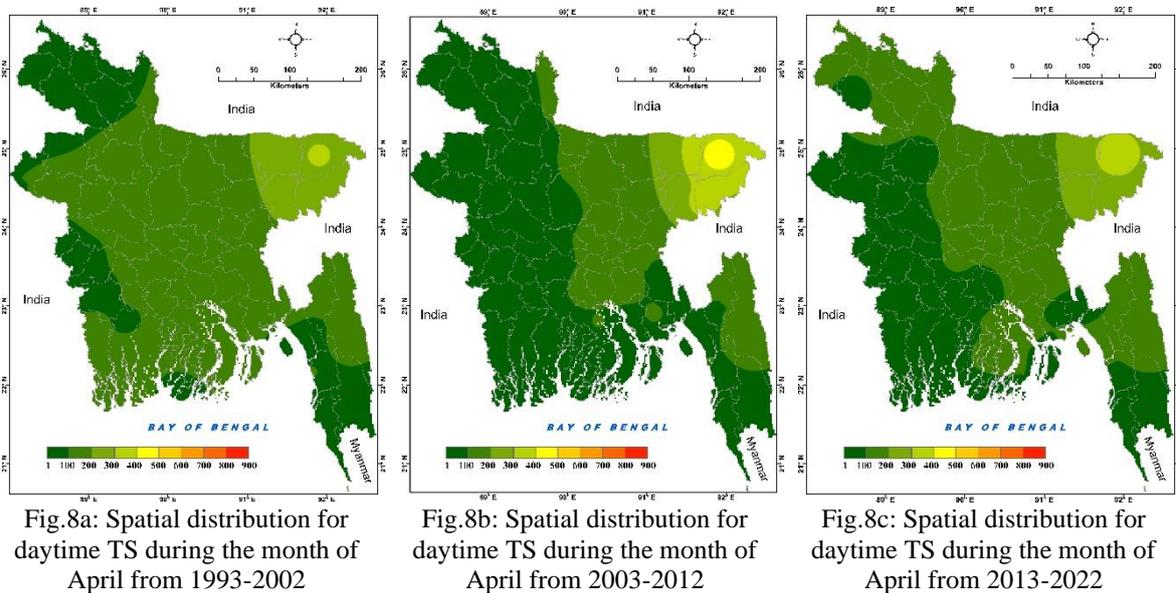
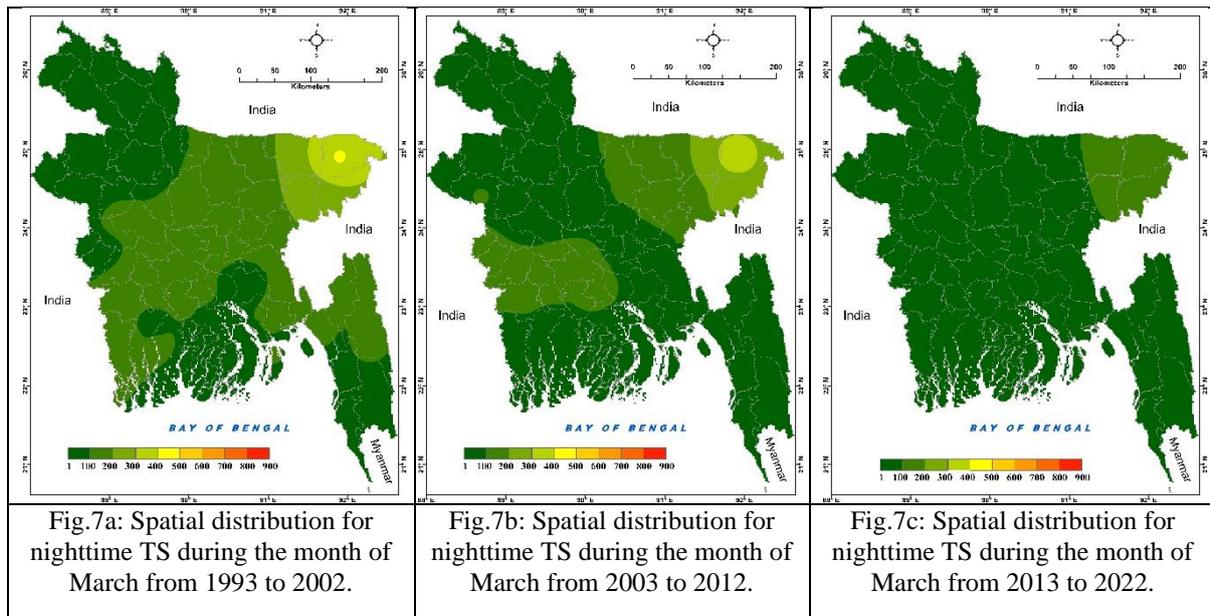


Fig.6c: Spatial distribution for daytime TS during the month of March from 2013-2022

The scenarios were approximately similar for the other two decades. Compare to the first decade, second decade experienced less number of thunderstorms. When authors paid attention to the third decade, they found that for daytime observations, the number of occurrences was very low compared to the other two decades. Fig.6a, for the first decade, Fig.6b for the second decade and Fig.6c for the third decade are the reflections of the above-described situation.

After that authors became attentive to find out the situation of March for nighttime. When authors analyzed the first decade for nighttime, it was found that the Northeastern part experienced a comparatively higher number of TS and the other part of the country can be identified as moderately intensified for TS and the scenario is represented in Fig.7a. It should be mentioned that the Northern part and Southern part of the country received the lowest number of TS among the other zones of the country. The central part of the country experienced moderate number of thunderstorms. Analyzed the second decade of the same category also done spatial distribution and is presented in Fig.7b, which indicates that the Northeastern part was comparatively intensified and southwestern part can be considered as moderately intensified and central part of the country was less intensified compared to the mentionable zones of the country. Fig.7c is also the visualization of the third decade of this category which can be explained that the whole country received comparatively a smaller number of TS compared to the other two decades of this category. The country received a few bits higher frequencies of TS in Sylhet and Srimangal.



In this step, the authors decided to reveal the scenario of April and also had done the spatial distribution for the selected three decades and for both segments of daytime and nighttime. When authors looked at the first decade which is presented in Fig.8a they found that in April country received a higher number of TS compared to the same decade of daytime segment as previously described for March. By analyzing the situation authors explained that the country received a mentionable number of TS all over the country except a few places of northern, northwestern and southeastern part where TS occurred comparatively fewer times during this period of daytime. Sequentially this time authors explained the second decade for the same segment which is visualized in Fig.8b.

The situation was a little bit different as explained in the first decade. During this period country experienced a less number of TS over the country compared to the first decade of the same segment but quite a higher number of TS than the same category of March. Following the spatial distribution authors found that the Northeastern part was prominent for TS. Northern, Northwestern Southwestern and Southeastern parts were least prominent where TS occurred comparatively more infrequently than in the surrounding regions. As usual, Teknaf received the lowest number of TS during this time. The central part to the Eastern part can be considered as moderately intensified zones. The authors presented their analysis of spatial distribution for third decade in Fig.8c and described that the situation was approximately the same as defined in the second decade. The northeastern part of the country was the most intensified and the central part to the North and Eastern part can be considered as moderately intensified but the Western, Southern and Southwestern part were comparatively less intensified compared to the other parts of the country.

The authors were focused on finding their findings/observations for the divided three decades of April for the nighttime segments and presented their findings/outcomes of the first decade in Fig.9a. In the first-decade country experienced a high frequency of TS except for some places of Northern and Southeastern part. The northeastern part received the highest frequency of TS compared to the other areas of the country. The central part to the North and Northwestern part and Southern parts also experienced a mentionable number of TS. Secondly, the authors tried to explain the scenario of the second decade of this category and Fig.9b is the visualization of their explanation. This time the total number of observed frequencies was bit less than in the previous decade. The Northeastern part, especially Sylhet and Srimangal received a remarkable number of TS during this period at night time. The central part to the Northern and Northwestern part also received a moderate frequency of TS except some scattered places. The southern and Southwestern parts received comparatively less number of TS. The third decade of this category is also explained and the scenario is visualized in Fig.9c. During this time TS occurred comparatively less time than two decades of the same category. Northern, Northwestern and Southern part experienced less number of thunderstorms than parts of the country. This time TS occurred at the lowest times in Teknaf and the highest times in Sylhet.

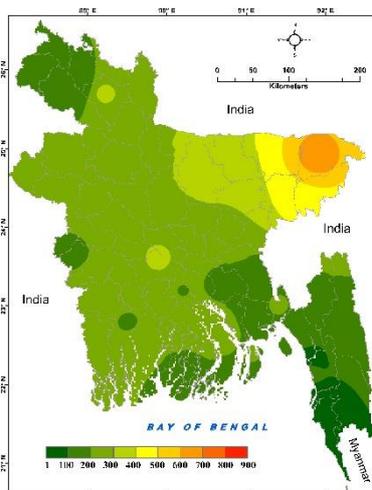


Fig.9a: Spatial distribution for nighttime TS during the month of April from 1993-2002

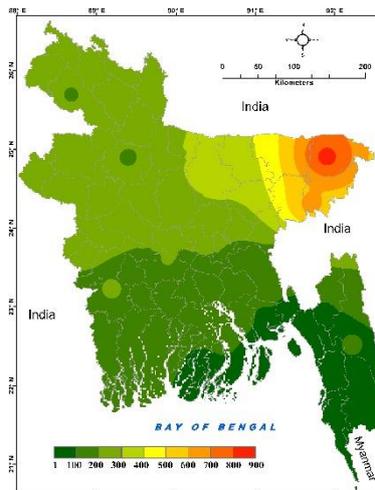


Fig.9b: Spatial distribution for nighttime TS during the month of April from 2003-2012

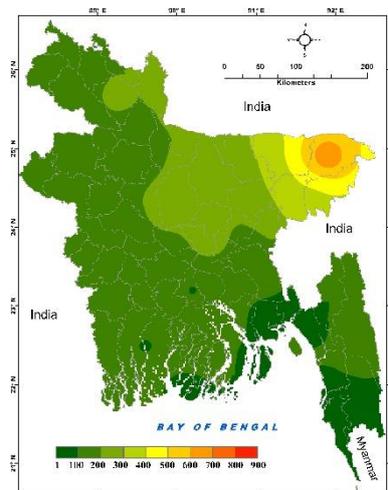


Fig.9c: Spatial distribution for nighttime TS during the month of April from 2013-2022

May is the last month of the pre-monsoon period and the authors also decided to sequentially reveal the overall situation for the selected three decades and also for both segments of daytime and nighttime. To achieve their aim, they also had done the spatial distribution by utilizing GIS software. After analyzing the daytime of the first decade, it can be clarified that this time TS occurred much more frequently than in other months of the pre-monsoon period of the same category. The northeastern part mainly Srimangal, then Sylhet and their surrounding regions received the higher frequency of TS. By analyzing the situation, authors explained that the country received a mentionable number of TS except in a few places in the extreme Northern area and Teknaf. The above description is presented in Fig.10a. Consecutively, authors explained the second decade for the same segment which is visualized in Fig.10b. The situation was as same as explained in the same decade of March and April. During this period country experienced a less number of TS over the country compared to the first decade of the same segment but quite a higher number of TS than the same category of March and April. Following the spatial distribution, the Northeastern part received a higher number of TS than the other part of the country. Northern, Northwestern, Southern and Southeastern part experienced less number of thunderstorms except some scattered

places. The central part to the North and Eastern part can be considered as moderately intensified zones. Some random places were also located that received a higher number of TS, mentionable are Madaripur and Rangamati.

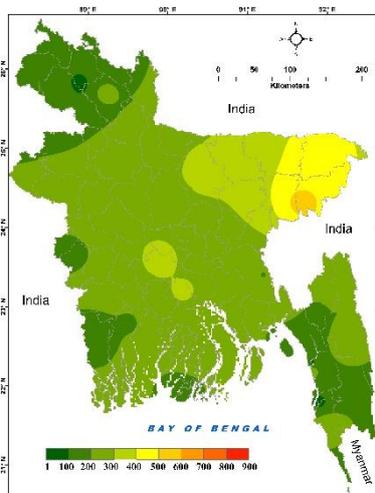


Fig.10a: Spatial distribution for daytime TS during the month of May from 1993-2002

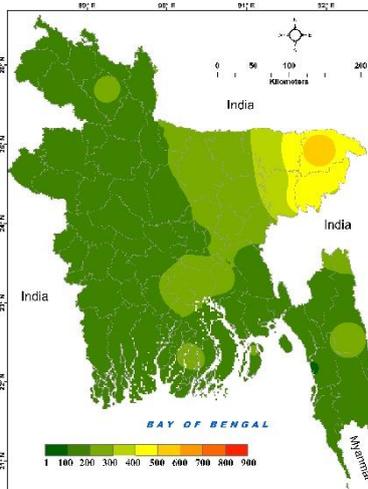


Fig.10b: Spatial distribution for daytime TS during the month of May from 2003-2012

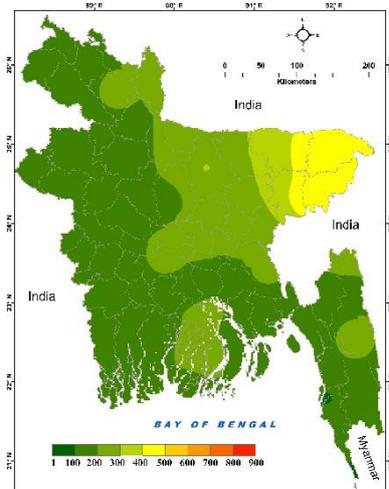


Fig.10c: Spatial distribution for daytime TS during the month of May from 2013-2022

The authors presented their analysis of spatial distribution in Fig.10c and described that the situation was approximately the same as defined in the second decade. The northeastern part of the country was the highest intensified and the central part to the North and Northwestern part can be considered as less intensified. Some parts of the Southern and Southeastern were comparatively more intensified compared to the surrounding areas. Kutubdia was the place where TS occurred the most infrequently in this decade.

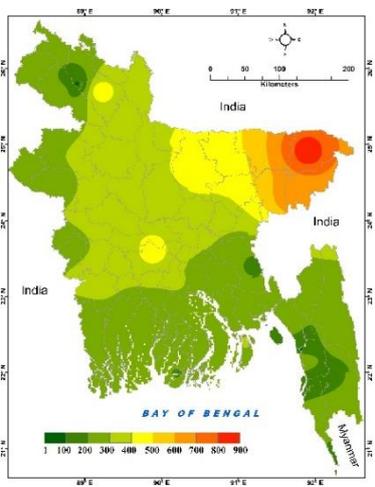


Fig.11a: Spatial distribution for nighttime TS during the month of May from 1993-2002

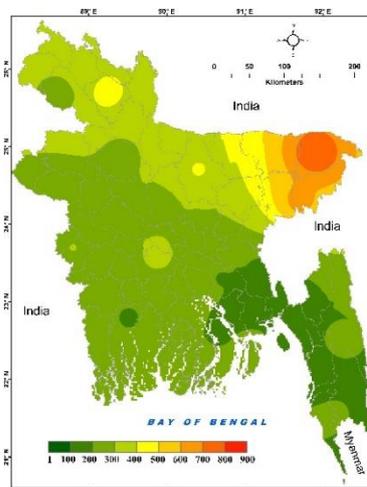


Fig.11b: Spatial distribution for nighttime TS during the month of May from 2003-2012

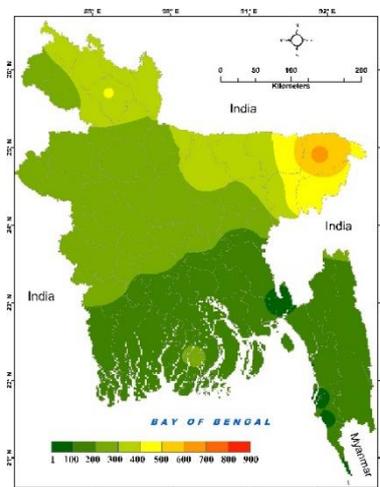


Fig.11c: Spatial distribution for nighttime TS during the month of May from 2013-2022

The authors explored the situation of nighttime of the last month of the pre-monsoon period for the selected three decades. The output of the first decade is visualized in Fig.11a. The highest frequency of TS was recorded in the Northeastern part of the country. Sylhet, Srimangal and their surrounding areas received the highest number of TS in the country. The central part of the country received a higher number of TS compared to the regions of extreme Northern, Northwestern, Southern, Southwestern and Southeastern parts. The scenario of the second decade also followed the same scenario of March and April of this category. The outcomes are visualized in Fig.11b. The Northeastern part experienced the highest number of TS and the central to Northern part received a high to moderate number of TS. A little bit less amount of TS was recorded in the Southern part than in the other parts of the country. Some disintegrated places such as Faridpur, and Dinajpur experienced high frequency of TS

than their surrounding areas. Lastly, the authors decided to find out the variability of the TS over the country for the third decade and the result is presented in Fig.11c. The frequency of TS was lower in this decade than in the other two decades. The southern part experienced the lowest number of TS than the other areas of the country. Central to the Northern part received a moderate frequency of TS. Disintegrated, Rangpur and some extended parts experienced a higher number of TS.

5. CONCLUSION

The study investigated thunderstorm frequency during the pre-monsoon period spanning from 1993 to 2022 and found some important results.

1. May is the month with the most thunderstorms, while March has the fewest.
2. Thunderstorm intensity is the highest at 18 UTC which means from 9 PM to 12 AM and the lowest at 03 UTC which means from 6 AM to 9 AM.
3. The analysis (of three-hourly thunderstorm frequencies at 35 observatories during the months of March, April, and May) consistently showed that the Sylhet region, including Srimangal, experienced the highest frequency of thunderstorms, while thunderstorm occurrences were infrequent in Teknaf and its surrounding areas.
4. Researchers conducted the Mann-Kendall test and observed an increasing trend in May at 00 UTC and 09 UTC during the first decade (1993-2002). However, the third decade (2013-2022) resulted in a decreasing trend in March at 12 UTC and in May at 15 UTC, 18 UTC, and 21 UTC. Over the 30-year span, decreasing trends were identified in different significant levels in March at 12 UTC, 15 UTC, 18 UTC, and April at 21 UTC, as well as May at 15 UTC, 18 UTC, and 21 UTC.
5. Spatial distribution analysis for each decade of the pre-monsoon period from 1993 to 2022 indicated that the northeastern region consistently experienced the highest number of thunderstorms, while the southern and extreme northern parts had the fewest occurrences.
6. Thunderstorms occurred more often at night compared to during the day. Additionally, when considering the different decades, the first decade had the highest number of thunderstorms, while the third decade had the fewest.

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REFERENCES

- [1] Rahman, S.M.M., Hossain, S.M. and Jahan, M.U., 2019: Thunderstorms and lightning in Bangladesh. *Bangladesh Medical Research Council Bulletin*, 45(1), 1-2.
- [2] Wahiduzzaman, M., Islam, A.R.M.T., Luo, J.J., Shahid, S., Uddin, M.J., Shimul, S.M. and Sattar, M.A., 2020: Trends and Variabilities of Thunderstorm Days over Bangladesh on the ENSO and IOD Timescales. *Atmosphere*, 11(11), 1176.
- [3] Akther, S., Rahman, M.M. and Rezwana, N., 2022: The emergence of lightning as a natural disaster in Bangladesh and its impact on household dynamics.
- [4] Ferdous, J., Quadir, D.A., Alam, M.S., Panda, S.K., Das, S., Ahasan, M.N., Rabbani, K.M.G. and Shuvo, S.D., 2021: Prediction of Thunderstorms based on Atmospheric Instability Indices over Bangladesh using WRF-ARW Model. *Jalawaayu*, 1(2), 21-38.
- [5] Biswas, A., Dalal, K., Hossain, J., Baset, K.U., Rahman, F. and Mashreky, S.R., 2016. Lightning Injury is a disaster in Bangladesh?-Exploring its magnitude and public health needs. *F1000 Research*, 5, 2931.
- [6] A.J. Dhali, Study on pre-monsoon thunderstorm frequency and its relation with rainfall in Bangladesh during 1990-2017, M.S Thesis, Bangladesh University of Engineering and Technology (BUET), Dhaka, 2019.