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L E T T E R S

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CASE STUDY ON SEVERE THUNDERSTORM ACTIVITY OVER CHHATTISGARH ON 21ST MAY, 2016

1. Thunderstorm, resulting from intense convective activity, is one of the most disastrous weather phenomena in the earth's atmosphere. The severe thunderstorms associated with thunder squall, hail storm, flash flood and lightning cause extensive damage and losses to lives and property. A common feature of the weather during the pre-monsoon season over Indian region is the outburst of severe local convective storms. Its development can be identified only by Radar observation and sometimes from satellite imageries. The picture of severe thunder cloud development is shown in Fig. 1.

Preparedness against thunderstorm, squally wind, tornado etc. is most essential for human being. The main objective of this study is to identify the synoptic features and state of instability over Chhattisgarh on the day of consideration, *i.e.*, 21st May, 2016. This paper may help the forecasters to assess the possibility of thunderstorm activities and serve as base line information for the development of the thunderstorm risk assessment model for the Chhattisgarh region.

This paper presents the aspects of the realized significant weather phenomena of thunderstorm, which is supported through the analyses of thermodynamic instability condition of atmosphere, instability indices based on the Radio-Sonde and Radio wind (RS/RW) ascent observation at Raipur and Jagdalpur in Chhattisgarh. Satellite imageries, surface and upper air charts have also been analyzed which support the thunderstorm activities in different locations of Chhattisgarh. The Showalter Index (S-Index), K-Index, Total-totals Index and convective available potential energy (CAPE) show the favorable conditions for the severe thunderstorm to occur in above mentioned stations; however, due to physiographic uniqueness of the state, the values of CAPE and other thermodynamic parameters show different values in different stations. The reason for dry thunder storm with sever squall has been discussed. Moreover, the variation in threshold values of CAPE in different regions makes thunderstorm forecasting difficult which may add uncertainty to loss estimation for risk assessment.

Fig. 1. A photograph of severe thunder cloud

The thunderstorm activity is associated with heavy rain, lightening, hailstorm and strong gusty winds. Besides these; severe turbulence, severe icing, micro-bursts, generating squalls or gust fronts giving severe low-level turbulence, high liquid water content are the associated hazardous weather phenomena to aviation activity.

Thunderstorm leads to damage of property and life. The early detection and warning is very essential for reduction of damage due to thunderstorm. The traditional method of radiosonde observation with T-ϕ gram analysis is very useful tool for prediction of thunderstorm. The DWR are the latest tool to know the genesis of Cb cloud and local thunderstorm activities.

2. Severe thunderstorm with squall was experienced on 21st May, 2016 over several parts of Chhattisgarh during evening; for study of which T-ϕ grams of Raipur and Jagdalpur from Radio-Sonde data of 0000 UTC of 18th May, 2016 to 21st May, 2016 have been obtained and used for analysis. The upper air charts were obtained from IMD website and satellite imagery from INSAT 3D (http://satellite.imd.gov.in/insat.htm). Rainfall, thunderstorm and squall reports were also obtained from Meteorological Centre Raipur for this study.

3. The stability indices have been reviewed and utilized by the study of Peppier (1988). Various aspects of thunderstorm over India during pre-monsoon season have been discussed in his paper by Yashwant Das (2015). The important thermodynamic indexes considered in this study are discussed below.

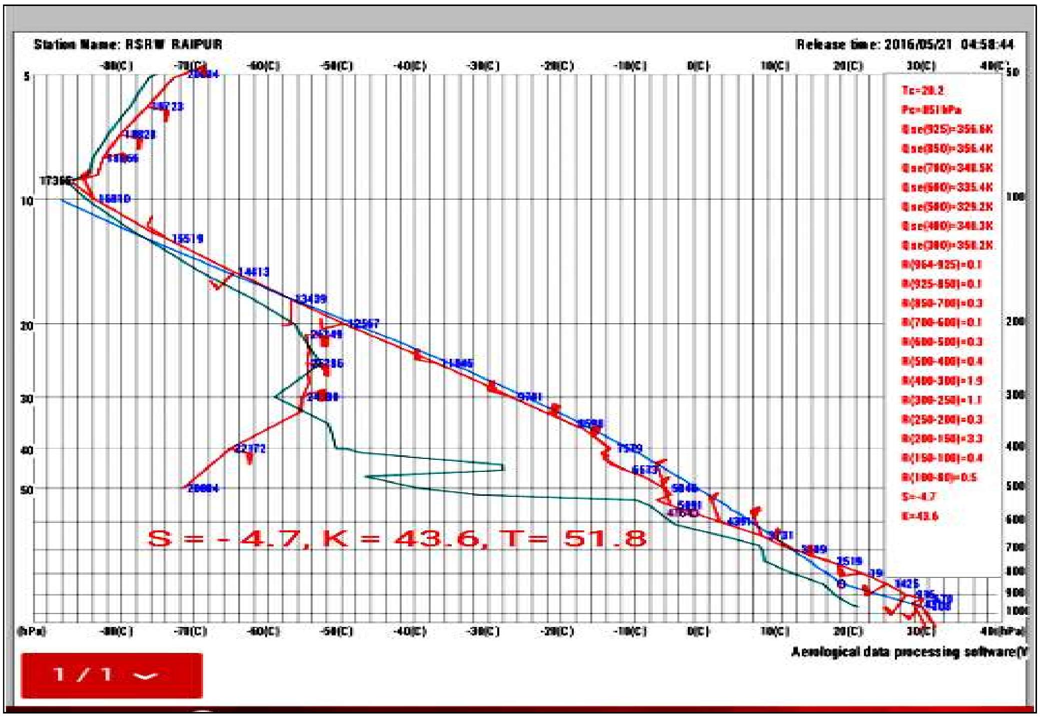

Fig. 2. T- ϕ gram 0000 UTC Raipur (42874)

Station information and sounding indices - RAIPUR at 0000 UTC on 21st May, 2016		
Showalter index	:	-4.7
K index	:	43.60
Total totals index	:	51.80
Convective Available Potential Energy	:	1109.74
CAPE using virtual temperature	:	1316.83
Precipitable water [mm] for entire sounding	:	49.28

3.1. *Convective Available Potential Energy (CAPE) (Moncrieff and Miller, 1976)*

It is the total amount of work done by the upward buoyancy force that is exerted on an air parcel as it is lifted from its initial level to its final Equilibrium Level (EL): CAPE (J/ kg) = $\int Rd(Tp - T)\, d(\ln p)$, where Tp and T are the temperatures of the parcel and the environment, respectively. This is actually the maximum energy available to an ascending air parcel. Compared to the other stability indices, CAPE has an advantage because it is not limited to only one particular atmospheric level. Observed values in thunderstorm environments often may exceed 1,000 joules per kilogram (J/kg) and in extreme cases may exceed 5,000 J/kg. However, as with other indices or indicators, there are no threshold values above which severe weather becomes imminent. CAPE using virtual temperature (CAPE) is calculated similarly to the CAPE index, but instead of Tp and T, the values Tvp and Tv (the virtual temperatures of the air parcel and the environment respectively) are used.

3.2. *Showalter index (SI) (Showalter, 1953)*

The SI is computed from the formula SI = T500 – Tp500 where Tp500 is the 500 hPa temperature which a parcel will achieve if it is lifted dry-adiabatically from 850 hPa to its condensation level and then moist-adiabatically to 500 hPa. The Showalter index, designed originally for thunderstorm forecasting in the southwestern United States, estimates the potential instability of the 850 to 500 hPa layer by measuring the buoyancy at 500 hPa of an air parcel lifted to that level. The index is a function only of the 850 and 500 hPa levels. It also provides an estimate of the latent instability of the layer, in that a negative value reveals the existence of positive buoyant energy above the LFC and the possibility of subsequent free convection. Showalter (1953) found values of SI $\leq$ +3 to be indicative of showers and possible thunderstorm activity, while values $\leq$ -3 were associated with severe convective activity.

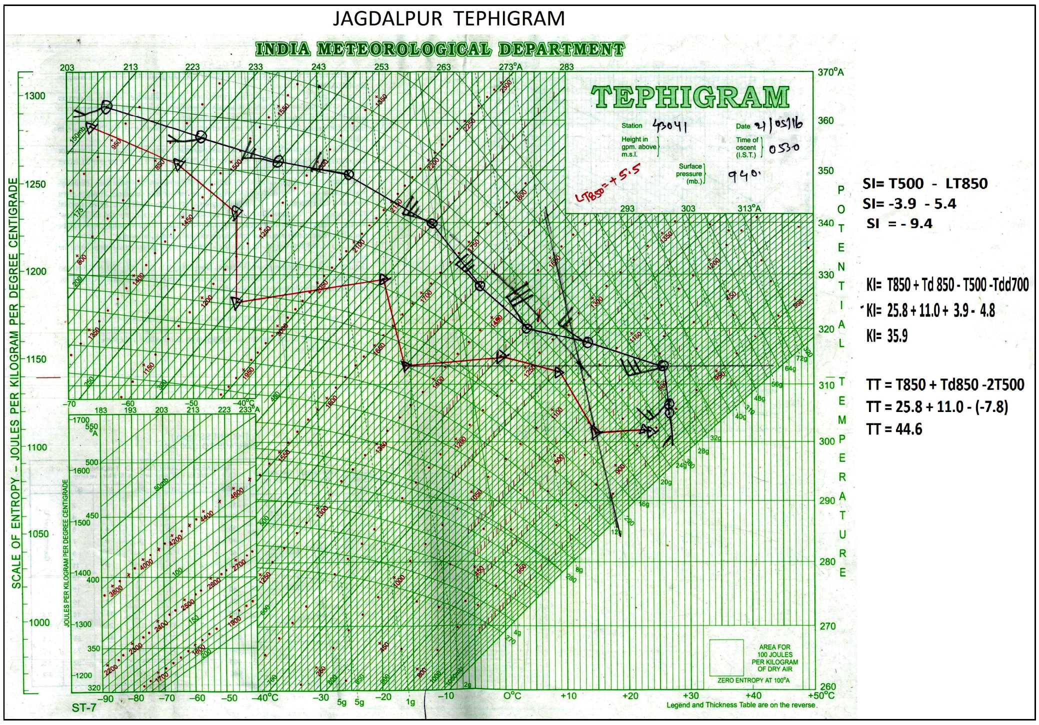

Fig. 3: T- ϕ gram 0000 UTC Jagdalpur (43041)

Station information and sounding indices - Jagdalpur at 0000 UTC on 21st May, 2016		
Showalter index	:	-9.4
K index	:	35.9
Total totals index	:	44.6
Convective Available Potential Energy	:	1271.4

3.3. *K-index (George, 1960)*

The K-index is defined as KI = (T850 – T500) + Td850 – (T700 – Td700). The K-index arithmetically combines the 850-500 hPa temperature difference, the 850 hPa dew-point (a direct measure of low-level moisture content) and the 700 hPa dew-point depression (an indirect measure of the vertical extent of the moist layer) to help forecast continental summer time air mass thunderstorm potential. Air mass thunderstorms were defined by George as "those developing in areas of weak winds without apparent frontal or cyclonic influence". The index was developed from Rawin Sonde data covering the eastern two-thirds of the United States and portions of extreme southern Canada. The inclusion of the dew-point depression term reflects the unique emphasis of K on assessing the vertical penetration of low-level moisture, thought to be essential for the formation of air mass storms. Using charts with isoplethed K-index fields and superimposed thunderstorm reports, value of K≥20 were found to indicate an increasing frequency in air mass thunderstorm activity.

3.4. *Total Totals index (TT) (Miller, 1967)*

The TT index is defined as TT = (T850 − T500) + (Td850 − Td500). The TT Index is calculated as the sum of the 850 hPa temperature and dew-point temperature minus the 500 hPa temperature and dew-point temperature: The showers and thunderstorms become increasingly likely from the TT values of about 30 and severe thunderstorms are considered to be likely for the TT values of 50 or more. TT index fails to consider the latent instability below the 850 hPa level.

4. Severe thunderstorm with squall was experienced on 21st May, 2016 over several parts of Chhattisgarh during evening. For study of which T-ϕ grams of Raipur and Jagdalpur from Radio-Sonde data of 0000 UTC of 21st May, 2016 shown in Figs. 2&3, the surface and upper air charts showing synoptic situations in Figs. (4-9) and satellite imageries showing signature of line squall of thunderstorm in Figs. (10-13) have been taken. Rainfall, thunderstorm and squall reports were also obtained from Meteorological Centre, Raipur.

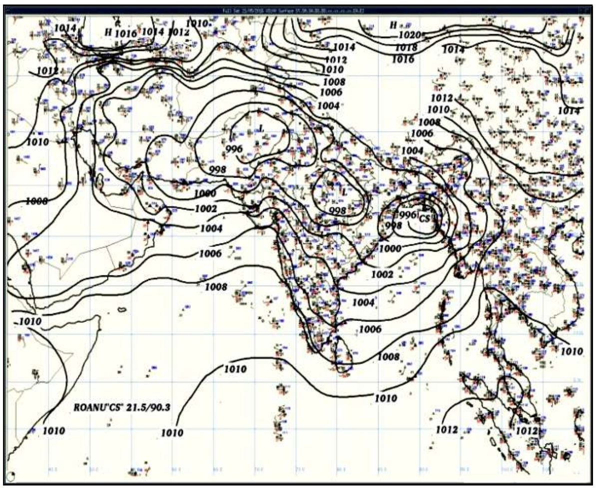

Fig. 4. Analysed surface chart 0300 UTC of 21st May, 2016

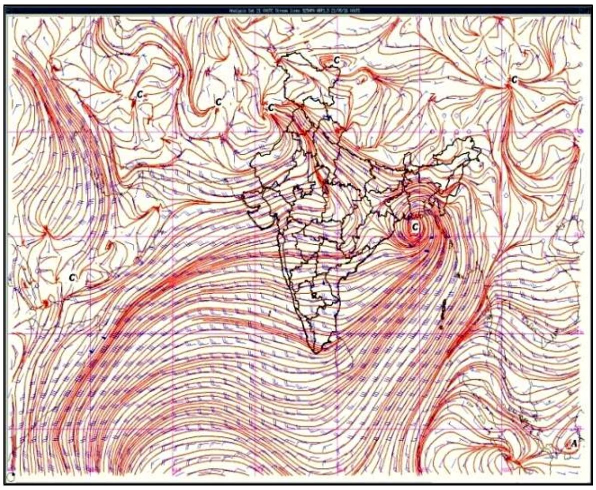

Fig. 5. 925 hPa wind chart 0000 UTC 21st May, 2016

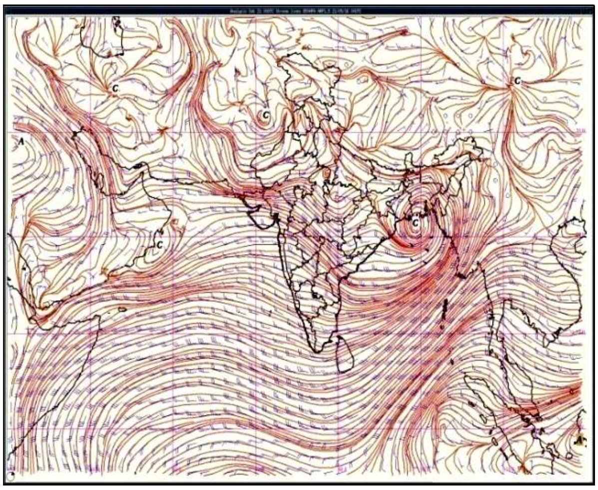

Fig. 6. 850 hPa wind chart 0000 UTC 21st May, 2016

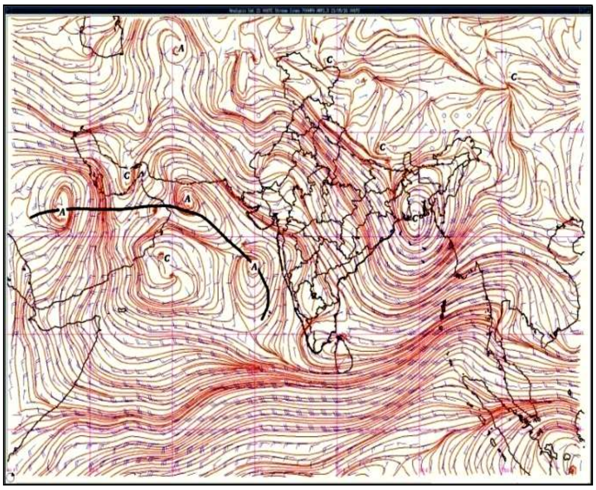

Fig. 7. 700 hPa wind chart 0000 UTC of 21st May, 2016

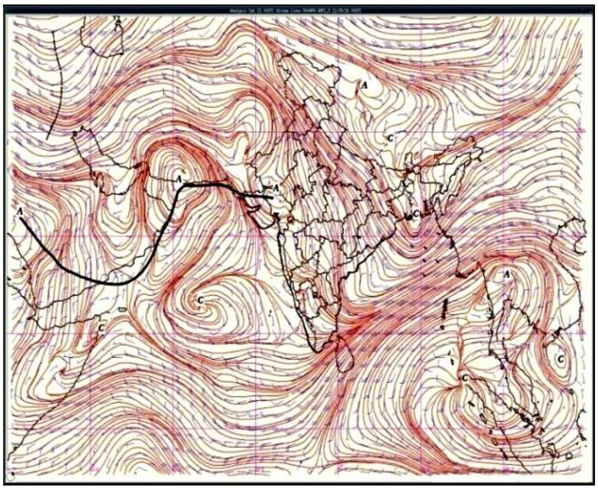

Fig. 8. 500 hPa wind chart 0000 UTC 21st May, 2016

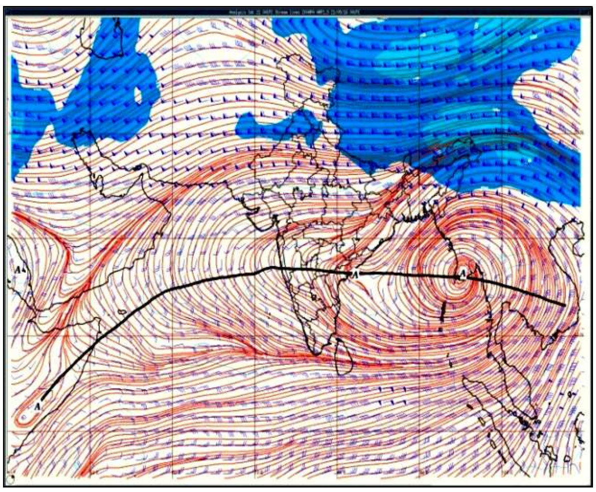

Fig. 9. 200 hPa wind chart 0000 UTC 21st May, 2016

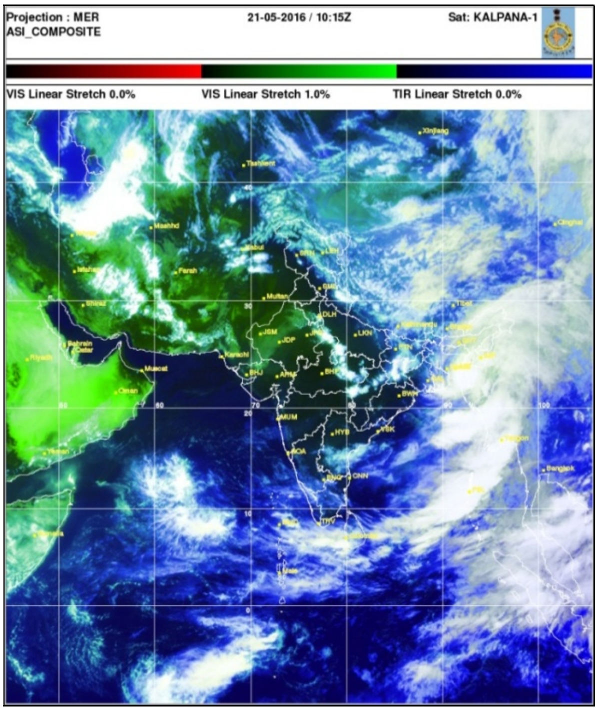

Fig. 10. Kalpana-1 Image of 1015 UTC 21st May, 2016

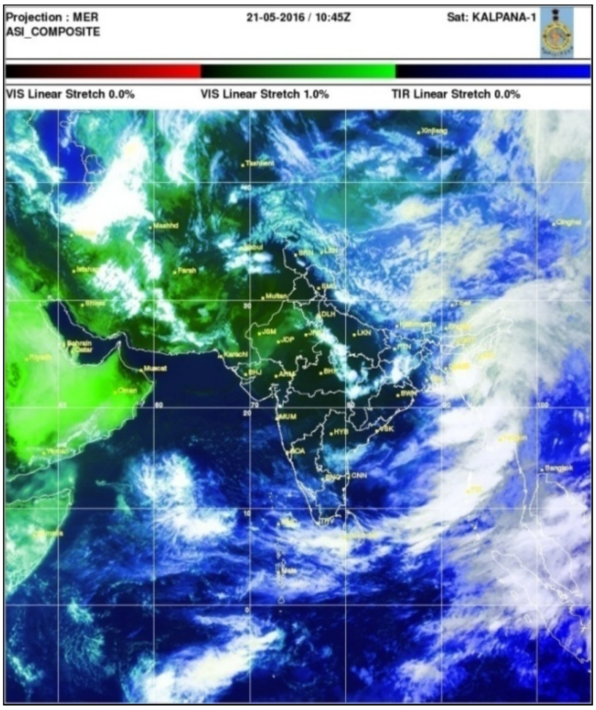

Fig. 11. Kalpana-1 Image of 1045 UTC 21st May, 2016

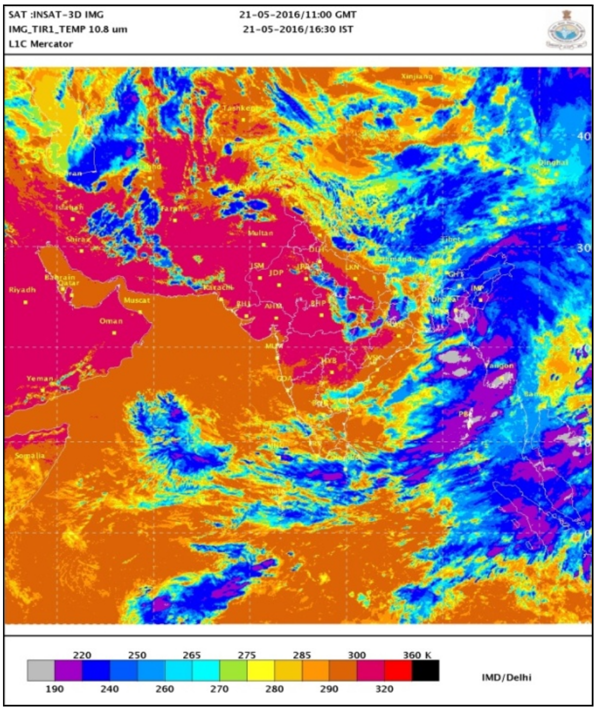

Fig. 12. INSAT-3D Image of 1100 UTC 21st May, 2016

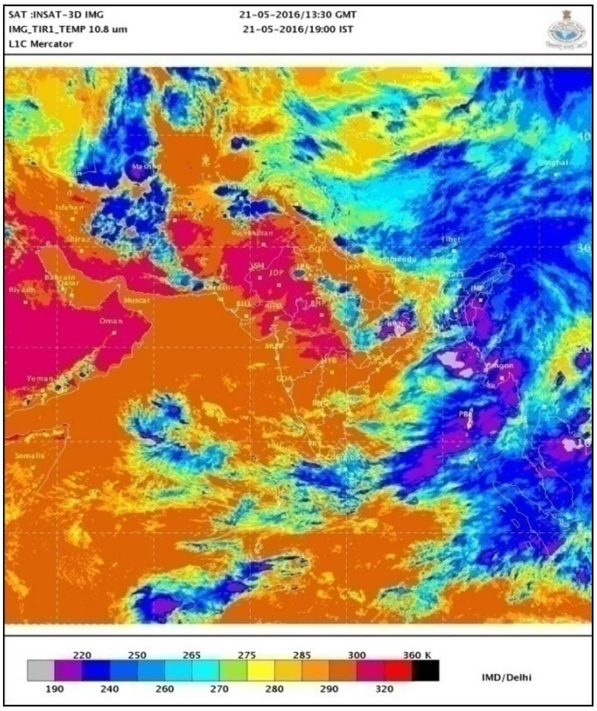

Fig. 13. INSAT-3D Image of 1330 UTC 21st May, 2016

On 21st May, 2016 severe thunderstorm with squall was reported over Chhattisgarh but very less rainfall was recorded. The reason for less rainfall was less moisture incursion due to strong dry westerly winds in lower

TABLE 1

Thunderstorm indices calculated from Raipur 0000 UTC based RS/RW observation

Dates ►	18 May	19 May	20 May	21 May
S- Index	-1	1	-0.67	-4.7
K-Index	31.5	26.5	23.7	43.6
Total Index	46.6	44.6	45	51.8
CAPE	706.7	103.4	223.0	1109.7

TABLE 2

Thunderstorm indices calculated from Jagdalpur 0000 UTC based RS/RW observation

Dates ►	18 May	19 May	20 May	21 May
S- Index	1.5	-1	-0.6	-9.4
K-Index	27.9	31.9	31.7	35.9
Total Index	43.2	44.4	42.8	44.6
CAPE	150.4	236.7	99.9	1271.4

atmosphere coming from hotter region of Maharashtra and Madhya Pradesh. The maximum temperature over the region was more than 40 °C, so moisture available was not sufficient for rainfall.

The thermodynamic indices for Raipur and Jagdalpur are shown in Tables (1&2) respectively from 18 to 21 May, 2016. It can be seen that on 18th, 19th and 20th all the indices were not very favourable but on 21st all indices were very favourable for very strong thunderstorm at Raipur and Jagdalpur. There is clear indication of instability increase seen in the indices from 20 to 21 May, 2016. Hence, prediction of meso scale system like thunderstorm can be made. But it is not possible to predict it well in advance as indices showed possibility of severe thunderstorm only in 12 hrs advance.

The Showalter indices are negative for both at Raipur (-4.7) and Jagdalpur (-9.4) which are less than -3. Hence, conditions are favorable for convective activity at both the places. Similarly K-indices are Raipur 43.6 and Jagdalpur 35.9 which are more than 20 and total indices 51.8 and 44.6 which are comparable with 50. CAPE value is more than 1000 in both places. All the index and parameters of 0000 UTC were very favorable for severe thunderstorm over most parts of Chhattisgarh. So severe thunderstorm occurred over the region in the evening after 1200 UTC but it was dry thunderstorm over most places. Strong wind of more than 50 km/h was recorded over the region. Trees were uprooted at many places, electric poles and kachcha houses were damaged.

On the surface level chart it has been depicted that high pressure gradient prevailed over the Chhattisgarh state due to presence of Cyclonic storm ‘Roanu’ in the northwest Bay of Bengal off Odisha coast on 20th. As it moved over to northeast Bay of Bengal near Myanmar coast on 21st, moisture supply from Bay of Bengal was cut from the region.

A trough at MSL from Punjab to Chhattisgarh across Rajasthan and Madhya Pradesh was present on 20th and 21st May on synoptic charts. The upper level wind charts at 925 hPa showed strong Westerly approaching from Maharashtra and Madhya Pradesh which were obstructed by the trough at mean sea level from Punjab to Chhattisgarh extending in lower levels. This resulted in convergence of winds due to trough over Odisha and Chhattisgarh and moderate to severe thunderstorm occurred over central and North Chhattisgarh. But, being extreme summer season over the region and due to wind coming from dry land region of Madhya Pradesh and Maharashtra the availability of moisture was less and also Cyclonic Storm ‘Roanu’ over NW Bay moved away so moisture was not available from Bay, so only light rainfall occurred in the region and dry thunderstorm squall occurred over Raipur.

The satellite images showed a line squall along the E-W trough from Punjab to south Chhattisgarh and tilted towards north Odisha and Gangetic West Bengal.

Amounts of rainfall in C.G. (in cm): Kurud, Gunderdehi and Pithora 1 cm each. Raipur, Jagdalpur and other stations reported no rain. Rainfall amounts in mm are shown in Fig. 14.

5. This study shows that there was strong convective activity over Chhattisgarh on 21st May, 2016. The T-ϕ gram of Raipur and Jagdalpur were very favorable for TS activity. The Showalter Index, K index and TT index were very favorable for TS activity. The Satellite picture was also showing strong convection over Chhattisgarh. Hence TS activity was recorded at many places of C.G. as per favorable parameters, but rainfall activity was very less and maximum 1cm of rainfall was recorded at isolated places. The high wind speed of more than 50 km/h or thunder squall was recorded at number of places. At Raipur there was no rainfall, *i.e.*, dry TS with sever squall was recorded. Dust storm was also recorded in Raipur. The reason for less rainfall was less moisture incursion due to strong dry westerly winds in lower atmosphere coming from very hot region of Maharashtra and MP. The maximum temperature over the region was

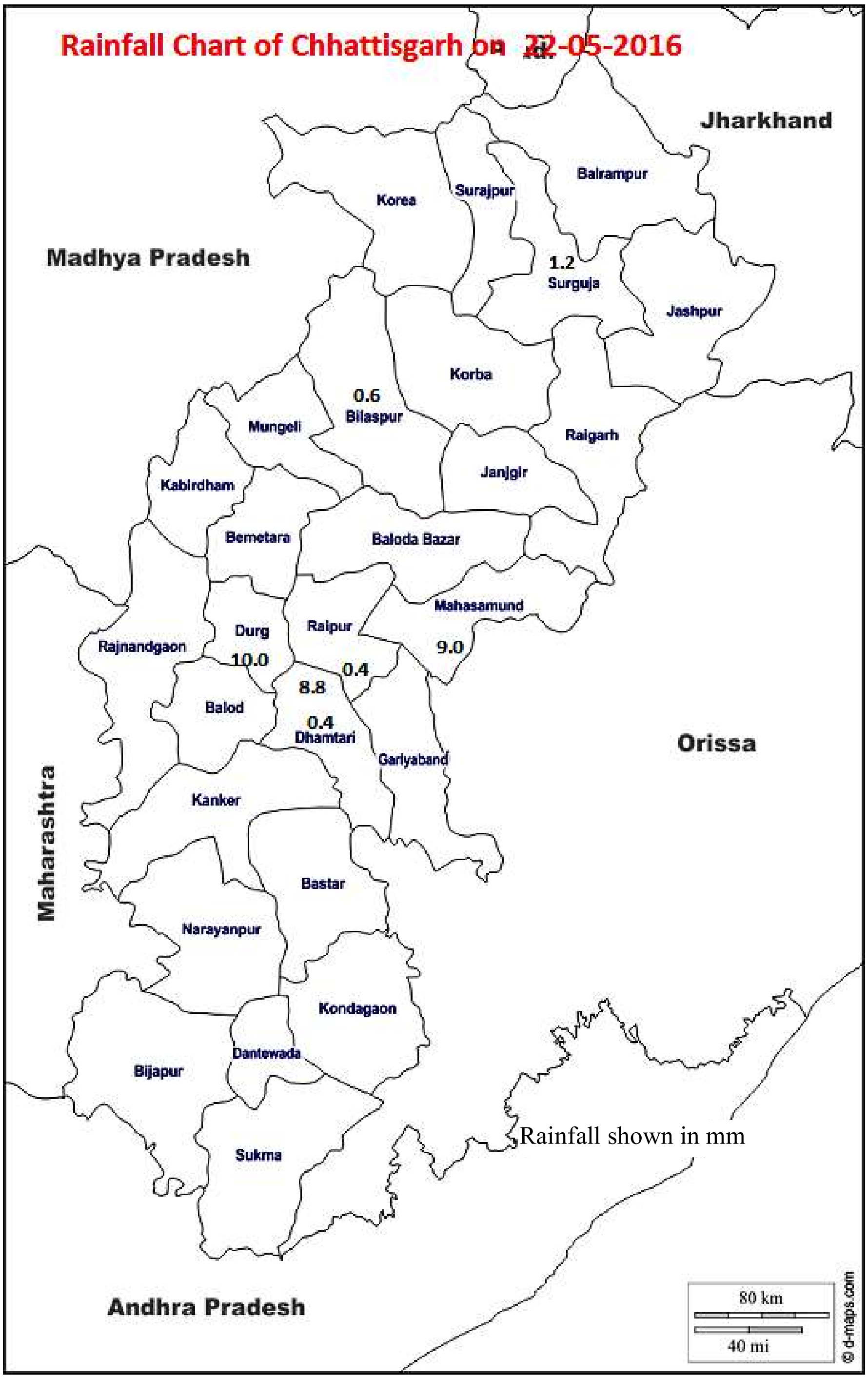

Fig. 14. Rainfall chart of 22nd May, 2016

more than 40 °C, so moisture available was not sufficient for rainfall. The cyclonic storm 'Roanu' over NW Bay moved away so moisture incursion from Bay was also very less. Therefore less rain and strong thunder squall reported over C.G.

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