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Study of Thunderstorms over a Madhya Pradesh Region, India

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Abstract:
Thunderstorms typically occurrence there is cumulonimbus clouds within the sky will be natural hazard and if they are severe. Most previous studies have focused on physical and dynamic structure of electrical storm with very little focus on exploring the trends of electrical storm incidence. In this paper, analysis of thunderstorms at five stations over a central Indian region (2000 to 2010) and focus only seasonal study of pre monsoon (March, April and May). The result of this study mostly thunderstorms appear in 2001, seasonal study of April, May and June 2001. In this paper studied condition of super cell appear in 10 June 2001 that day rainfall over a Bhopal station is 15.60 mm due to heavy rainfall and convective available potential energy value also is more than 4000 J/kg super cell condition will be generate.

1. Introduction

A thunderstorm also familiar as associate degree storm, a lightning storm, or a thundershower, is a style of storm characterized by the presence of lightning and its acoustic result on the Earth's atmosphere called thunder. Thunderstorms occur in association with a type of cloud called a cloud. They are sometimes among robust winds, heavy rain and generally snow, sleet, hail, or, in contrast, no precipitation at all. Thunderstorms may line up in a series or rain band, known as a polar front. Strong or severe thunderstorms might rotate, known as super cells. While most vertical wind shear causes a deviation in their course at a right angle to the wind shear direction.

Thunderstorms move with the mean wind flow through the layer of the layer that they occupy, result from the rapid upward movement of heat, moist air. They can occur within heat, moist air lots and at fronts. As the warm, moist air moves upward, it cools, condenses, and forms cumulonimbus clouds that will reach heights of over twenty kilometers. As the rising air reaches its temperature, water droplets and ice form and begin fall the long distance through the clouds towards the layer. As the droplets fall, they collide with other droplets and become larger. The falling droplets create a draught of cold air and wet that spreads out at the Earth's surface, causing the robust winds normally associated with thunderstorms, and occasionally fog.

There are four varieties of thunderstorms: single-cell, multicell cluster, multicell lines, and super cells. Super cell thunderstorms are the strongest and the most related to severe weather phenomena. Mesoscale convective systems formed by favorable vertical wind shear inside the tropics and climatic zone square measure accountable for the event of hurricanes. Dry thunderstorms, with no precipitation, can cause the occurrence of wildfires with the heat generated from the cloud-to-ground lightning that accompanies them. Several strategies square measure used to study thunderstorms, such as radiolocation, weather stations.

Bosart and Bluestein (2008) have investigated thunderstorm occur when cumulonimbus cloud appears in the sky due to convective system caused by a local or synoptic low pressure cell. Thunderstorms are a major storm type that includes lightning thunder and heavy rainfall in addition to extreme weather events such as hail, gusty winds and tornadoes (Lutgens and tarbuck, 2013; Ahrens, 2016). In the most severe situations, thunderstorms can create very destructive tornadoes and hurricanes (Sene, 2010; kunz et al., 2009). Severe thunderstorms can cause damage to agriculture, infrastructure facilities, building etc., whereas hail, heavy showers and surface gusty winds can result in significant losses in crop production as well as damage in rural and municipal region (Hyndman, 2009). A cumulonimbus clouds is categorized as a low cloud as its base height is less then 2000m, but this cloud can expand up to the tropopause when the intensity of the convective system is high (Barry and Chorley, 2009). On the other hand, the occurrence of thunderstorm can also have benefits for water production (Changnon, 2001). The other study of motion characteristic of thunderstorms was studied in the summer months from 1992 to 1996 in southern Germany and the result showed that CAPE of 583, 701 and 876 J/kg can be used to detect the stationarity, movement and line of thunderstorms (Hagen et al., 1999). Changnon and changnon (2001) studied days with thunderstorms were studied from 1896 to 1995 in the United States and it was concluded that significant positive trends existed in the west, while downward trends were found in the east. Study of thunderstorm activity during the Indian monsoon season (March to May) was explored from 1970 to 1980 and the possible influences of El Nino on thunderstorms occurrence was analyzed (Manohar et al., 1999). Thunderstorms days were analyzed 1974 to 2003 in southwest Germany and the relationship between vapor pressure, temperature and thunderstorms activity was interpreted (Kunz et al., 2009). Bielecbakowska (2003) studied in Poland, it was concluded that eastern advection had the largest effect on the occurrence of days with thunderstorms in the region. Analyzing thunderstorms from 1998 to 2007 in Finland revealed that there was no clear trend in days with thunderstorms during the period (Tuomi and Makela, 2008). Bielec (2001) analyzing thunderstorm occurrences in Cracow, Poland from 1986 to 1995 showed that days with thunderstorm usually occurred during cyclonic situations. In another study, variation of days with thunderstorms and structural formation of thunderstorms were studied in Belarus (Loginov et al., 2010). Analyzing 76 climatological stations and 26 perception station in Bulgaria during 1961 to 2006 showed that most of severe convective storms in this region were associated with cold fronts, cyclonical pressure field, and Mediterranean cyclones (Simeonov et al., 2009). Zheng et al. (2010) In China, analyzing data from 517 weather stations from 1980 to 2008 showed spatial and temporal variations in thunderstorms over the country. The result of research showed that the height frequency of thunderstorm occurrence was in June, May and October, at hourly series scale (Khalesi, 2014). Studying days with thunderstorms in three cities in southeast Brazil revealed that after 1951, there was a significant positive trend in thunderstorm activity, especially in Rio de Janeiro (Pinto et al., 2013). Allen and Karoly (2014) studied inter-annual variability of thunderstorms in Australia from 1979 to 2011 and the influences of ENSO on thunderstorm occurrence and focus on the warm season since severe thunderstorms occur at the time of year. In a recent study, the trend of severe thunderstorms was analyzed in the Atlanta, Georgia metropolitan region of United States (Paulikas, 2014). Pawar et al. (2010) studied at severe thunderstorm using radiosonde data to identify a useful indicator for lightning discharges. They found that lower positive charge centers (LPCC) play an important role in initiating lightning. Wei et al. (2011) trends, periodicity, spatiotemporal pattern and the distributions of thunderstorms events were studied in the Jiangsu province of China based on data sets for the period of 1951 to 2007. In a comprehensive study in United States, it was revealed that change in the frequency of thunderstorms were not significant based on report (Kunkel et al., 2013). In the eastern Tibetan Plateau, several instability indices (e.g. Showalter Index and K-index, etc) were used to study and forecast the high frequency occurrence of thunderstorms in that particular region (you et al., 2015). In another studied in India, the variability in thunderstorms associated with El Niño and La Niña was explored for the period of 1981 to 2005, and the result suggested that ENSO conditions change the pattern of thunderstorms activities over the country (Kulkarni et al., 2013). Enno et al. (2013) analyzing the thunderstorm climate of the Baltic countries using 59 weather stations during 1951 to 2000 showed that the mean annual no. of thunderstorm days in this region was around 12 to 29.5.

As can be seen, lots of studied thunderstorms over a world mostly focus on dynamic, synoptic and thunderstorm events. In this paper, Seasonal study (April, May and June) of five stations (Bhopal, Guna, Gwalior, Jabalpur and Sagar) at 2001 to 2010 over a central Indian region. According to IMD, Bhopal data thunderstorm mostly comes in 2001 at Bhopal station.

2. Data and Methodology

Thunderstorms and rainfall data collected from IMD, Bhopal and CAPE, wind speed, potential temperature and temperature data collected from http://weather.uwyo.edu/upperair/sounding.html. Many kind of thunderstorms occurrence obtained from the Indian Meteorological Department, Bhopal during the period from 2001 to 2010 (for five stations). A list of selected stations as shown in Table 1, according to data in 2001 mostly thunderstorms appear in 2001 in Bhopal as compare to other stations. In 2001 rainfall data as shown in table 2, Figure 1 shown the no. of thunderstorm occurrence over a Madhya Pradesh region 2001 to 2010, these data collected from IMD, according to data mostly thunderstorm produce a small Gwalior station but in these station CAPE and other value are not shows on the website, so Bhopal is capital of Madhya Pradesh all values are related to these data. Figure 3 shown no. of thunderstorms appears in Bhopal station 2001 to 2010. Mostly thunderstorms in 2001in April, May and June and few selected dates as shown in graph Figure 4,5,6,7,8,9 and 10. In April month CAPE value between 145 to 400 J/kg, May month value of CAPE is lie 837 to 1821 J/kg and June month maximum thunderstorms appears in this month 737 to 4371 J/kg. In May according to CAPE values there is moderately thunderstorm but in June month values are greater than 4000 it means possibilities of super cell. Thunderstorms have effects on environmental resource and thus knowledge regarding temporal and spatial trends of thunderstorms occurrence can be very useful for developing sustainable management plans (e.g. Halbe et al., 2013; Hable et al., 2014; Kolinjivadi et al., 2014; Straith et al., 2014; Bulter and Adamowski, 2015; Inam et al., 2015) such as in the scheduling of agricultural activities as well as in the development of urban protection plans.

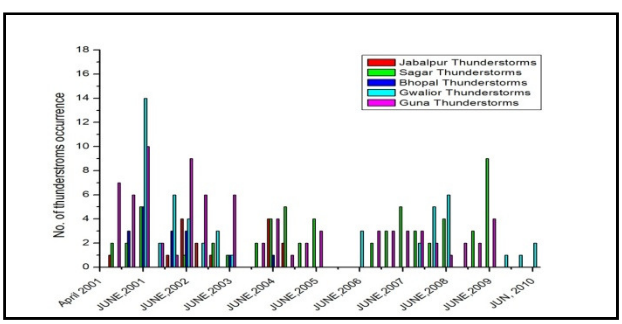

Figure 1: No. of thunderstorms over a Madhya Pradesh 2001 to 2010

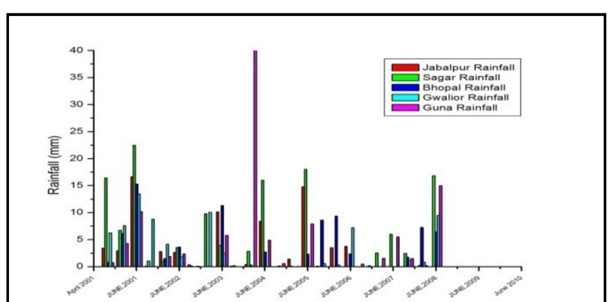

Figure 2: Rainfall occurrence over a Madhya Pradesh 2001 to 2010

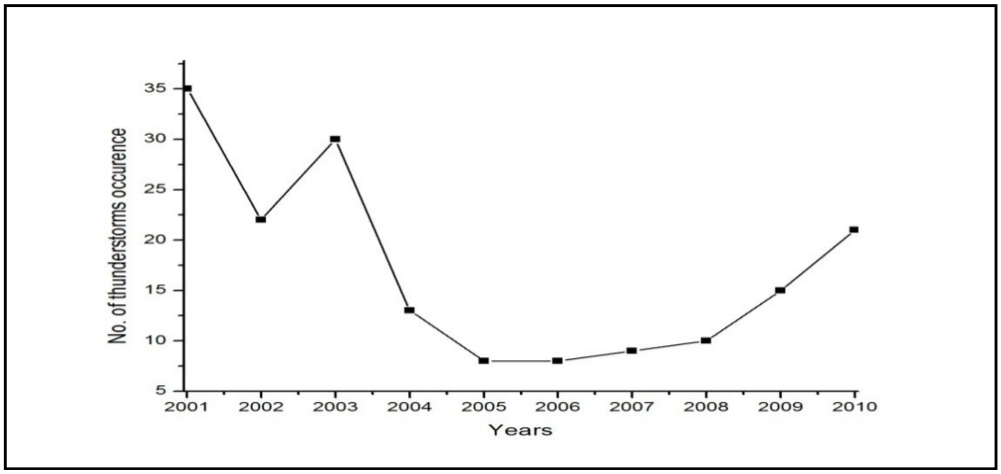

Figure 3: No. of thunderstorms 2001 to 2010 at Bhopal station

Date	Jabalpur		Sagar		Bhopal		Gwalior		Guna	
	Rainfall (mm)	No. of Thunder-storms	Rainfall (mm)	No. of Thunder-storms	Rainfall (mm)	No. of Thunder-storms	Rainfall (mm)	No. of Thunder-storms	Rainfall (mm)	No. of Thunder-storms
APRIL 2001	-				-		-		-	
JUNE 2001	16.65	28		30	15.34	35	-	34	-	30
MAY 2004	-	25	-	21		24	-	20	508.77	22
JUNE 2004	-	24	16.01	25	-	23	-	17	-	25
JUNE 2005	14.81	28	18.02	22	-	18	-	22	-	21
JUNE 2008	-	21	16.84	20	-	20	-	25	15.05	15

Table 1: Detail of Rainfall values >10mm

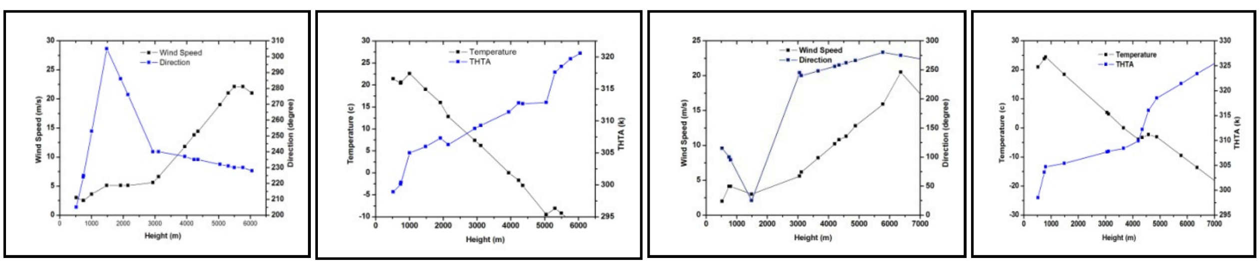

Figure 4: 17 April 00Z and 18 April 00Z

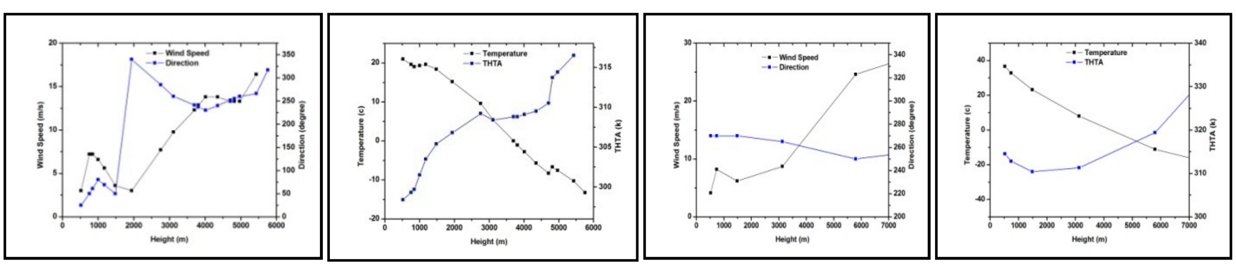

Figure 5: 19 April 00Z and 12 Z

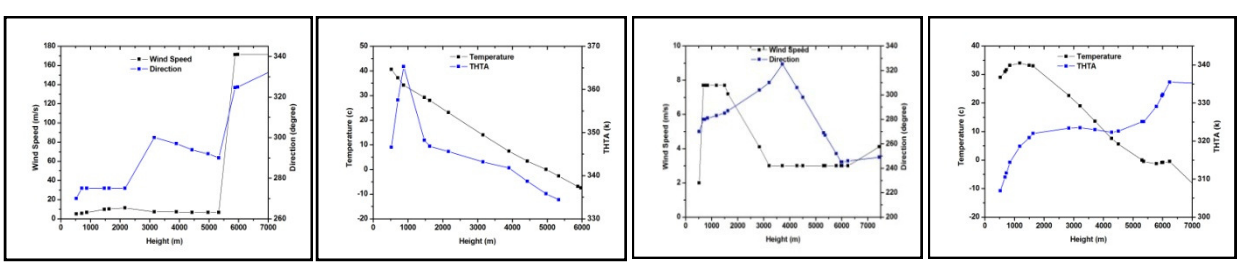

Figure 6: 14 May 12Z and 15 May 00Z

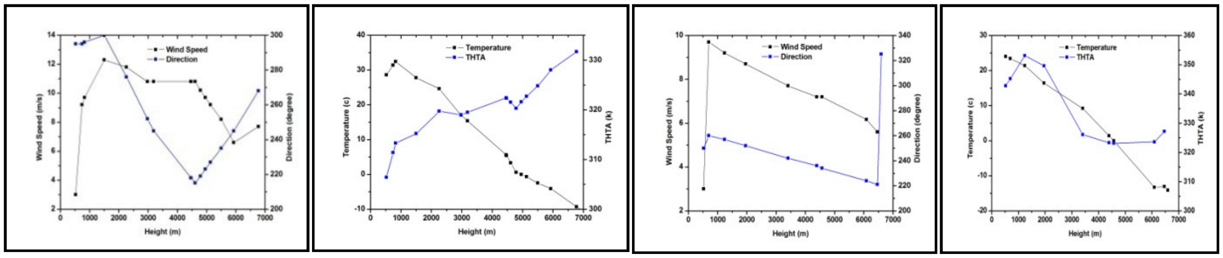

Figure 7: 16 May 00Z and 18 May 00Z

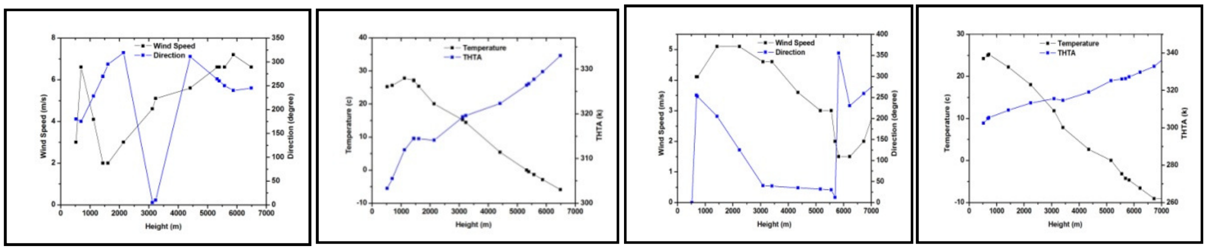

Figure 8: 7 June 00Z and 8 June 00Z

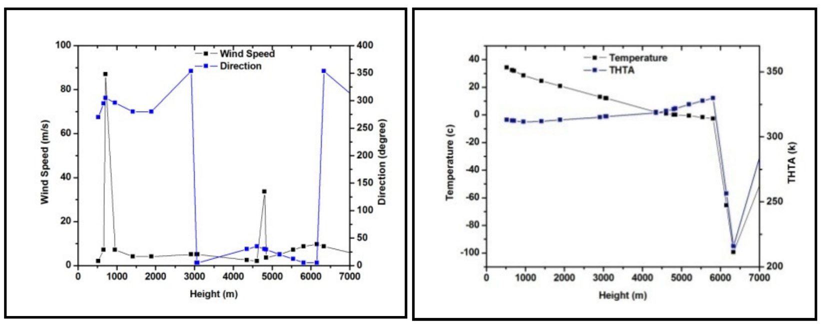

Figure 9: 10 June 12 Z

The thermodynamic parameters CAPE and different instability indices were evaluated from the IMD, Bhopal and radiosonde data from web.wheather.uywo.edu/sounding as per detail methodology describe in Babu (1996) based on the following equations

$$CAPE = -\int_{PLFC}^{PLNB} (T_{VP} - T_{VE}) R_d \, d(InP) \quad (1)$$

$$CINE = -\int_{PSurface}^{PLFC} (T_{VP} - T_{VE}) R_d \, d(InP) \quad (2)$$

Where P_{LFC} is level of free convective for the air parcel and P_{LNB} is level of neutral buoyancy for parcel, T_{ve} is the virtual temperature of the environment at pressure level P through which parcel rises, Tvp is the virtual temperature of the parcel and R_d is ideal gas constant for dry air.

Many studies were according on stability indices for the prediction of thunderstorms (Anthes.,1976; Neumann.,1971) explains application of various stability indices for prognostication of convective clouds. Throughout convective situations, temperature change of heat air within the lower levels and cold air within the higher levels increase the conditional instability affirmative the event of severe weather events (Rao.,1976; Rao et al., 1971). SI Showalter., 1953; LI (Galway., 1956; KI (George., 1990); TTI (Miller., 1972) values were computed using the subsequent equations

Showalter Stability Index: $SI = T_{500} - T_{p500}$ (3)

Where T_{500} is the dry bulb temperature at 500 hpa and T_{p500} is is parcel temperature at 500 hpa in which the parcel is being lifted from 950 hpa to LCL dry adiabatic and then saturated adiabatically from LCL to 500 hpa

Lifted Index: $LI = T_{500} - T_{p500}$ (4)

Were T_{500} is the dry bulb temperature at 500 hpa and T_{p500} is is parcel temperature at 500 hpa in which the parcel is being lifted from 950 hpa to LCL dry adiabatic and then saturated adiabatically to 500 hpa.

$KI = (T_{850} - T_{500}) + T_{d850} - (T_{700} - T_{d700})$ (5)

$TTI = T_{850} - T_{d850} - 2*(T_{500})$ (6)

Where T is the temperature and T_d is the dew point temperature at corresponding levels.

3. Result and Discussion

To see the temporal and spatial distribution of thunderstorms, data calculated seasonal month of year 2001, mostly appear thunderstorms in June month as compare to others months and there is possibilities of super cell according to CAPE values and in this month of May moderately condition of thunderstorms according to data. As shown in Table 3 rainfall data in 2001 of Bhopal station in June month lot of heavy rainfall as a result super cell also produced in this month. In 10 June 12Z temperature of that day is -100 c, THTA is 210 k, wind speed is 8 m/s and direction is 350 degree. Winds are coming from towards northerly direction and rainfall is 15.60 mm that day of Bhopal station.

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