TEST Engineering & Management

May-June 2020
ISSN: 0193-4120 Page No. 917 - 922

Severe Thunderstorm Event over Hindol Region on 22nd April, 2012

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Article Info
Volume 83
Page Number: 917 - 922
Publication Issue:
May-June 2020

Article History
Article Received*: 11 August 2019*
Revised*: 18 November 2019*
Accepted*: 23 January 2020*
Publication*: 09 May 2020*

Abstract:
In this study, one case study was presented on Hindol region (20.61ºN 85.20ºE) by using the ECMWF ERA5 reanalysis data. The parameters like K-Index (KI), Total totals Index (TTI), Convective Available Potential Energy (CAPE), Convective Inhibition (CIN), Cloud base height (CBH) and Total precipitable water (TPW) have been used for analyzing the thunderstorm case study. Our attempt was to bring out the impact of thunderstorm influencing parameters on precipitation. Hindol region is located in Odisha state, India. KI, CAPE, TTI and TPW parameters were indicating high threshold before the occurrence of thunderstorm. CAPE values were greater than 2500 J/kg. TTI parameter value was also above 48 K which represents the severity of the thunderstorm. ERA5 satellite results are so useful in analyzing the thunderstorm events.

Keywords: *ERA5, Thunderstorm, Rainfall.*

I. INTRODUCTION

Thunderstorm is a combination of lightning and thunder. When the land surface is heated up by high temperatures, the warm moist air rises above surface which is identified as updraft. The cool dry air present in the upper pressure level sink in the downward direction called as downdrafts. Thunderstorms occur mostly in cumulonimbus clouds which is a result of the impact between updraft and downdraft. Nearly, 2000 thunderstorms occur at any time across the world. These storms are also referred as dangerous convective storms [1]. The development of thunderstorm takes place in three steps. In first step, a small development of updraft can be observed. This is called as initial stage of thunderstorm. In second step, the instability observed in initial stage intensifies and cause severe rains, lightning, thunder and speedy winds. This is called as mature stage of thunderstorm. In third step, the thunderstorm intensity decreases slowly and dissipates. This is called as dissipating stage. Even though, the mature stage of thunderstorm last for shorter time period, the damage will be huge [2].

In India, high temperatures are recorded during summer season. This summer season is known as pre-monsoon season. In pre-monsoon season, the air above the land surface rises due to intense heat. Upper level cool westerly winds influence most of the thunderstorm occurrences across the country. This hot air interacts with the cold air creating high instability leading for the occurrence of severe thunderstorm. The cool westerly winds are also

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known as Norwesters [3]. In general, the formation of thunderstorm activity can be identified using real-time satellite images over India. Thunderstorms are single cell and sometimes multi cell. Usually, single cell thunderstorms are observed in afternoon session of pre-monsoon season over India. Multi cell thunderstorms occur less when compared to single cell thunderstorms. These multi cell thunderstorms are a group of two or more thunderstorms which arrange in squall lines. This type of thunderstorms produce very intense rainfall and their cloud bases are nearer to earth surface and their cloud tops are nearer to tropopause. They cover vast area (~few hundred kms) and their life cycle prolongs for 6-12 hours [3]. There are many data sources available for analyzing thunderstorms for many countries. A research work by [2] indicated the usage of Tropical Rainfall Measuring Mission (TRMM) satellite data for measuring the thunderstorm related rainfall [4] explained the analysis of thunderstorm related convective systems with MODIS satellite. An attempt by [5] and [6] represented the study of thunderstorm related systems using Indian geostationary satellite INSAT [7] study showed the importance of INSAT satellite data for analyzing thunderstorms in pre-monsoon and post-monsoon season. Most of the climatological studies were done using reanalysis datasets. These reanalysis datasets use the past observations to study the weather conditions in order to understand the present weather condition [8].

The above mentioned research works gave the required knowledge needed to make an attempt to study the thunderstorm case study over Hindol, Odisha on April 22nd, 2012. Parameters like K-Index (KI), Total totals Index (TTI), 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.

II. DATA

In this study, the complete analysis was done on the Hindol region at 20.61°N and 85.20°E. 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 [9]. The ERA5 dataset has 0.25° spatial resolution at 37 pressure levels.

III. METHODOLOGY

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

(i) K-index (KI): The K-index calculation is performed using temperature and dew point temperature terms which are obtained at different pressure levels as shown below [10]:

$$\mathbf{KI = (te_{850} - ted_{500}) + ted_{850} - (t_{700} - ted_{700})} \text{ --- (1)}$$

where te is the temperature; ted is the 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 there is 90% chance for thunderstorm occurrence.

(ii) Total Totals Index (TTI):

This index is estimated by using the formula shown below [11]

$$TTI = te_{850} + ted_{850} - 2te_{500} \quad \text{-----} \quad (2)$$

When TTI values are larger than 44 K then there's high probability for thunderstorm occurrence.

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(iii) Convective available potential energy (CAPE)

CAPE is determined by the below formula defined by [12]

$$CAPE = \int_{Z_f}^{Z_n} g[\frac{T_{v,parcel} - T_{v,env}}{T_{v,env}}]\, dz \quad \text{---------- (3)}$$

Where $T_{v,parcel}$ and $T_{v,env}$ represents the virtual temperature of the parcel and environment respectively. Z_f and Z_n denotes the level of free convection and neutral buoyancy. When CAPE values ranges between 2000 and 2500 J/kg, then there is high chance for severe thunderstorm.

(iv) Convective Inhibition (CIN):

CIN is determined by the below formula defined by [13]

CIN is defined as

$$CAPE = \int_{Z_l}^{Z_f} g[\frac{T_{v,parcel} - T_{v,env}}{T_{v,env}}]\, dz \quad \text{---------- (4)}$$

Where $T_{v,parcel}$ and $T_{v,env}$ represents the virtual temperature of the parcel and environment respectively. Z_f and Z_l denotes the level of free convection and surface level.

The data for cbh, TPW and rainfall are estimated by the ERA 5 data.

IV. Results and Discussion

The hourly rainfall data was collected for the Hindol region of Odisha state which is monitored for 24 h on 22nd, April, 2012. 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 case study was collected and analysed. The results of the case study were presented below:

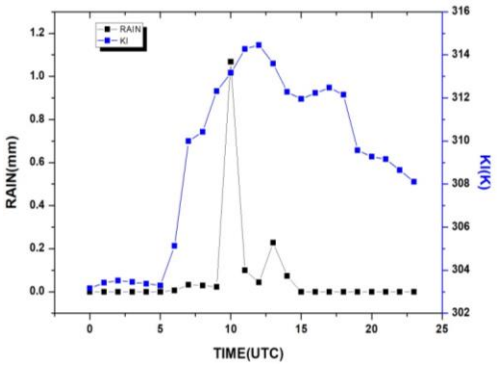

Fig. 1 Hourly variations of rainfall and KI.

From Fig.1, we can see that a sudden rainfall activity at 8UTC and it reached peak at 10UTC and dissipated by 15UTC. At 08UTC, the rainfall recorded was 0.1 mm and at 10UTC the rainfall was 1.1 mm.

The KI values were low until 5UTC and a sudden increment was clearly observed at 6UTC and KI values were increasing rapidly and at peak rainfall activity the KI value was 315 K which indicates 90% chance for a severe thunderstorm occurrence. The KI values were also terminated slowly along with rainfall. This indicates that KI parameter was effective in estimating the severity of rainfall before 5 h.

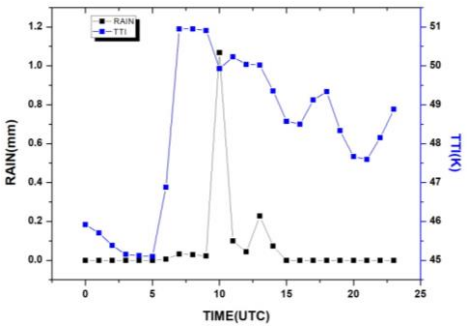

Fig. 2 Hourly variations of rainfall and TTI.

From Fig.2, we can see that a sudden rainfall activity at 08UTC and TTI value at that instant was recorded as 51 K. At 10UTC the rainfall was 1.1 mm whereas TTI value was 50 K. Later, it dissipated by 15UTC. The TTI values were low until 5UTC and a sudden increment was clearly observed at 6UTC similar to KI parameter.

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By 7UTC the TTI values were increasing rapidly and at peak rainfall activity the TTI value was 51 K which indicates good chance for a severe thunderstorm. The TTI values were also reduced gradually similar to rainfall. This indicates that TTI parameter was so helpful in estimating the severity of rainfall before 5 hours.

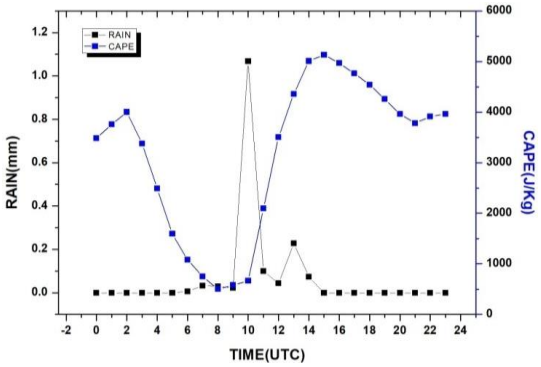

Fig. 3 Hourly variations of rainfall and CAPE.

From Fig.3, we can see that a sudden rainfall activity at 06UTC and CAPE value at that instant was recorded as 1000 J/kg. At 10UTC the rainfall was 1.1 mm whereas CAPE value started increasing from 2000 J/kg. Later, it dissipated and again it increased by 13UTC. The CAPE values were low until 4UTC and a sudden increment was clearly observed at 10UTC. By 13UTC the CAPE values were indicating ~4000 J/kg.

The CAPE values greater than 2500 J/kg indicate very high chance for a severe thunderstorm. The CAPE values indicated very high chances for severe thunderstorm occurrence. A lot of energy was observed.

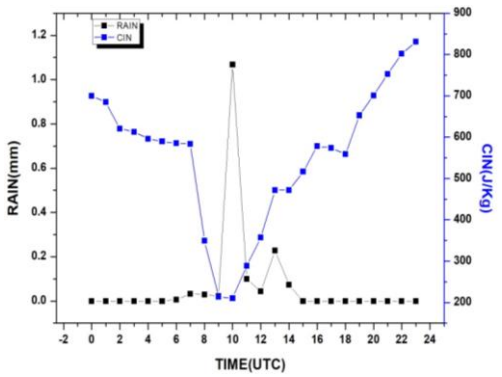

Fig. 4 Hourly variations of rainfall and CIN.4

From Fig.4, we can see that a sudden rainfall activity at 06UTC and CIN value at that instant was recorded as -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 -200J/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 h.

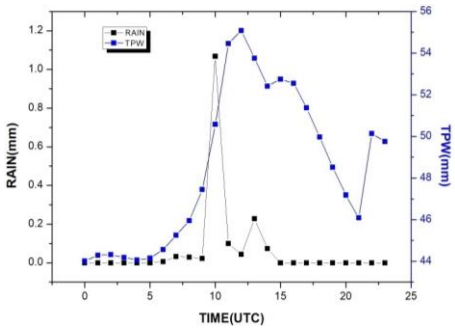

Fig. 5 Hourly variations of rainfall and TPW.

From Fig. 5, we can see that a sudden rainfall activity at 06UTC and TPW value at that instant was recorded as 44 mm. At 10UTC the rainfall was 1.1 mm whereas TPW value was 55 mm. Later, it dissipated by 15UTC. The TPW values were low until 5UTC and a sudden increment was clearly observed at 6UTC. By 7UTC the TPW values were increasing rapidly and at peak rainfall activity the TPW value was 56 mm which indicates good chance for a severe thunderstorm. The TPW values were also reduced gradually similar to rainfall. This indicates that TPW parameter was so helpful in estimating the severity of rainfall before 4 h.

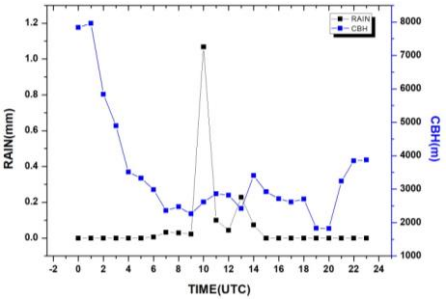

Fig. 6 Hourly variations of rainfall and cbh.

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From Fig.6, we can see that a sudden rainfall activity at 06UTC and cbh value at that instant was recorded as 3000m. At 10UTC the rainfall was 1.1 mm whereas cbh value was 2500 m. Later, it dissipated by 15UTC. The cbh values were high until 4UTC and a sudden decrement was clearly observed at 5UTC. By 7UTC the cbh values were increasing rapidly and at peak rainfall activity the cbh value was 2500 m which indicates low cloud base nearer to earth surface causing heavy rainfall at the thunderstorm region. The cbh values were also increased gradually as rainfall dissipated. These parameters indicate the height of the cloud.

The cbh is an important atmospheric parameter which plays a crucial role in aviation sector. Most of the local thunderstorm activities are related to the clouds. When the cloud bases are low, the chance for condensation is high [14].

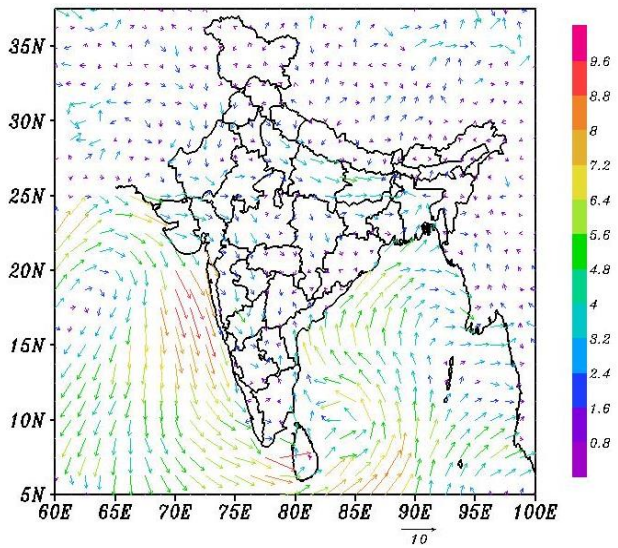

Fig. 7 Spatial plot of total precipitable water interpolated with wind vectors over Virajpet at 14UTC on 22nd April, 2012.

We have generated the vector plot of wind data using ECMWF ERA5 data to study the dynamics related to the thunderstorm occurrence on Hindol region. From Fig.7, we can see a clear anticyclone in Bay of Bengal Sea. The high speed anticyclonic winds are flowing towards north Andhra Pradesh and Odisha state. The low speed cool winds from north-western and central India are meeting with the warm moist air. A trough was observed across the coastal regions of south peninsular India.

V. CONCLUSION

A single cell thunderstorm case study which occurred on April 22nd, 2012 over Hindol, Odisha was analyzed in this work. The parameters based on temperature and dew point temperature values were calculated and retrieved from ERA5 reanalysis data. This ERA5 data was so helpful in now casting of thunderstorm cases.

KI and TTI parameters revealed the occurrence of severe thunderstorm before 5 h whereas CIN, TPW indicated the thunderstorm possibility before 3 h. High CAPE value is a good indication for the occurrence of intense thunderstorm occurrence.

VI. Acknowledgment

The authors are thankful to ECMWF ERA5 reanalysis data, UK for providing the data. This paper was financially supported by CSIR-SRF fellowship, sponsored by Govt. of India with sanction no. - **09/1068(0001)/2018-EMR-I**.

REFERENCES

1. Rahman, Shah Md Mahfuzur, Shah Monir Hossain, and Mahmood-uz Jahan. "Thunderstorms and lightning in Bangladesh." *Bangladesh Medical Research Council Bulletin* 45, no. 1 (2019): 1-2.
2. Houze, R. A. Jr., Wilton D. C. and Smull, B. F., 2007, “Monsoon convection in the Himalayan region as seen by the TRMM Precipitation Radar”, Quart. J. Roy. Meteor. Soc., 133, 1389-1411.
3. Tyagi, A., Sikka, D.R., Goyal, S. and Bhowmick, M., 2012. A satellite based study of pre-monsoon thunderstorms (Nor’westers) over eastern India and their organization into mesoscale convective complexes. *Mausam*, *63*(1), pp.29-54.
4. Jayakrishnan, P.R. and Babu, C.A., 2013. Assessment of convective activity using stability indices as inferred from radiosonde and MODIS data. *Atmospheric and Climate Sciences*, *2014*.
5. Bhatia, R. C. and Kalsi, S. R., 1992, “Satellite observations of development of thunderstorm

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ISSN: 0193-4120 Page No. 917 - 922

complexes in weakly forced environments", Vayumandal, 22, 3-4, 65-76.

6. Mukhopadhyay, P., Sanjay, J., Cotton, W. R. and Singh, S. S., 2005, "Impact of surface meteorological observations on RAMS forecasting of monsoon weather systems over Indian region", Meteorol. Atmos. Phys., 90, 77-108.
7. Laing, A. G., and J. M. Fritsch, 1997: The global population of mesoscale convective complexes. Quart. J. Roy. Meteor. Soc., 123, 389–405, https://doi.org/10.1002/qj.49712353807.
8. Thorne, P. W., and R. S. Vose, 2010: Reanalyses suitable for characterizing long-term trends. Bull. Amer. Meteor. Soc., 91, 353–361, https://doi.org/10.1175/2009BAMS2858.1.
9. Hersbach, H., Dee, D., 2016. ERA5 reanalysis is in production. ECMWF Newsletter No. 147, 7.
10. George, J. G., 1960 "Weather Forecasting for Aeronautics," *Academic Press*, p. 673.
11. Miller RC (1967) Notes on analysis and severe storm forecasting procedures of the Military Weather Warning Center. Tech. Report 200, AWS, USAF.
12. Moncrieff MW & Miller MJ (1976) The dynamics and simulation of tropical cumulonimbus and squall lines. Quarterly Journal of the Royal Meteorological Society, 102(432), 373-394.
13. Parker DJ (2002) The response of CAPE and CIN to tropospheric thermal variations. Quarterly Journal of the Royal Meteorological Society: A journal of the atmospheric sciences, applied meteorology and physical oceanography. 128(579) 119-130.
14. Xu, J., Liu, D., Wang, Z., Wu, D., Yu, S. and Wang, Y., 2019. A Study of the Characteristics of Vertical Cloud Base Height Distribution over Eastern China. *Atmosphere*, *10*(6), p.307.