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Thunderstorms over A.P using INSAT- 3D Satellite Data

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Abstract: ***Extreme events related to severe thunderstorms have been increasing day by day in recent years over India. Due to the shorter span of occurrence, these events are tough to be predicted. To achieve this, we took the help of the satellite data. In this paper, we analysed the two severe thunderstorm cases in May 2019 by INSAT-3D satellite data. This satellite data helps us to monitor the convective cloud system every 30 minutes. Using this satellite data we are able to calculate the atmospheric indices like LI, KI, TTI and HI for every 30 minutes. These satellite derived atmospheric indices gives us a clear indication of development of Convective system before 3 -4 hours.***

Keywords: Thunderstorm, atmospheric indices, brightness temperature, rainfall.

I. INTRODUCTION

Thunderstorms are considered to be severe natural hazard that threatens today's world and also property. Although these are considered to be local scale phenomena, they damage agriculture, buildings, infrastructure with heavy rainfall, hail, gusts in less time period. [1] They can occur at anytime and anyplace throughout the globe. Recent study suggest that almost 2000 thunderstorms occur at any give time on the planet (http://www.nssl.noaa.gov/education/svrwx101/thunderstorms/). Usually thunderstorms occur in pre-monsoon and post-monsoon seasons. Their frequency is highest in pre-monsoon season over India. Moisture, atmospheric instability and parcel lifting are three elements which we observe during its occurrence. They are also likely to occur in post-monsoon season because of western disturbance effect. Atmospheric Instability is associated with the air which raises from lower levels of the atmosphere to the upper levels causing deep convection. This convection helps for the initial point for the development of thunderstorm. [2]Based on the differences between temperature and dew point temperature at different pressure levels, we can calculate some indices which drives as the basic indicators for the thunderstorm study. They can be calculated by radiosonde observations or forecasting models to predict thunderstorms [3-7]. The above studies analysed the relationship between these indices and thunderstorms. Studies by Jayakrishnan and Babu, 2014 [8] and Umakanth, 2019 [9] have calculated the stability indices from the satellite data for the real-time analysis of thunderstorm. INSAT-3D is an advanced weather satellite designed by ISRO, which has 6-channel imager and a 19-channel sounder as shown in Figure 1. Its main objective is to enhance the weather based observations over land and ocean. This satellite has better sensor features to capture the weather phenomena than the previous INSAT missions.

Figure 1 INSAT-3D satellite viewing Indian region

In this paper, we analysed the two severe thunderstorms by INSAT-3D satellite data. This helps us to monitor the convective cloud system every 30 minutes. Using this satellite data we are able to calculate the atmospheric indices like LI, KI, TTI and HI for every 30 minutes. These atmospheric indices gives us a clear indication of development of Convective system before 3 -4 hours.

II. DATA & METHODOLOGY

Data: INSAT -3D

In this paper, the area covering Andhra Pradesh which extends from 12-20 N and 75-85 E has been selected. The data from INSAT-3D satellite are collected at http://www.mosdac.gov.in/.

Methodology

2.2 Methodology

The formulas of different indices that are used for this work are discussed below.

(i) K-Index (KI): The K-Index is calculated by subtracting temperature and dew point temperature at 850, 700 and 500 hpa pressures levels as shown in below formula [8]:

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KI = (Temperature$_{850}$ – Temperature$_{500}$) + Dew Point Temperature$_{850}$ – (Temperature$_{700}$ – Dew Point Temperature $_{700}$) – (2)

where Temperature is the air temperature; Dew PointTemperature is the dew point temperature.

Thunderstorm Probability	K index (KI)
0%	<288
<20% unlikely	288-293
20-40% isolated thunderstorm	294-298
40-60% widely scattered thunderstorms	299-303
60-80% widespread thunderstorms	304-308
80-90% numerous thunderstorms	309-313
>90% chance for thunderstorms	>313

(ii) Total Totals Index (TTI):

This index is a integration of two totals. The total totals index is estimated by adding cross totals product and vertical totals product as shown in below formula. When TTI values are greater than 44K there is high chance for thunderstorm possibility.

Cross totals= **Dew Point Temperature** 850 –**Temperature** 500

Vertical totals = **Temperature** 850 – **Temperature** 500

Total totals, TT = Cross totals + Vertical totals = **Temperature** 850 + **Dew Point Temperature** 850 – 2**Temperature** 500 – (3)

The risk of severe weather activity is defined as follows:

Thunderstorm Probability	TT index (K)
Isolated moderate thunderstorm	44 – 45
Scattered moderate thunderstorms	46 – 47
Scattered isolated severe thunderstorms	48 – 49
Scattered severe thunderstorms	50 – 51
Scattered heavy thunderstorms	52 – 55
Numerous thunderstorms	>55

(iii) Lifted Index (LI):

This Index valuation is done to check the lower troposheric stability levels. LI values lesser than -2 are indication of thunderstorm occurrence [9].

Lifted index (LI) = $T_{500} - T_{parcel}$ -(4)

Occurrence of Thunderstorm	Lifted index (K)
No Thunderstorm activity	> 2
Probability of Thunderstorms	0 < LI < 2
possible for small Thunderstorms	-2< LI <0
Possible for moderate Thunderstorm	-4< LI <-2
Possible for Severe thunderstorms	LI <-4

III. RESULTS AND DISCUSSIONS

By analysing the thunderstorm reports and cloud images for May month 2019, we have identified two severe thunderstorm cases over Andhra Pradesh. INSAT-3D satellite data has been collected and analysed for the two cases. First we have calculated Brightness temperature from INSAT-3D IMAGER product for the clouds and the rainfall occurred using hydro-estimator rainfall data. Later using INSAT-3D Sounder data we have calculated different indices for studying the occurrence of thunderstorm. Results of the two cases of thunderstorm are presented as follows:

3.1 Case 1 (07 May 2019):

For identification of thunderstorm, INSAT-3D brightness temperature (BT) data and Rainfall (RF) data at half-hour interval was analysed and examined. The BT and RF plots in figure 2 clearly explains the three stages of thunderstorm i.e initial stage, mature stage and dissipating stage. The BT and RF values have shown no development of the thunderstorm till 0800 UTC. It started forming from 0830 UTC (Figure 2(a)) which intensified into a strong thunderstorm over Kunchanapalli region at 1030 UTC(Figure 2(b)). At this time, the BT value was 198.035K whereas RF value was 12.04 mm. This is considered as the peak stage of thunderstorm. It started dissipating slowly from 1130 UTC, completely dissipated by 1330 UTC(Figure 2(c)). From the RF plots shown in Figure 2(d-f) we identified that high rainfall activity in mature stage and no rainfall in other two stages. The sudden drop in BT values correspond to development of severe thunderstorm associated with rainfall **(Figure 2)**.

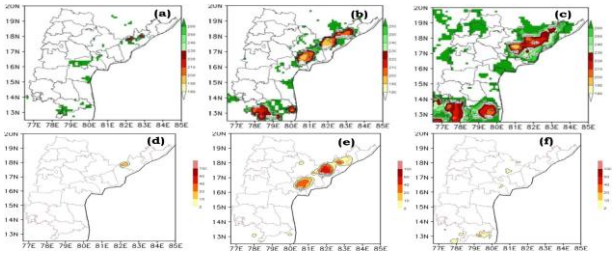

Figure 2: (a) - (c)Spatial distributions of BT (K) at (a) initial stage, (b) peak stage, (c) dissipating stage. (d) – (f) spatial distributions of Rainfall (mm) at (d) initial stage, (e) peak stage, (f) dissipating stage; all derived from INSAT-3D Imager satellite; all for May 07,2019.

Later we calculated LI, KI, TTI and TPW from INSAT-3D sounder as shown in Figure 3.These indices showed high threshold values for the occurrence of thunderstorm before 2-3 hours. At 0600 UTC, KI values showed almost 324K over the thuderstorm region which is 90% chance for severe thunderstorm (Figure 3(a)). LI values also dropped to -10K over the thunderstorm region which indicates a severe thunderstorm occurrence over the region (Figure 3(b)). TPW values were high such as 51mm which indicates high moisture availability for the thunderstorm over the region (Figure 3(c)). TTI values are also high which is of the order 55K indicating a heavy thunderstorm occurrence (Figure 3(d)). These indices helps us to understand the stability of the atmosphere.

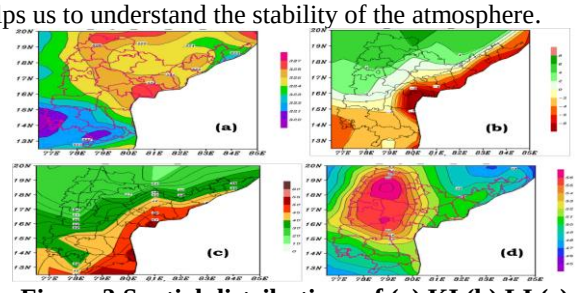

Figure 3 Spatial distributions of (a) KI (b) LI (c) TPW(mm) (d) TTI; all derived from INSAT-3D satellite for May 07,2019

3.2 Case 2 (14 May 2019):

In this case for identification of thunderstorm, the BT and RF values have shown no development of the thunderstorm till 0830 UTC. It started forming from 0900 UTC (Figure 4(a)) which intensified into a strong thunderstorm over Tirupati region at 1330 UTC(Figure 4(b)). At this time, the BT value was 213K whereas RF value was 20.54 mm. This is considered as the peak stage of thunderstorm. It started dissipating slowly from 1430 UTC, completely dissipated by 1700 UTC(Figure 4(c)). From the RF plots shown in Figure 4(d-f) we identified that high rainfall activity in mature stage and no rainfall in other two stages. The sudden drop in BT values correspond to development of severe thunderstorm associated with rainfall **(Figure 4)**.

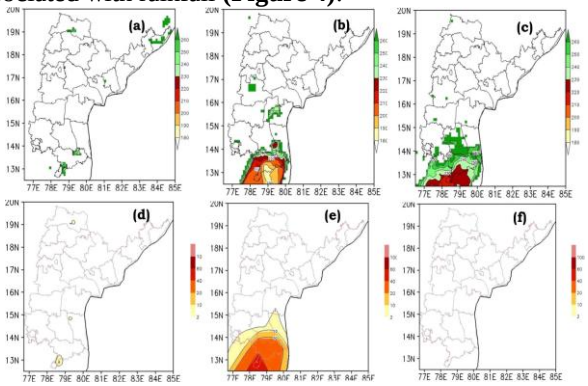

Figure 4: (a) - (c) Spatial distributions of BT (K) at (a) initial stage, (b) peak stage, (c) dissipating stage. (d) – (f) spatial distributions of Rainfall (mm) at (d) initial stage, (e) peak stage, (f) dissipating stage ; all derived from INSAT-3D Imager satellite; all for May 14,2019.

Later we calculated LI, KI, TTI and TPW from INSAT-3D sounder as shown in Figure 5.These indices showed high threshold values for the occurrence of thunderstorm before 3-4 hours. At 0600 UTC, KI values showed almost 325K over the thuderstorm region which is 90% chance for severe thunderstorm (Figure 5(a)). LI values also dropped to -8K over the thunderstorm region which indicates a severe thunderstorm occurrence over the region (Figure 5(b)). TPW values were high such as 48mm which indicates high moisture availability for the thunderstorm over the region (Figure 5(c)). TTI values are also high which is of the order 50K indicating a heavy thunderstorm occurrence (Figure 5(d)). These indices help us to understand the stability of the atmosphere.

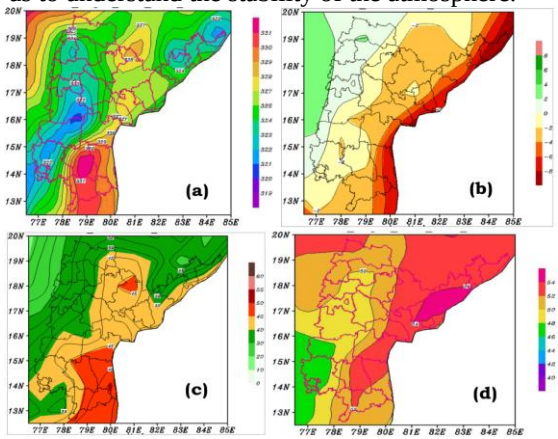

Figure 5 Spatial distributions of (a) KI (b) LI (c) TPW(mm) (d) TTI; all derived from INSAT-3D satellite for May 14,2019

IV. SUMMARY AND CONCLUSIONS:

In this paper, an attempt is made to analyse the BT, RF and indices from INSAT 3D satellite data products. These products helps us in identifying and analysing the thunderstorms before 2 – 3 hours. By analysing the thunderstorm reports and cloud images for May month 2019 we have identified two severe thunderstorm cases over Andhra Pradesh. INSAT-3D data has been collected and analysed for the two cases. The INSAT 3D brightness temperature data and rainfall at 30 minute interval were used to identify the occurrence and duration of convection. This is done to clearly understand the importance of indices calculated from INSAT-3D satellite in thunderstorm prediction. The indices calculated from INSAT-3D satellite shown in Table 1 have shown extreme usefulness of satellite in thunderstorm prediction. Negative values of LI less than -7; KI >317 K; TTI >50 K; TPW > 52 mm significantly indicate severe thunderstorm with associated rainfall.

Table 1

Cases	Date of Event	Region of Thunderstorm	Brightness Temperature (k)	Rainfall (mm)	Lifted-Index (k)	K-Index (k)	Total Precipitable Water (mm)	Total Totals Index (k)
Case-1	May 07, 2019	Kunchanapalli	198.03	12.04	-10.2	324.67	51.4	55.3
Case-2	May 14, 2019	Tirupati	213.14	20.54	-8.3	325.14	48.6	50.32

This study reveals the possibilities of increased utilisation of satellite data especially from INSAT 3D for thunderstorm studies over Andhra pradesh.

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