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Review Article

INFLUENCE OF CONVECTIVE WEATHER RELATED PARAMETERS ON RAINFALL OVER VIRAJPET REGION ON 26 APRIL 2013

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Abstract
In the present paper, one case study was presented on Virajpet region (12.25°N 75.97°E) by using ECMWF ERA5 reanalysis data. Our attempt was to bring out the interconnection of rainfall with convective based weather parameters over Virajpet region. Virajpet region is located in Karnataka state, India. We have made use of few convective based weather parameters such as k Index (kI), Total Totals Index (TTI), Convective Available Potential Energy (CAPE), Convective Inhibition (CIN), cloud base height (cbh) and total precipitable water (TPW) for studying their impact on rainfall. KI, CAPE, TTI and TPW parameters were indicated high threshold before the occurrence of convective system. The results indicated the importance of ERA5 reanalysis data in analyzing the convective weather events.

Keywords: Mesoscale convective system, rainfall, ERA5.

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INTRODUCTION

Mesoscale convective system (MS) is a cloud linked system that brings heavy precipitation over a region which covers large area (~100 km) spatially (1). These are commonly linked to cumulonimbus clouds. In some cases, a single convective system group with other convective system to form into a bigger system which lasts for longer duration (more than 3 h). These systems account for the majority of the intense rainfall events (2). These systems are also referred as largest convective storms and in few cases they also become mesoscale circulation (3-4). (5) reported that MS's are a result of high speed westerlies which causes upward motion of air to occur. A study by (6) reveals the comparisons between rapidly developing and slowly developing MS's. (7) concluded that upper level troughs are very important for the initiation of MS's. These systems account for 50% of summer season rainfall in USA (8).

These systems have three stages. (i). Initial stage: In this stage, the development of convective system starts. A small updraft can be observed. (ii). Mature stage: At this stage, the complete development of system can be seen. We usually observe updrafts and downdrafts in this stage. Speedy winds with heavy precipitation may take place. (iii). Dissipating stage: The intensity of the system reduces gradually. Downdrafts are seen at this stage. In some cases, the dissipating stage of one system triggers the near by new system causing more damage.

(5) reported that sometimes MS prolong for longer time duration with intense quasi circulation. This situation was referred as mesoscale convective complex.

According to (1) MS structure is linked with rising motion of warm air above the earth surface. It also relates to the descending motion of –ve air. Large MS's are seen over Pacific ocean

In Indian sub-continent, land surface gets heated up during day time which leads to the convection initiation. This intense heating occurs across central India and few other parts of the country. This is triggered by combining with the moist low level air mass from Bay of Bengal. Normally, these systems start developing during day time and dissipate in the evening hours or night time. Sub-tropical upper level westerly flow at 500 hpa and lower level moist winds provide upper level divergence and lower level convergence which tends to the formation of norwesters. These norwesters helps the convective systems over India during pre-monsoon season. These norwesters impose strong effects on northeastern states and hilly places for the convection to take place. The MS's formed over India during this pre-monsoon season have very tall giant clouds with their top touching tropause and their bottom close to earth surface. This type of clouds have heavy downpour which leads to flash floods. (9).

Many research works are carried out on MS's in tropical countries (10-11). (12-13) studies reveal the general life cycle of MS and he also studied few MS events over sumatra and Java using satellite data. There are some research studies reflecting the convective systems over India. (14) reported the occurrence of a tornado on April 8th, 1838 which was a result of the high speed westerly winds (norwesters). A researcher named (15) made the first attempt to study the convective system during the pre-monsoon season over India. High availability of convective available potential energy plays a crucial role in pre-monsoon convective system over India (16). The data Tropical Rainfall Measuring Mission (TRMM) satellite helped a lot for the estimation of convective relation rainfall (17) . The evolution of MS's was studied using INSAT satellite data by (18) and (19). A research work by (20) reveals the usage of INSAT satellite data for studying the cloud developments for every 3 h during pre-monsoon and post-monsoon seasons in the year 1988.

From the knowledge acquired by reading the above research works, we made an attempt to analyze a mesoscale convective system over Virajpet, Karnataka on April 26th, 2013. Convective based weather parameters such as 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 studied using ECMWF ERA5 reanalysis data.

DATA

In this study, the complete analysis was done on the Virajpet region at 12.25°N and 75.97°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 (21). The ERA5 dataset has 0.25° spatial resolution at 37 pressure levels.

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 formulae 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. (22):

kI = (te_{850} – ted_{500}) + ted_{850} – (t_{700} – ted_{700}) --------- (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 (23)

TTI = te_{850} + ted_{850} – 2te_{500} ------- (2)

When TTI values are greater than 44 K there is high chance for thunderstorm possibility.

(iii) Convective available potential energy (CAPE)

CAPE is determined by the below formula defined by (24)

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

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 there is high chance for severe thunderstorm.

(iv) Convective Inhibition (CIN):

CIN is determined by the below formula defined by (25)

CIN is defined as

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

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.

RESULTS AND DISCUSSION

The hourly rainfall data was collected for the Virajpet region of Karnataka which is monitored for 24hours on 26th, April, 2013. 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 was presented below:

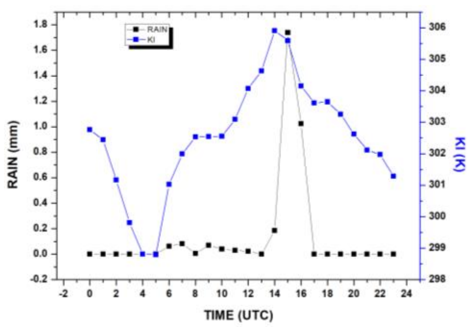

Fig. 1 Hourly variations of rainfall and KI.

From Fig.1 we can see that a sudden rainfall activity at 13UTC and it reached peak at 15UTC and dissipated by 17UTC. At 13UTC, the rainfall recorded was 0.2 mm and at 15UTC the rainfall was 1.8 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 305 K which indicates 90% chance for a severe convective system. The kI values were also reduced gradually similar to rainfall. This indicates that kI parameter was so helpful in estimating the severity of rainfall before 3 h.

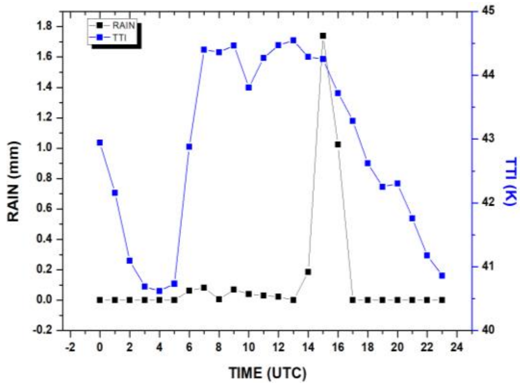

Fig. 2 Hourly variations of rainfall and TTI.

From Fig.2, we can see that a sudden rainfall activity at 13UTC and TTI value at that instant was recorded as 44 K. At 15UTC the rainfall was 1.8 mm whereas TTI value was 45 K. Later, it dissipated by 17UTC. The TTI values were low until 5UTC and a sudden increment was clearly observed at 6UTC similar to kI parameter. By 7UTC the TTI values were increasing rapidly and at peak rainfall activity the TTI value was 44.5 K which indicates good chance for a severe convective system. 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 6 h.

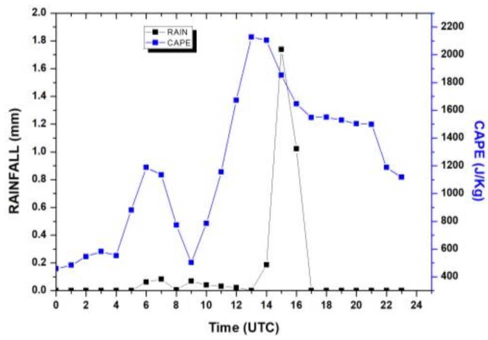

Fig. 3 Hourly variations of rainfall and CAPE.

From Fig.3 we can see that a sudden rainfall activity at 13UTC and CAPE value at that instant was recorded as 2100 J/kg. At 15UTC the rainfall was 1.8 mm whereas CAPE value was 1900 J/kg. Later, it dissipated by 17UTC. The CAPE values were low until 4UTC and a sudden increment was clearly observed at 5UTC similar to kI parameter. By 7UTC the CAPE values were increasing rapidly and at peak rainfall activity the CAPE value was ~2000 J/kg which indicates good chance for a severe convective system. The CAPE values were also reduced gradually similar to rainfall. This indicates that CAPE parameter was so helpful in estimating the severity of rainfall before 3 h.

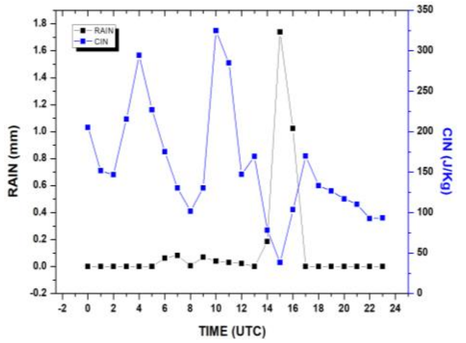

Fig. 4 Hourly variations of rainfall and CIN.

From Fig.4, we can see that a sudden rainfall activity at 13UTC and CIN value at that instant was recorded as -75 J/kg. At 15UTC the rainfall was 1.8 mm whereas CIN value was -25 J/kg. Later, it dissipated by 17UTC. The CIN values were high until 4UTC and a sudden decrement was clearly observed at 5UTC. By 7UTC the CIN values were decreasing rapidly and at peak rainfall activity the CIN value was -25 J/kg and it indicates good chance for a severe convective system. This indicates that CIN parameter was so helpful in estimating the severity of rainfall before 3 hours.

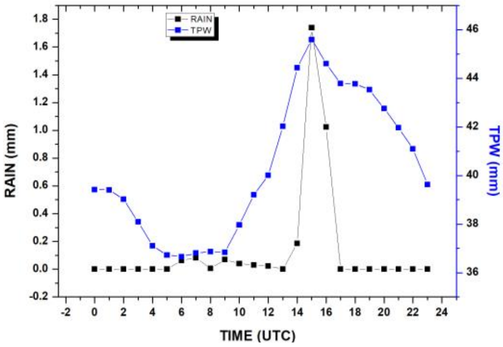

Fig. 5 Hourly variations of rainfall and TPW.

From Fig.5, we can see that a sudden rainfall activity at 13UTC and TPW value at that instant was recorded as 42 mm. At 15UTC the rainfall was 1.8 mm, whereas TPW value was 45 mm. Later, it dissipated by 17UTC. The TPW values were low until 4UTC and a sudden increment was clearly observed at 5UTC similar to kI parameter. By 7UTC the TPW values were increasing rapidly and at peak rainfall activity the TPW value was 46mm which indicates good chance for a severe convective system. 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 3 h.

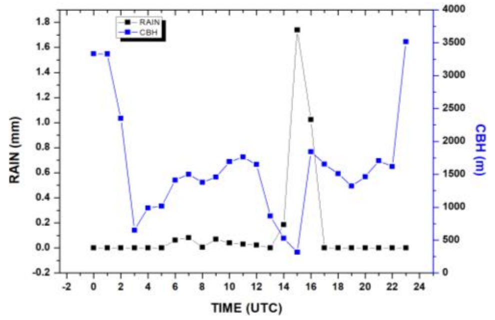

Fig. 6 Hourly variations of rainfall and cbh.

From Fig.6, we can see that a sudden rainfall activity at 13UTC and cbh value at that instant was recorded as 1000 m. At 15UTC the rainfall was 1.8 mm whereas cbh value was 250 m. Later, it dissipated by 17UTC. The cbh values were high until 4UTC and a sudden increment was clearly observed at 5UTC similar to kI parameter. By 7UTC the cbh values were increasing rapidly and at peak rainfall activity the cbh value was 200 m which indicates low cloud base nearer to earth surface causing heavy rainfall at the region of convective system. The cbh values were also increased gradually as rainfall dissipated. This parameters indicates the height of the cloud. By knowing the temperature of the cloud, we can estimate occurrence of rainfall before 3 h.

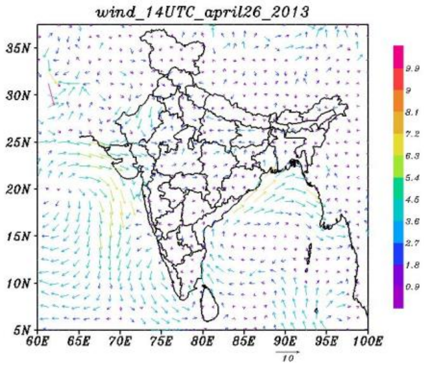

Fig. 7 Spatial plot of wind vectors over Virajpet at 14UTC on 26th April, 2013.

We have generated the vector plot of wind data using ECMWF ERA5 data to study the dynamics related to the convective system over Virajpet region. From Fig.7, we can see a clear anticyclone at head of Arabian Sea. Another anticyclone was seen in Bay of Bengal also. A Cyclonic circulation is clearly evident at Karnataka as shown in Fig.7. A trough was moving towards Karnataka was also observed.

CONCLUSION

In this paper, an attempt has made to analyze a mesoscale convective system over Virajpet, Karnataka on April 26th, 2013. The convective based weather parameters which are calculated and retrieved from ERA5 reanalysis data has helped us to analyze the severity of convective system.

kI and CAPE parameters revealed the occurrence of convective system before 3 h whereas, TTI indicated before 6 h. High TPW value is a good indication of high moisture availability needed for the occurrence of intense convective system. CIN was also showing weak inhibition needed for the occurrence of convective system. Low cbh value shows that the cloud is very nearer to earth surface which is ready for precipitation.

This study also reveals the importance of ECMWF ERA5 reanalysis data for now casting the mesoscale convective systems.

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