A meteorological parameters study and its relationship with thunderstorms in Rajshahi district of Bangladesh

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Abstract

A thunderstorm is a weather phenomenon characterized by the occurrence of lightning, thunder, heavy rainfall, strong winds, deep convection and sometimes tornado & hail. It is a localized atmospheric disturbance that occurs within a convective cloud system, known as a cumulonimbus cloud. Thunderstorms typically form when there is an unstable atmosphere with an ample supply of moisture and an upward movement of warm, humid air. A time series model for thunderstorm prediction involves analysing historical data to identify patterns, trends, and seasonal variation in thunderstorm occurrences over time. Time series analysis techniques can then be applied to forecast future thunderstorm events based on these patterns. This study aims to correlate thunderstorm events with different meteorological parameters. Trend of the different meteorological parameters such as cloud coverage, relative humidity, rainfall, dew point temperature, maximum temperature, pressure is analyzed to find the relation with thunderstorm activities. From the analysis, it is found that cloud coverage, relative humidity & rainfall showed proportional relationship and dew point temperature, maximum temperature and pressure showed inversely proportional relationship with thunderstorm events within a certain values of them.

Keywords: Thunderstorm, meteorological parameters, correlation, time series data

1. Introduction

Bangladesh is one of the worst disaster-prone areas in the world. Since it is located in South Asia, Bangladesh experiences a significant amount of thunderstorm activity due to its tropical climate and geographical location. Thunderstorms are a common meteorological phenomenon in the country, especially during the pre-monsoon and monsoon seasons. Thunderstorm is a type of weather phenomenon characterized by thunder, lightning and various atmospheric disturbances. It is often accompanied by heavy rainfall, strong winds and sometimes hail. Thunderstorms are caused by the interaction of warm and cold air, which leads to the rapid vertical movement of air and the release of energy in the form of lightning and thunder. The pre-monsoon hot summer season from the month of March to May brings with it heat, rainfall and thunderstorm. With the shifting from winter anti-cyclonic pressure regime to summer, this season has a hallmark characteristic of high temperature and cyclonic storms brewing in the Bay of Bengal. Thunderstorm hazards and associated lightening as a national disaster in Bangladesh.

In recent years, there have been many incidents of severe thunderstorms with associated lightning and many casualties in the country. In this situation, it is very necessary to protect life from these events which indicate that it needs the forecast of thunderstorm or Early Warning System (EWS). Conventional methods of EWS are not very effective in this regard. The synoptic and upper synoptic conditions of the atmosphere can play an important role in the formation of thunderstorms. In this research, meteorological parameters such as cloud coverage, rainfall, dew point temperature, relative humidity, maximum temperature, pressure etc. are analyzed to find correlation with thunderstorm activities. The aim of the study is to find out the individual relationships between thunderstorms and these meteorological parameters so that it can advance EWS based on meteorological parameters.

There are some initiatives that have been used in lightning detection or thunderstorm early warning systems. Kanchan et al. (2017) provided a comprehensive survey on the application of soft computing and data mining techniques for predicting thunderstorms and lightning [1]. They highlighted the limitations of traditional meteorological methods and emphasized the significance of accurate prediction for public safety and various industries. Wayan Suparta et al. (2012) conducted a research study to investigate the impacts of GPS Precipitable Water Vapor (PWV) during heavy thunderstorms over Kuala Terengganu, Malaysia [2]. The researchers aimed to understand the relationship between PWV measurements obtained from GPS signals and the occurrence and intensity of thunderstorms in the region. Yu. P. Mikhailovsky et al. (2019) conducted a study to investigate the features of thunderstorm activity control using different radio physical measuring instruments

such as radar, lightning detection systems, and ground-based flux meters [3]. Hartono Zainal Abidin et al. (2003) conducted a study focusing on the relationship between thunderstorm days and ground flash density in Malaysia [4]. Ali et al. (2011) focused on the application of Artificial Neural Networks (ANN) for thunderstorm forecasting [5]. The researchers aimed to develop a predictive model using ANN to forecast thunderstorms accurately. Valentina Gorbatenko et al. (2001) investigated the variations of thunderstorm tornadoes (thunder-tor) and their characteristics [6]. Shpyg Vitalii et al. (2022) focused on simulating and verifying thunderstorm forecasts using the Weather Research and Forecasting (WRF) model, specifically focusing on reflectivity [7]. Singye et al. (2005) developed a thunderstorm-tracking system that utilized neural networks and measured electric fields from a few field mills [8]. Stéphane Schmitt et al. (2022) focused on Thunderstorm Warning Systems and their adherence to the IEC 62793 standard [9]. Villa et al. (2015) proposed a system that utilizes an Electrostatic Field Sensor Network to locate thunderstorms [10]. Alexander Serkov et al. (2022) developed a Thunderstorm Hazards Early Warning System [11]. Schulz et al. (2015) conducted a study on the European lightning location system called Euclid [12]. A statistical-fuzzy coupled approach is proposed to investigate the consistency between Convective Available Potential Energy (CAPE) and Convective Inhibition Energy (CINE) during the prevalence of severe thunderstorms [13]. Litta A. J et al. (2012) focused on the development of an artificial neural network (ANN) model for the prediction of thunderstorms over Kolkata [14].

2. Experimental Setup & Methodology

The current research describes relationship of thunderstorm intensity with meteorological variables. The observed meteorological data is used to understand the characteristics of thunderstorm and have developed the relationship between thunderstorms and meteorological parameters such as cloud coverage, rainfall, dew point temperature, relative humidity, maximum temperature, pressure etc.

2.1. Research Procedure

The research procedures are as follows:

(a) Data Collection: It is ccollected meteorological data related to thunderstorms including cloud cover, pressure, temperature, dew point temperature, rainfall and relative humidity from reliable weather station i.e. Rajshahi. Data is collected from Bangladesh Meteorological Department (BMD).

(b) Data Processing: The collected meteorological data was daily average of cloud coverage, rainfall, dew point temperature, relative humidity, maximum temperature, pressure etc. The data is then processed and calculated as monthly, seasonally and annually.

(c) Data Cross Checking: The processed data was cross checked with thunderstorm events (Thunderstorms data is also collected from BMD) for parallel analysis. Actually, it is ensured that the data covers a significant period, preferably spanning several thunderstorm events to capture variations in intensity.

(d) Parameter Analysis: (1) Cloud Cover: It is ccalculated the average cloud coverage during the thunderstorm event. The hhigher cloud coverage indicates increased moisture and potential for more intense thunderstorms.

(2). Pressure: It is analyzed the changes in atmospheric pressure before, during and after the thunderstorm event and ssudden drops in pressure may indicate the development of severe thunderstorms.

(3). Temperature and Dew Point Temperature: It is ccalculated the temperature and dew point temperature during the thunderstorm event and hhigher temperatures combined with high dew point temperatures suggest greater atmospheric instability and increased potential for severe thunderstorms.

(4). Rainfall: It is mmeasured the total rainfall amount during the thunderstorm event and hheavy rainfall rates are often associated with more intense thunderstorms.

(5). Relative Humidity: It is ccalculated the average relative humidity during the thunderstorm event and higher humidity levels contribute to the instability of the atmosphere, potentially increasing the intensity of thunderstorms.

(e) Comparison & Validation: Thunderstorm and other meteorological parameters are compared and validated with open source satellite data (MODIS Terra & Aqua) in some cases.

(f) Correlation Finding: The processed meteorological parameters such as cloud coverage, rainfall, dew point temperature, relative humidity, maximum temperature, pressure etc. are correlated with thunderstorm events by curve fitting techniques.

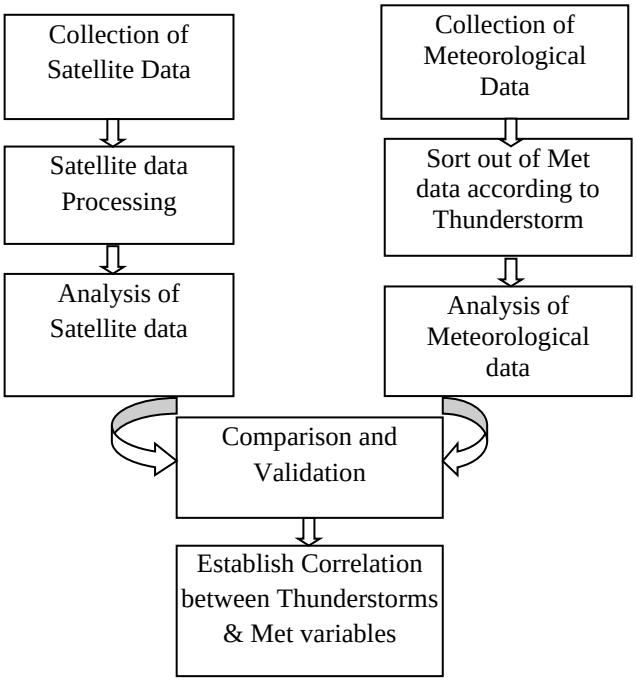

Fig. 1: Flowchart of Methodology

2.2. Study Area

The study area of the current research is Rajshahi District. Rajshahi is a located in the northwestern part of Bangladesh. It is one of the administrative districts of the country and is known for its historical, cultural, and economic significance. The district is characterized by its fertile lands, diverse cultural heritage, and historical landmarks. The region is primarily situated on the northern banks of the Padma River, which is a major river in the country. The district encompasses a mix of landscapes, including fertile plains, rivers, and some low hills. Geographically, Rajshahi is located within Barendra Bhumi, 23 meters (75 ft) above sea level and located at 24°22′26″N and 88°36′04″E.

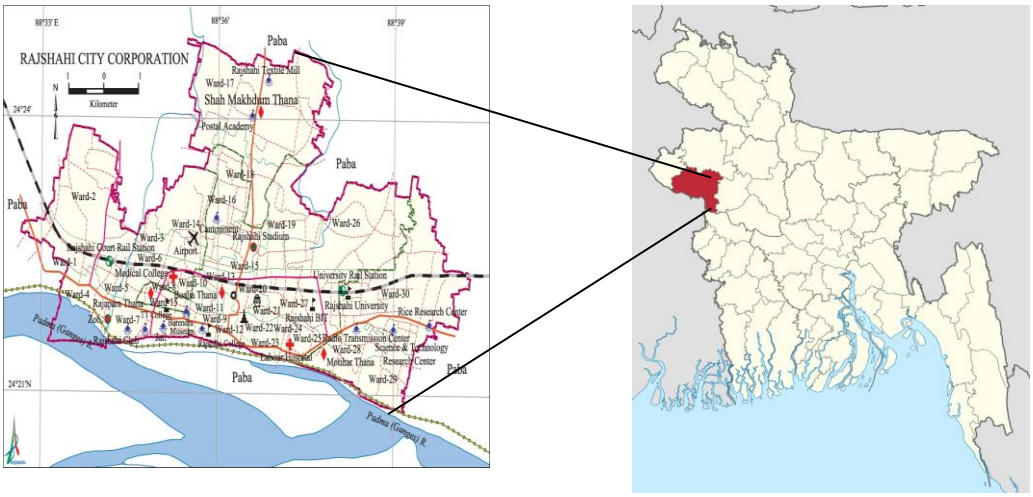

Fig. 2: Study Area: Rajshahi district of Bangladesh

2.3. Data Used

The daily observed thunderstorm events and daily average meteorological parameters such as cloud coverage, rainfall, dew point temperature, relative humidity, maximum temperature, pressure etc data is collected from Bangladesh meteorological department (BMD). At the same time, open source satellite data (MODIS Terra & Aqua) is used for validation of meteorological events.

3. Results and Discussion

Meteorological data plays a pivotal role in understanding and predicting occurrence of thunderstorms, providing crucial insights into the complex interplay of atmospheric factors. By meticulously analyzing variables such as

cloud coverage, rainfall patterns, dew point temperature, relative humidity, maximum temperature, and atmospheric pressure on a yearly and monthly basis, meteorologists gain a comprehensive understanding of the atmospheric conditions that precede thunderstorm formation. The meteorological data analysis of the study area Rajshahi district is given below. Here is taken meteorological data from 1990 to 2020 to show the trends in thunderstorms with various variables.

Cloud Coverage:

The yearly average cloud coverage (in octa) versus thunderstorms events over Rajshahi district is shown in figure 3. It is shown that over Rajshahi for the year 1990 to 2020 and the trend of yearly thunderstorm events are decreased with the decreasing of average cloud coverage.

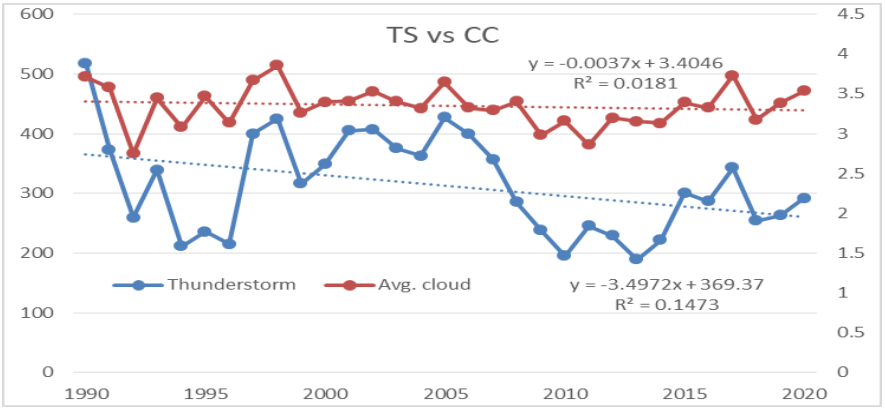

Fig. 3: Yearly trend of average cloud coverage and thunderstorm events in Rajshahi for 1990-2020

The monthly average cloud coverage over Rajshahi for the year 2015 to 2020 is shown in figure 4. From the analysis it is found that the intensity of thunderstorms is increased in the months of March, April, May & June when cloud coverage is also increased. It means that there is a direct proportional relationship between thunderstorms events and cloud coverage.

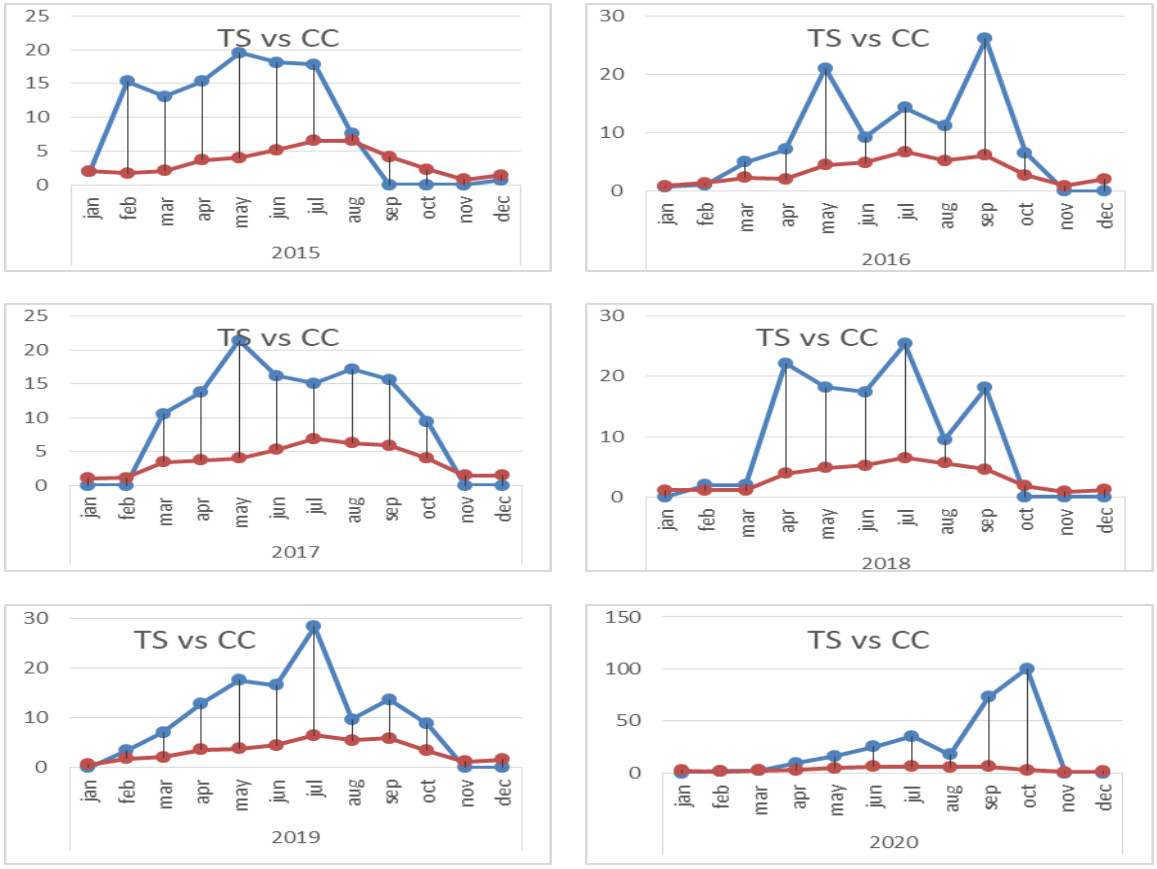

Fig. 4: Monthly variation of Thunderstorm with average cloud coverage in Rajshahi for 2015-2020

Dew Point Temperature:

The yearly average dew point temperature versus thunderstorms events in Rajshahi district is shown in figure 5. It was found that the occurrence of thunderstorms decreased with the trend of increasing of yearly average dew point temperature, which means that there is an inverse proportional relationship between them.

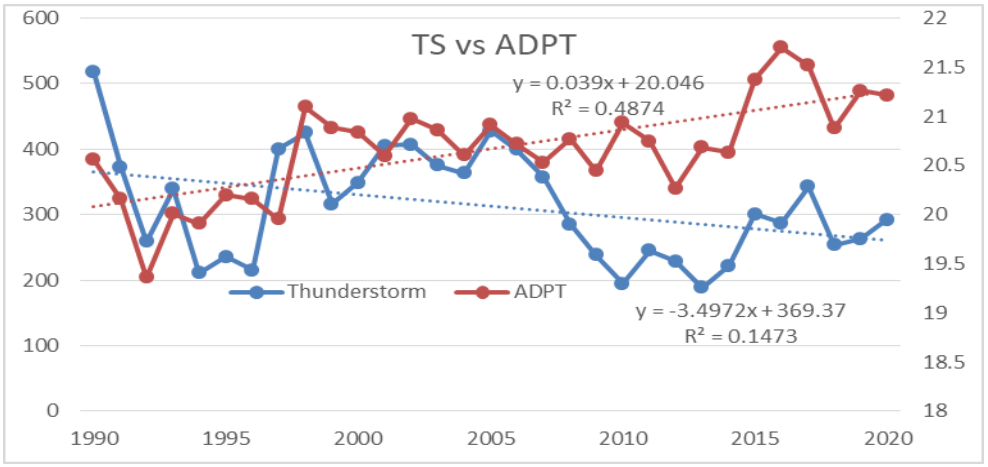

Fig. 5: Yearly trend of avg dew point temp and thunderstorm events in Rajshahi for 1990 - 2020

The monthly average dew point temperature versus thunderstorm events in Rajshahi district is shown in figure 6 over Rajshahi for the year 2015 to 2020. From the analysis it is found that average dew point temperature is increased from the month of April to September and decreased from November to March and thunderstorms are similar intensity in this period of time.

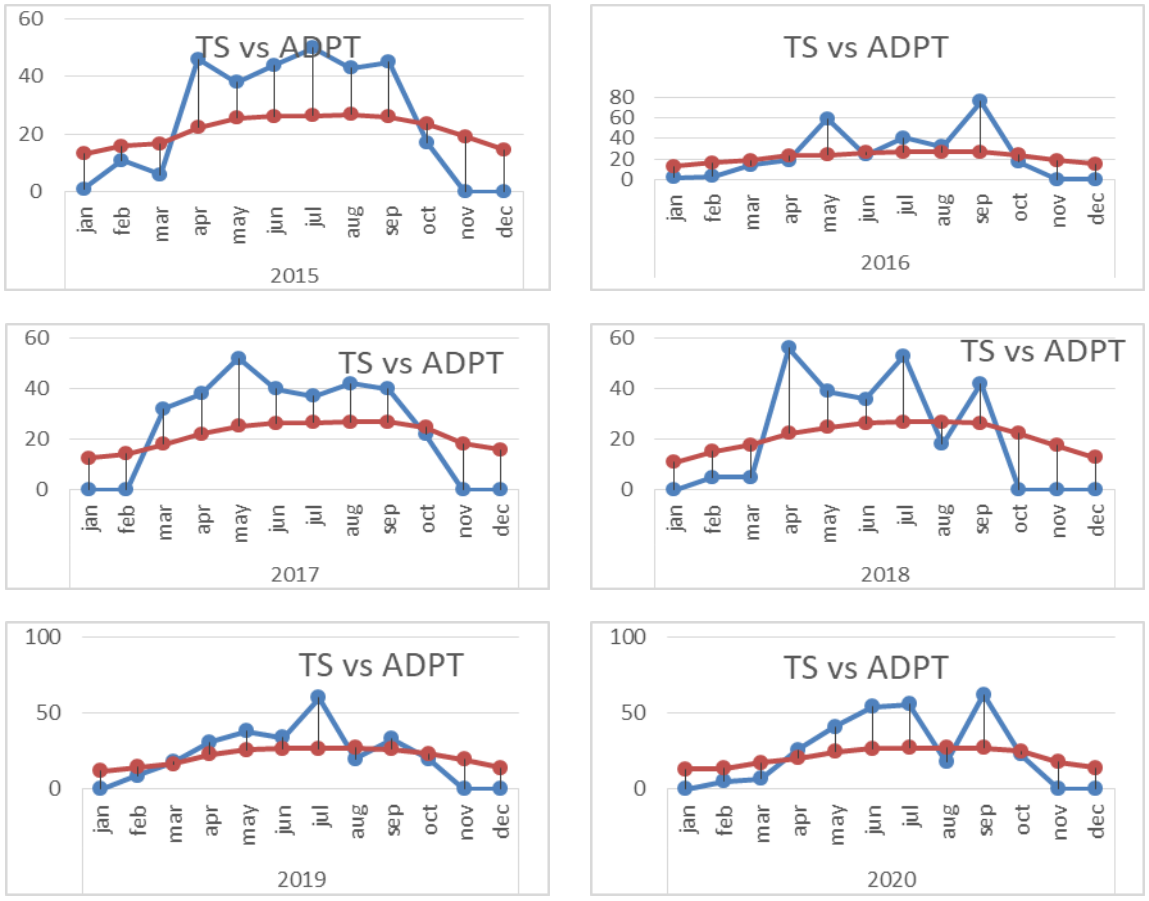

Fig. 6: Monthly variation of Thunderstorm with avg dew point temp in Rajshahi for 2015-2020

Rainfall:

The yearly average rainfall versus thunderstorms events in Rajshahi is shown in figure 7. It is shown that over Rajshahi for the year 1990 to 2020 and the trend of yearly average rainfall is decreased with decrease of thunderstorm events. The values of yearly average rainfall is analyzed to correlate with thunderstorms.

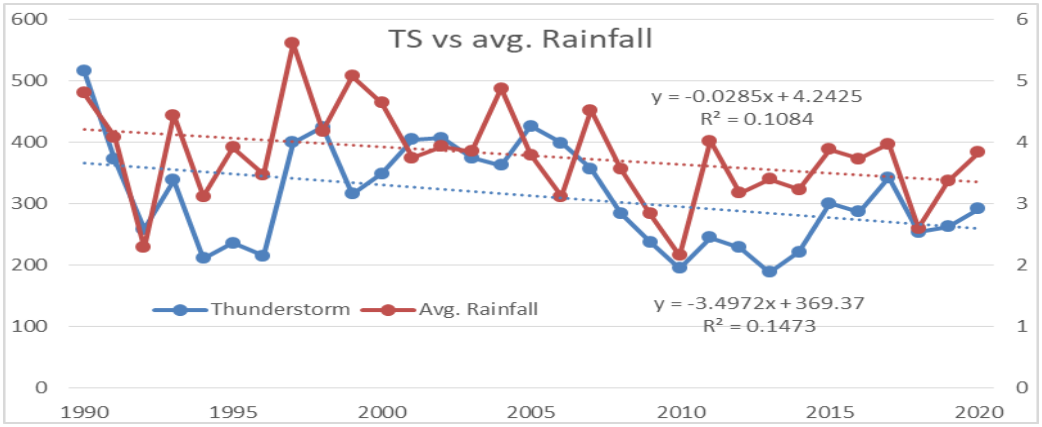

Fig. 7: Yearly trend of average rainfall and thunderstorm events in Rajshahi for 1990 - 2020

The monthly average rainfall versus thunderstorm events is shown in figure 8 over Rajshahi for the year 2015 to 2020. From the analysis it is found that average rainfall is increased from the month June to September and decreased from November to March and thunderstorms are similar intensity in this period of time. So, there is a direct proportional relationship between them.

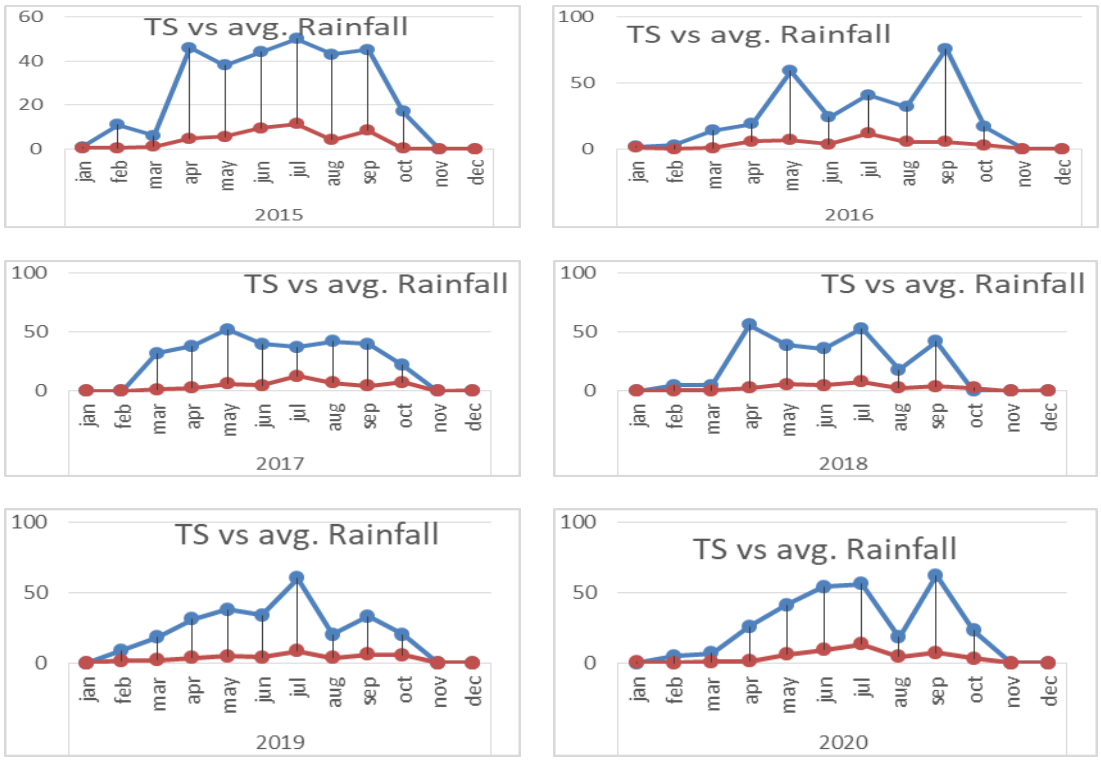

Fig. 8: Monthly variation of Thunderstorm with average rainfall in Rajshahi for the year of 2015-2020

Maximum Temperature:

The yearly average maximum temperature (Avg.T) versus thunderstorms events (TS) in Rajshahi is shown in figure 9. It is found that in Rajshahi thunderstorm activities are decreased with the increasing of yearly maximum temperature for the year 1990 to 2020. which means that there is an inverse proportional relationship between them.

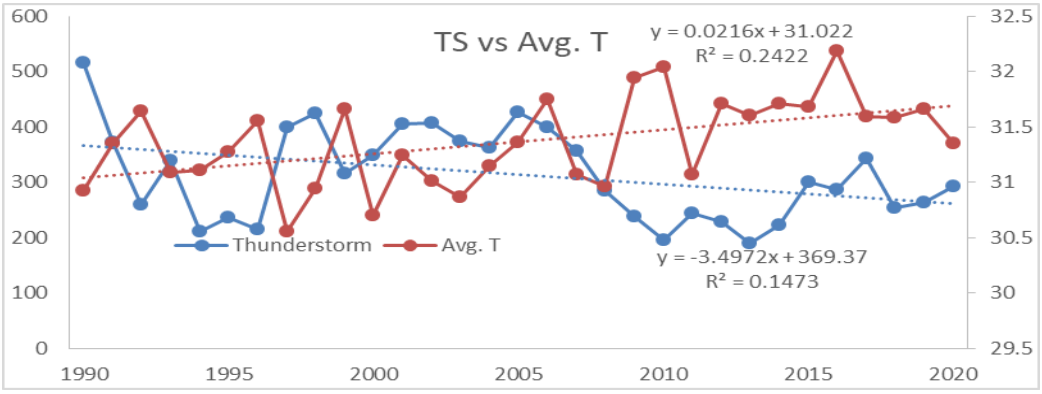

Fig. 9: Yearly trend of avg maximum temp and thunderstorm events in Rajshahi for 1990 -2020

The monthly average maximum temperature versus thunderstorm events is shown in figure 10 over Rajshahi for the year 2015 to 2020. From the analysis it is found that average average maximum temperature is decreased in November to February and increased from March to June. Thunderstorm activities are increased in the months of March, April, June and October and from December to February the events are very less amount. Hence, the results of both monthly and yearly analysis are similar.

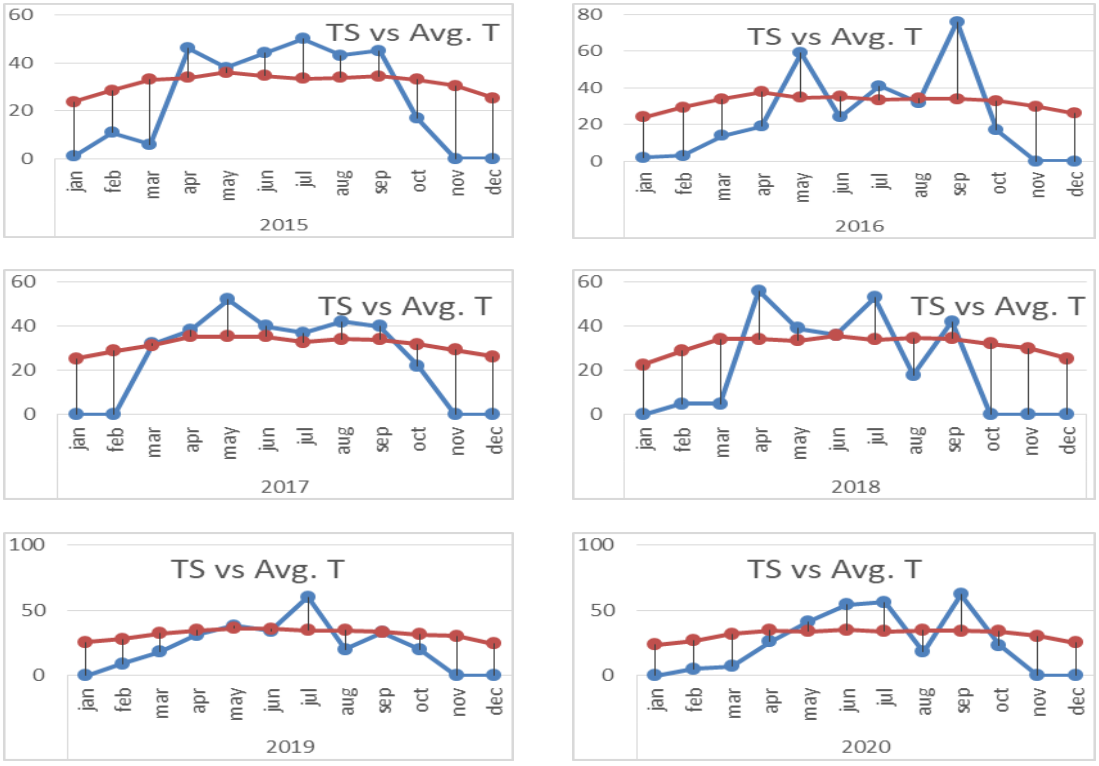

Fig. 10: Monthly variation of Thunderstorm with avg maximum temp in Rajshahi for 2015-2020

Pressure:

The yearly average pressure(Avg P) versus thunderstorms events (TS) in Rajshahi is shown in figure 11. It is found that over Rajshahi for the year 1990 to 2020, the trend of yearly average pressure is decresing with time. The similar nature for thunderstorms also.

The monthly average average pressure versus thunderstorm events is shown in figure 12 over Rajshahi for the year 2015 to 2020. From the analysis it is found that the average pressure is increased in the month November, December, January and February and in this time thunderstorm activities are decreased. So, there is an inverse relationship between thunderstorms and average pressure.

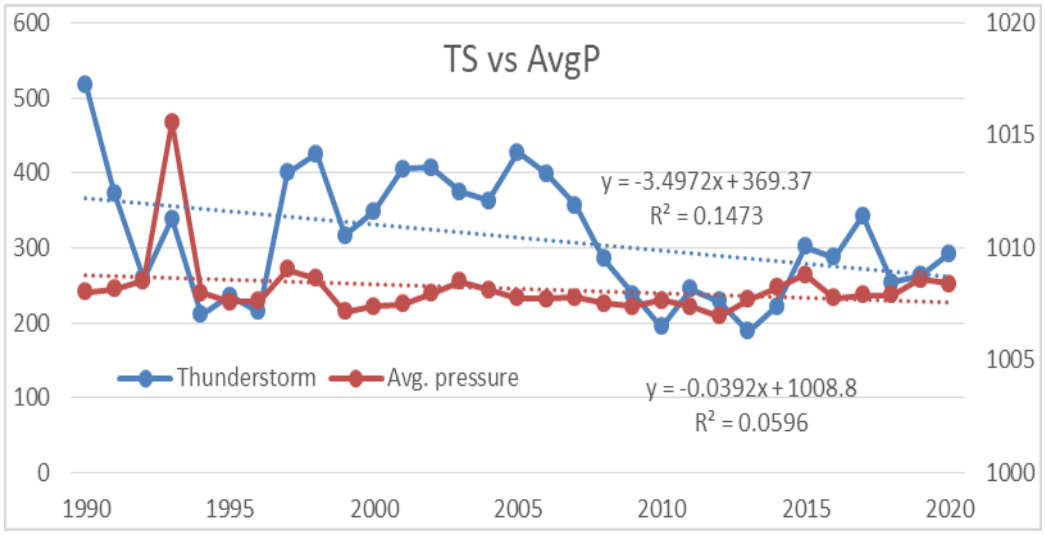

Fig. 11: Yearly trend of avg pressure and thunderstorm events in Rajshahi 1990 -2020

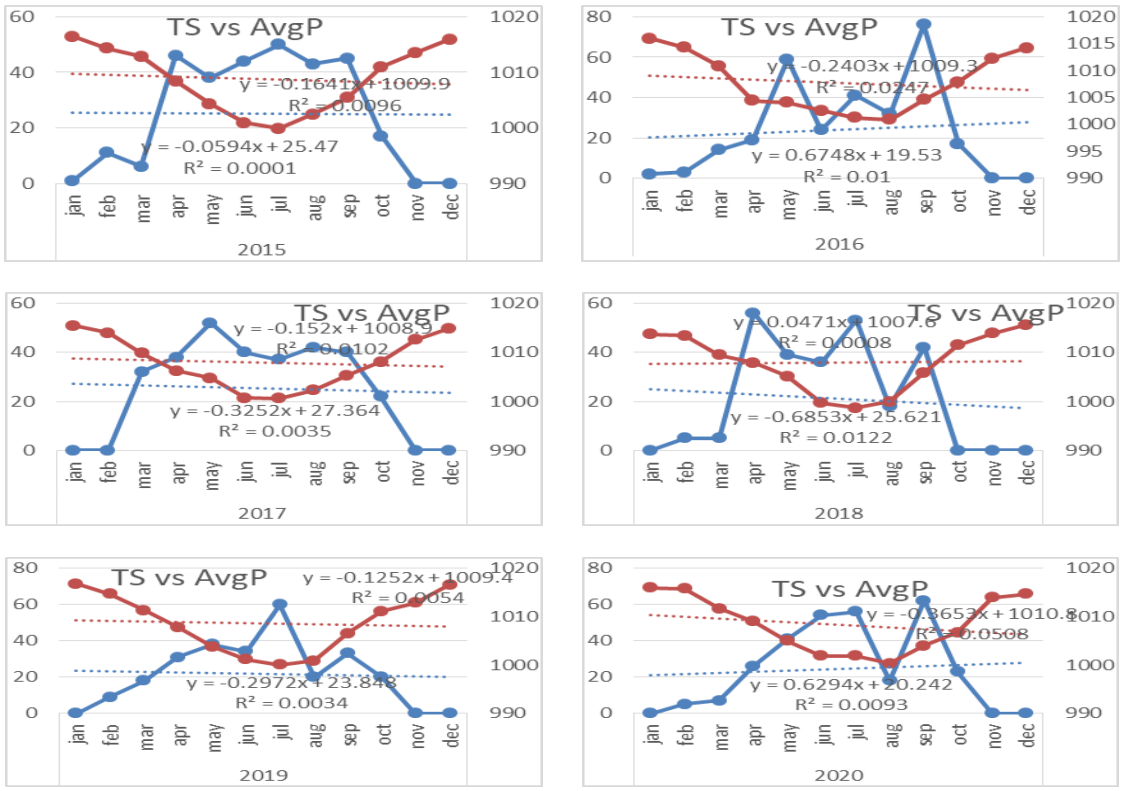

Fig. 12: Monthly variation of Thunderstorm with pressure in Rajshahi for 2015-2020

Interpreting the correlation coefficients, it can assess the relationships between the variables. Positive coefficients indicate a positive correlation, meaning that as one variable increases, the other tends to increase as well. Negative coefficients indicate a negative correlation, suggesting that as one variable increases, the other tends to decrease. The correlation of thunderstorms events, cloud coverage, relative humidity, dew point temperature, rainfall, maximum temperature and pressure are performed using python. The results of correlation are presented in figure 13.

From the results, it is found that cloud coverage, relative humidity and rainfall have positive correlation with thunderstorms and the values of them are 0.36, 0.21 and 0.55 respectively. On the other hand average dew point temperature, average maximum temperature and Pressure have negative correlation with thunderstorms and the values are -0.083, -0.39 and -0.28 respectively.

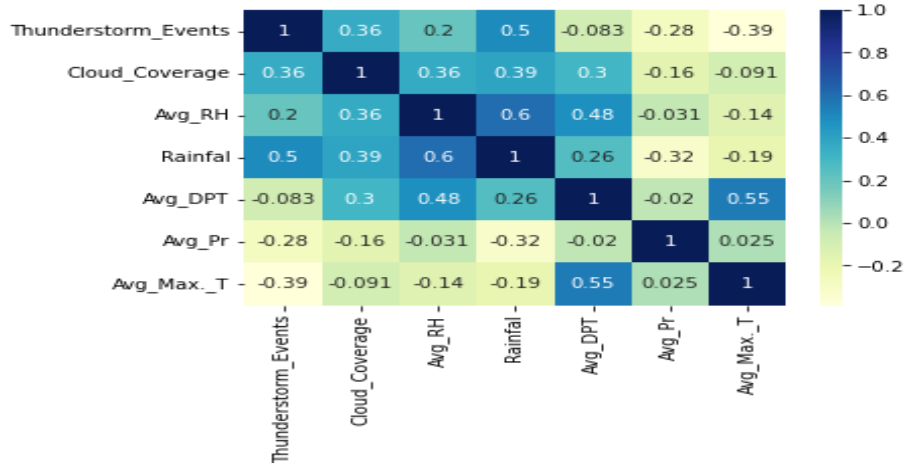

Fig. 13: Correlation coefficients of thunderstorms events, cloud coverage, relative humidity, dew point temperature, rainfall, maximum temperature and pressure within each other is performed

4. Conclusion

In conclusion, a comprehensive analysis of various meteorological parameters reveals insightful correlations with the occurrence of thunderstorms. Cloud coverage, relative humidity, and rainfall exhibit a positive correlation with the frequency of thunderstorm events. This signifies that higher levels of cloud coverage, relative humidity, and rainfall tend to create conditions conducive to thunderstorm formation. These factors contribute to the instability and convective processes necessary for thunderstorm development. On the other hand, average dew point temperature, average maximum temperature, and atmospheric pressure demonstrate a negative correlation with the occurrence of thunderstorms. Lower average dew point temperatures and maximum temperatures, along with decreased atmospheric pressure, indicate conditions that are less favorable for the initiation of thunderstorms. These parameters suggest a lack of necessary energy and moisture for the convective processes that drive thunderstorm formation. It is important to note that while these correlations provide valuable insights, thunderstorm formation is a complex interplay of numerous meteorological factors. Factors such as wind patterns, temperature gradients, and upper-level atmospheric conditions also play pivotal roles in the development and intensity of thunderstorms. A comprehensive understanding of these interactions is crucial for accurate weather prediction and mitigation of potential risks associated with thunderstorms.

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