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A STUDY OF THUNDERSTORM FEATURES OVER SRIKAKULAM REGION ON 26TH APRIL, 2020

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Abstract
Thunderstorms are the most destructive activities that pose a serious threat to mankind. The rainfall associated with these events cause heavy damage to crops, property and human lives. Studies analyzing these parameters have great significance. Srikakulam is one of the frequently exposed regions to intense thunderstorms during pre-monsoon season. An attempt has been made to study the thunderstorm features over Srikakulam region (18.34°N 83.9°E) using the ECMWF ERA5 reanalysis data. We examined the hourly data for the entire Andhra Pradesh (AP) region for the particular date (26th April, 2020). We used parameters like Lifted Index (LI), K-Index (KI), Humidity Index (HI), Convective Available Potential Energy (CAPE), Convective Inhibition (CIN), Thunderstorm Prediction Index (TPI) and Total precipitable water (TPW) for analyzing the thunderstorm activity. High rainfall activity was seen over Srikakulam region. Almost 16 cm rainfall occurred during thunderstorm activity. LI, HI, KI, CAPE, CIN, TPI and TPW parameters were indicated high threshold before 4 hours at the region of thunderstorm occurrence. CAPE values were greater than 3500 J/kg.

Keywords: Thunderstorm, Lifted Index (LI), Total precipitable water (TPW), Thunderstorm Prediction Index (TPI), ERA5.

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INTRODUCTION

Thunderstorms are interconnected with lightning, thunder, rainfall and blistery winds. When the warm moist air rises quickly to reach the cool dry air causes updraft which triggers the cumulonimbus clouds. The cool dry air present in the upper pressure levels of the atmosphere is the sinking place for warm air known as downdraft. Thunderstorm mainly occurs due to the interaction of updraft and downdrafts with cumulonimbus clouds. When the cloud bases are low, electric charge passes from cloud to ground lightning which causes severe damage to humans and infrastructure. The warm air present in updraft produces stun waves as a result of lightning [1]. The evolution of thunderstorm is of three steps. In first step, warm moist air rises in the development of updraft. This is called as cumulus stage of thunderstorm. In second step, the moist air condenses the ice crystals inside the cloud causing heavy precipitation. This is called as mature stage of thunderstorm. In third step, the downdraft of the thunderstorm dominates the updraft. This is called as dissipating stage [2].

Thunderstorms are classified as three types. They are single cell, multi-cell and super cell. Single cell thunderstorms are mostly seen in summer season. They develop due to intense heating of land surface. Disastrous convective events are not linked with single cell. The maximum duration of this type of thunderstorm is thirty minutes. High rainfall is usually observed in single cell thunderstorms. In multi-cell thunderstorm, two or more thunderstorms move together with their own phases of development. Sudden flooding, hails were usually observed in this thunderstorm event. Super-cell thunderstorms are the most violent thunderstorms which causes flash floods, high speed winds and tornadoes. A revolving updraft is usually observed in this type of thunderstorms leading towards severe damage [3].

Many research methods are utilized to study thunderstorms over different countries [2] studied the thunderstorm occurrence and its associated rainfall using Tropical Rainfall Measuring Mission (TRMM) satellite data. An attempt demonstrated the utilization of MODIS satellite for analyzing thunderstorms [4]. Studies by Bhatia and others illustrated the utilization of Indian geostationary satellite INSAT for the study of thunderstorms [5, 6]. An attempt depicted the significance of INSAT satellite data for investigating the thunderstorm activity during pre-monsoon and post-monsoon seasons [7]. Many climatological studies were carried out with the help of reanalysis datasets. These reanalysis datasets examine the present weather conditions using the past observations over the thunderstorm region [8].

Based on the above research works, an attempt has been done to analyze the thunderstorm event on April 26th, 2020. Parameters like K-Index (KI), Convective Available Potential Energy (CAPE), Convective Inhibition (CIN), Cloud base height (cbh) and Total precipitable water (TPW) were considered for the analysis of thunderstorm case study.

DATA

In this study, the complete analysis was done on the AP region which extends from 12-20° N latitudes and 75-85° E longitudes. Daily precipitation data from GPM IMERG final precipitation L3 1 day 0.1° by 0.1° V05 (GPM_3IMERGDF) was collected for the date 26th April, 2020 [9]. We have collected ECMWF ERA5 reanalysis data from the website https://climate. copernicus.eu/climate-reanalysis. ERA5 is the recent reanalysis data generated by ECMWF [10]. The ERA5 dataset has 0.25° spatial resolution at 37 pressure levels.

METHODOLOGY

By using temperature and relative humidity datasets from ERA5 re-analysis data, we have calculated dew point temperature parameter. Using temperature and dew point data at different pressure levels, we have computed different parameters using the formulae given below.

(i) K-Index (KI)

The K Index is the subtraction of temperature and dew point temperature at different pressure levels of the atmosphere as shown below [11].

KI = (Temp850–Temp500)+Tempd850–(Temp700–Tempd700) ---------- (1)

Where Temp represents temperature; Tempd represents dew point temperature.
If KI values are below 288 K there is no thunderstorm occurrence.
If KI values are ranging between 288 and 303 K, then there is a chance of 20-60% thunderstorm occurrence.
If KI values are ranging between 304 and 313 K, then there is a chance of 60-90% thunderstorm occurrence.
If KI values are above 313 K, then there is 90% chance for thunderstorm occurrence.
(ii) Lifted Index (LI)
This index is calculated to analyze the atmospheric conditions in the lower layers of troposphere. The LI threshold values are discussed below [12].
Lifted Index (LI)=$Temp_{500}$–$Temp_{parcel}$ --- (2)
Where Temp is the air temperature, $Temp_{parcel}$ is the parcel temperature that is lifted from surface to 500 hpa pressure level.
If LI values are greater than 2 K, then there is no thunderstorm occurrence.
If LI values are ranging between -2 and -4 K, then there is a chance of severe thunderstorm occurrence.
If LI values are below -4 K, then there is very high chance for severe thunderstorm occurrence.
(iii) Humidity Index (HI)
Humidity Index is a measure of water vapour availability at 850, 700 and 500 hPa pressure levels [13]. It is one of few indices which show the significance of relative humidity in the severe thunderstorm occurrences.
HI = (Temp-Tempd)850+(Temp-Tempd) 700+ (Temp-Tempd)500 ----------- (3)
Where Temp is temperature and Tempd is dew point temperature.
If HI values are below 30 K, then there is very high chance for severe thunderstorm occurrence.
(iv) Convective available potential energy (CAPE)
CAPE is determined by the below formula defined by [14]
$CAPE = \int_{Z_f}^{Z_n} g[\frac{T_{v,parcel}-T_{v,env}}{T_{v,env}}]\, dz$ --------- (4)
Where $T_{v,parcel}$ and $T_{v,env}$ represent the virtual temperature of the parcel and environment respectively. Z_f and Z_n denotes the level of free convection and neutral buoyancy.
The threshold values of KI parameter indicating the risk of severe weather activity.

CAPE	Thunderstorm chances
Less than 300 J/kg	little or no convective potential
Ranging between 300 and 1000 J/kg	weak convective potential
Ranging between 1000 and 2500 J/kg	moderate convective potential
Greater than 2500 J/kg	strong convective potential

If CAPE values are ranging between 0 J/Kg to 1000 J/Kg, then there is an indication for stable air mass condition. There is enough energy for the air mass to form a convective system. When the CAPE values range from 1000 J/kg to 2500 J/Kg, then the air masses are unstable. They contribute for severe weather which is an indication of atmospheric instability. When the values are above 2500 J/Kg then it is an indication for extreme unstable condition. The air parcels plays key role in this severe weather leading to the formation of tornadoes in some cases. When the CAPE values are higher, the air parcel instability also increases to extreme rising heights creating convective weather like tornado, thunderstorm, hail storm etc. CAPE is an estimation of energy calculated from air parcel temperature. It is measured in joules per kilo gram.

(v) Convective Inhibition (CIN):
CIN is determined by the below formula defined by [15]
CIN is defined as
$CIN = \int_{Z_l}^{Z_f} g[\frac{T_{v,parcel}-T_{v,env}}{T_{v,env}}]\, dz$ ----------- (5)
Where $T_{v,parcel}$ and $T_{v,env}$ represent the virtual temperature of the parcel and environment respectively. Z_f and Z_l denotes the level of free convection and surface level.
The threshold values of KI parameter indicating the risk of severe weather activity.

CIN values ranging	Thunderstorm chances
Less than 15 J/kg	Small chance for a thunderstorm development
15 – 50 J/kg	Small thunderstorms possible
15 – 50 J/kg	Moderate thunderstorms possible
Greater than 200 J/kg	Stability of stratification too high to overcome no thunderstorms develops

Convective inhibition is the energy needed for the atmosphere to make the air parcel rise due to convection at the region of thunderstorm occurrence. This is the ability of the cloud needed for the thunderstorm development.
(vi)Thunderstorm Prediction Index (TPI): This index is calculated by using the LI, CIN and CAPE parameters [16]
$TPI = \frac{CAPE}{2000} * \frac{-150}{CIN} * \frac{LI}{-5}$ ------------ (6)
If TPI values are above 1 K there is very high chance for severe thunderstorm occurrence.

RESULTS AND DISCUSSION

The hourly gridded rainfall data at 0.1 degree (~10 km) was collected for the AP region which is monitored for 24 hours on 26th April, 2020. From the analysis of daily rainfall data and comparison with thunderstorm reports, this case has been picked up and ERA5 reanalysis data pertaining to the thunderstorm study was collected and analysed. The results of this thunderstorm activity were presented below:

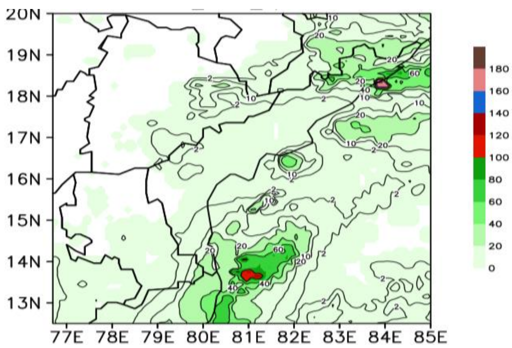

Fig.1 Spatial distribution of rainfall (mm) over AP on April 26th, 2020.

From Fig.1, high amount of rainfall activity was observed over Srikakulam district. The rainfall recorded was 17 cm. At 12UTC, the thunderstorm was at cumulus stage. It reached mature stage at 16UTC and dissipated by 20UTC. At 15UTC, the rainfall recorded was 0.2 mm. The mature stage was seen from 16UTC to 20UTC. During these four hours there was heavy downpour. At 21UTC, the thunderstorm reached dissipating stage. There was small showers of rain occurred due to thunderstorm activity over central and southern coastal places of AP. The rainfall around the southern and central places was below 4 cm. The exact location of severe precipitation was seen at 18.34°N and 83.9°E longitude.

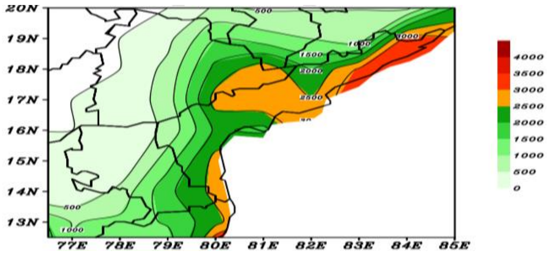

Fig. 2 Spatial distribution of CAPE (J/kg) at 12UTC over AP on April 26th, 2020.

The CAPE parameter was monitored for 24 hours. From Fig. 2, we can see that high CAPE values were seen at 12UTC around the region of intense thunderstorm activity. The CAPE values were above 2000 J/kg from the early morning hours. At 12UTC, the CAPE values reached 3000 J/kg and at the peak stage the CAPE value was 3500 J/kg and after 18UTC the CAPE values started decreasing. The CAPE values declined below 1500 J/kg during dissipating stage. The CAPE parameter indicated the severity of thunderstorm before 4 hours.

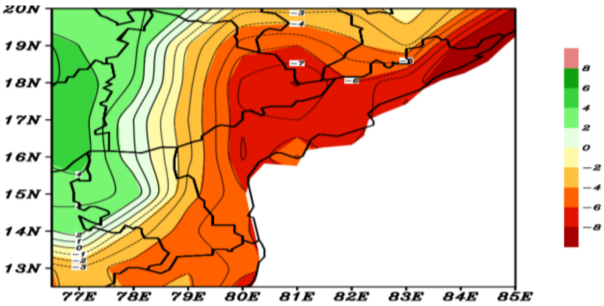

Fig. 3 Spatial distribution of LI (K) at 12UTC over AP on April 26th, 2020.

The LI parameter was examined for 24 hours. From Fig. 3, we can see that LI values were below -8 K at 12UTC which indicates the severity. LI values were below -4 before 0900 UTC. Later, the LI values decreased drastically around the region of intense thunderstorm activity. The LI values were below -3 K from the early morning hours. At 12UTC, the LI values decreased below -4 K around southern AP. The LI values were ranging between -6 and -8 across central AP. At the peak stage the LI values were below -8 K and later the LI values started increasing by 18UTC. The LI parameter indicated the severity of thunderstorm before 4 hours.

The KI parameter was analyzed for the entire day (24 hours). From Fig. 4, we can see that high KI values were seen at 12UTC around the region of intense thunderstorm activity. The KI values were above 305 K from the early morning hours. At 12UTC, the KI values reached 309 K and at the peak stage the KI value was 312 K and after 18UTC the KI values started decreasing. The KI values declined below 305 K. The KI parameter indicated the severity of thunderstorm before 4 hours.

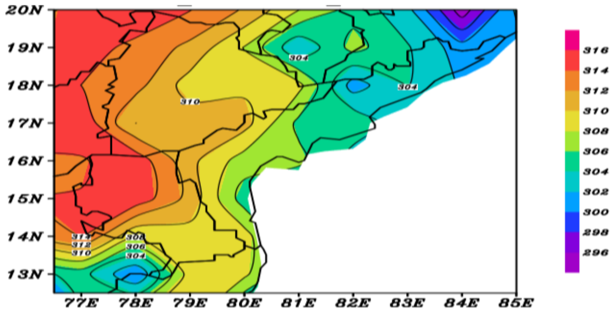

Fig. 4 Spatial distribution of KI (K) at 12UTC over AP on April 26th, 2020.

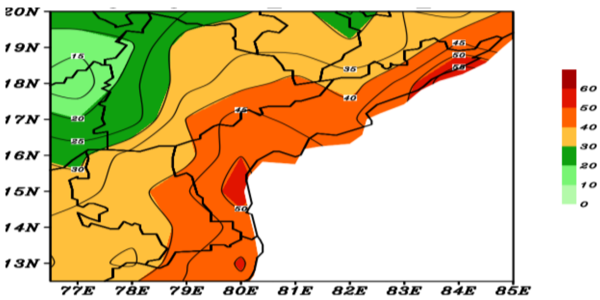

Fig. 5 Spatial distribution of TPW (mm) over AP on April 26th, 2020.

The TPW parameter was observed for the 24 hours. From Fig. 5, we can see that high TPW values were seen at 12UTC around the region of intense thunderstorm activity. The TPW values were ranging between 58 and 62 K over Srikakulam region. The TPW values were above 44 K from the early morning hours. At 12UTC, the TPW values reached 55 K and at the peak stage the TPW value was 58 K and after 18UTC the TPW values started decreasing. The TPW values declined below 42 K. The TPW parameter indicated the severity of thunderstorm before 4 hours. High availability of moisture was observed around central and southern parts of AP.

The HI parameter was examined for 24 hours. From Fig. 6, we can see that HI values were below 25 K at 12UTC which indicates the severity. HI values were below 40 K before 0900 UTC. Later, the HI values decreased drastically around the region of intense thunderstorm activity (Srikakulam). The HI values were below 38 K from the early morning hours. At 12UTC, the HI values decreased below 25 K around southern AP. The HI values were ranging between 30 and 40 K across central AP. At the peak stage the HI values were below 20 K and later the HI values started increasing by 18UTC. The HI parameter indicated the severity of thunderstorm before 4 hours.

The TPI parameter was studied for 24 hours. From Fig. 7, we can see that TPI values were above 2 K at 12UTC which indicates the severity. TPI values were above 1 K before 0900 UTC. Later, the TPI values increased drastically around the region of intense thunderstorm activity. The TPI values were above 1.5 K from the early morning hours. At 12UTC, the TPI values increased above 1 K around southern AP. The TPI values were ranging between 2 and 3 across central AP. At the peak stage the TPI values were above 3 K and later the TPI values started increasing by 18UTC. The TPI parameter indicated the severity of thunderstorm before 4 hours.

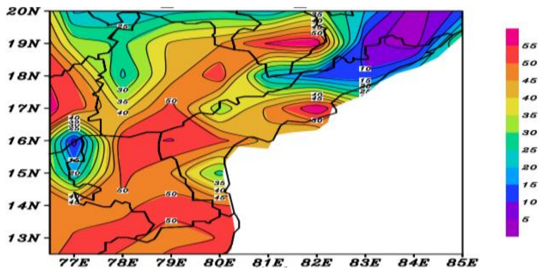

Fig. 6 Spatial distribution of HI (K) over AP on April 26th, 2020.

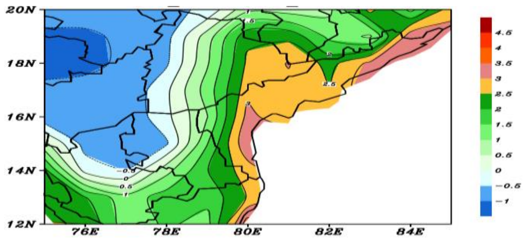

Fig. 7 Spatial distribution of TPI (K) over AP on April 26th, 2020.

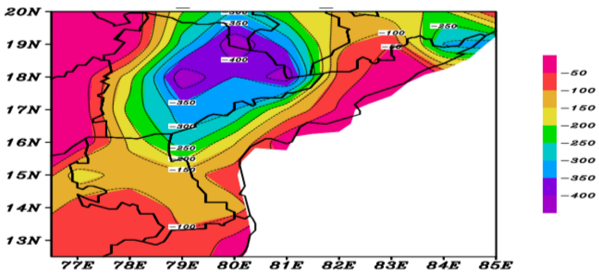

Fig. 8 Spatial distribution of CIN (J/kg) over AP on April 26th, 2020.

The CIN parameter was monitored for 24 hours. At 12UTC, we can see that CIN values were ranging between 0 and -50 J/kg (as shown in Fig. 8) over the Srikakulam region. The CIN values were above 120 J/kg from the early morning hours. At 12UTC, the CIN values started decreasing and at the peak stage the CIN value was -25 J/kg and after 18UTC the CIN values started increasing. The CIN values increased to 200 J/kg during dissipating stage. The CIN parameter indicated the severity of thunderstorm before 3 hours.

From Fig. 8, we can see that a sudden rainfall activity at 06UTC and CIN value at that instant was recorded -600 J/kg. At 10UTC the rainfall was 1.1 mm whereas CIN value was -200 J/kg. Later, it dissipated by 15UTC. The CIN values were high until 6UTC and a sudden decrement was clearly observed at 7UTC. By 7UTC the CIN values were decreasing rapidly and at peak rainfall activity the CIN value was -200 J/kg and it indicates good chance for a severe thunderstorm possibility. This indicates that CIN parameter was so helpful in estimating the severity of rainfall before 3 hours.

CONCLUSION

The thunderstorm activity which took place on April 26th, 2020 over the Andhra Pradesh region was monitored using ERA5 reanalysis data. There was good convective weather across central AP and southern AP which helped to record little showers of rain. All the parameters were calculated using the ERA5 reanalysis data which helped us in understanding the thunderstorm activity.

The Lifted Index and the TPW derived using ERA5 data showed high thresholds which cause intense rainfall activity. The LI values were less than -8 and TPW > 55 mm indicate the severity of thunderstorm activity.

The KI values were greater than 310 K where CAPE values indicated above 3500 J/kg. The CIN values were less than -35 J/kg significantly indicated an intense thunderstorm occurrence.

The TPI parameter has shown values above 2 K which is also indicating high chances for thunderstorm activity.

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