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Extreme Hydrological Events in January 2022: A Case Study over Telangana and Andhra Pradesh State, India

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Authors' contributions

This work was carried out in collaboration among all authors. The MS contributed to the manuscript's collection and writing. Authors KS and HS did data collection and preparation of some figures, Data plotting by the SP and CR. All authors read and approved the final manuscript.

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ABSTRACT

The study will look at extreme rainfall events in Andhra Pradesh and Telangana, where both the monsoon and post-monsoon seasons significantly contribute to rainfall. The winter season 2022 was highlighted by unusual rainfall in some districts of Andhra Pradesh and Telangana in the 2nd week of January 2022, causing significant damage. In this paper, we identify the observational

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aspects, main synoptic system, physical process, and thermodynamic features leading to such unusual rainfall during the winter season. According to the study's findings, a hailstorm was recorded over Telangana state on January 13, 2022, heavy rain fell in Telangana due to the most active western disturbance as a cyclonic circulation over Rajasthan and Pakistan; on January 14, 2022, heavy to very heavy rain fell in Vizianagaram (16 cm) due to the convergence of winds from the Arabian Sea and Bay of Bengal at lower tropospheric levels over east and adjoining central India and a trough from north interior Karnataka to north interior Odisha. The diurnal and temporal pattern of the hail storm and heavy rainfall over the Andhra Pradesh and Telangana States shows that late evenings are most conducive for the occurrence of extreme rainfall events due to the accumulation of precipitable water.

Keywords: Hail storm; heavy rainfall; trough; western disturbances.

1. INTRODUCTION

Andhra Pradesh is located on the eastern coast of the Indian peninsula. The coastal state of Andhra Pradesh, located between 78^{o}-89° east longitude and 12.7-19.07° north latitude. According to the 2011 census, it covers an area of 92,906 km2 and has a population of 34,193,868. This region covers the Andhra Pradesh region between Eastern Goth and the Bay of Bengal. It includes the districts of Srikakulam, Vizianagaram, Visakhapatnam, East Godavari, West Godavari, Krishna, Guntur, Prakasam and Nellore. The state has the second longest coastline (972 km) among all states in India. Coastal Andhra Pradesh has rich agricultural land thanks to the deltas of the Godavari and Krishna rivers. The prosperity of coastal Andhra can be attributed to the fertile agricultural lands and the abundant water supply of these two rivers. Andhra Pradesh Fisheries are also important to the region. Costal Andhra Pradesh is located to the east of Telangana, and the Rayalaseema regions share borders with Odisha to the north and Tamil Nadu to the west. It experiences heavy to very heavy rainfall associated with the meteorological systems during the pre-monsoon, southwest monsoon, and post-monsoon/NE monsoon seasons. Heavy rains fall over the region due to the passage of westerly-moving tropical disturbances and strong monsoon currents, resulting in heavy falls and intense convective activity over a short period of time during the pre-monsoon season. January 2022 saw heavy rainfall in Vizianagaram District, moderate to heavy rainfall in Visakhapatnam, and rainfall across Andhra Pradesh from January 11th to 16th (Fig. 1). Average monthly precipitation in January for Vizianagaram and Visakhapatnam is 9.9 mm and 10 mm, respectively (Table 1). Telangana is located in a semi-arid region with a predominantly hot and dry climate. Summer starts in March and high temperatures occur in May, with average highs in the range of 42°C (108°F). The monsoon starts in June and lasts until September, with about 755 mm (29.7 inches) of precipitation. A dry, mild winter begins in late November and lasts until early February, with little humidity and average temperatures in the range of 22–23 °C (72–73 °F) (Telangana Economic Research 2011–2012). The Central Deccan Plateau Dry Hardwood Forest Ecoregion covers most of the state including Hyderabad. Although more than 80% of the original forest area has been cleared for agriculture, timber harvesting or grazing, large areas of forest can be found in the Nagarjuna Sagar Srisailam Tiger Reserve and elsewhere. Wet deciduous forests of the Wet Eastern Highlands cover the Eastern Ghats of the eastern part of the state.

According to the National Weather Service (NWS), hail is defined as a showery precipitation in the form of irregular pellets or balls of ice more than five mm in diameter falling from a cumulonimbus cloud (NWS, 2009). Early in the developmental stages of a hailstorm, ice crystals form within a low-pressure front due to the rapid rise of warm air into the upper atmosphere and the subsequent cooling of the air mass. Frozen droplets gradually accumulate in to ice crystals until, having developed sufficient weight, they fall as precipitation in the form of balls or irregularly shaped masses of ice. The size of hailstones is a direct function of the size and severity of the storm. High-velocity updraft winds are required to keep hail suspended in thunderclouds. The strength of the updraft depends on the intensity of the heating of the Earth's surface. Higher temperature gradients in height above the surface increase the hanging time and size of hailstones. Hail is a potentially devastating consequence of severe thunderstorms (Northern Virginia Regional Commission [NVRC], 2006). Hail storms have become one of the most costly

natural disasters in the United States, causing more than $1 billion in damage to crops and property each year (Federal Alliance for Safe Homes, Inc., 2006). (RP 2000) Upward trends for extreme precipitation and discharge in some catchments would imply a greater risk of flooding on a regional scale. In their rigorous attribution study looking at the flood events in England and Wales in autumn 2000, Pall et al. [1] concluded that the probability of severe events occurring has likely increased because of anthropogenic warming.

Thunderstorms, hail and dust storms: As winter usually turns to spring, temperatures rise first in southern India, causing inherently dangerous thunderstorms and squalls. The extreme south is free of dust storms and hail, while the central, northeast, north and northwest regions are experiencing dangerous weather [2]. According to records, the largest hailstones were formed during a thunderstorm in April 1888 in Moradabad, a city near Delhi. The hail was the size of a dove's egg in diameter (IMD 1888). The hailstorm frequencies are highest in the Assam valley, followed by hills such as Uttaranchal, South Bihar (now known as Jharkhand), and Vidarbha in the eastern parts of Maharashtra (Philip & Daniel 1976). However, thunderstorms also occur in these areas during the rest of the year as well; for example, Calcutta (Kolkata) has the highest frequency of thunderstorms in September, while Delhi, Jaipur, and Ahmedabad have the highest frequencies in July. Hailstorms and heavy rainfall hit the peninsula and east coast in 2022 during the winter season. This paper will discuss the factors that contributed to the occurrence of such extreme events [3].

According to Patak et al. (2014) “The water cycle is closely related to changes in atmospheric temperature and radiative balance. A warmer climate can improve the hydrological cycle, increasing evaporation rates and increasing liquid precipitation. Changes in precipitation patterns can affect the spatial and temporal distribution of runoff, soil moisture and groundwater storage, and may increase the frequency of droughts and floods.”

Studies have confirmed asymmetry in precipitation anomalies. Other parts of the world are affected by the opposite phase of low ocean variability. Circulation patterns [6], (Qiu et al. 2014).
Studies have confirmed the asymmetry of precipitation anomalies. Other regions of the world are affected by the opposite phase of low ocean variability. Circulation model [4], (Qiu et al. 2014). Comparison of model predictions and atmospheric observations [5]; understanding atmospheric physics [6]; An understanding of regional meteorological mechanisms [7].

Goswami et al. [8] studied extreme precipitation trends in India using gridded daily precipitation data from the Indian Meteorological Department (IMD) from 1951 to 2003. However, their explorations were limited to central India. Their study reported a trend towards an increase in the frequency and intensity of extreme rainfall and a significant decrease in the frequency of moderate events in central India.

Rajivan et al. [9] used a 104-year grid dataset and Goswami et al. [8] and investigated variability and long-term trends in extreme precipitation.

Kotal et al. [10] analyzed dynamic and thermodynamic properties derived from an IMD WRF operating model (27 km resolution) in a weekly analysis field associated with heavy rain events in Uttarakhand and nearby areas from 16 to 18 June 2013. It causes flash floods, landslides, huge loss of life and property damage. Srinivasan [11] discussed possible causes of disasters such as clouds, meteorological phenomena, glacial lake eruptions and landslides in an editorial in Current Science. He noted that in the past such heavy rains have occurred in Uttarakhand, mostly in July, August or September, with the first one occurring in June 2013.

According to the criteria of the Indian Meteorological Department (IMD Monsoon Report 2014), extreme showers have been classified into three categories. These were (a) heavy rainfall (64.5 to 124.4 mm daily precipitation), (b) very heavy rainfall (124.5 to 204.5 mm daily precipitation) and (c) extremely heavy rainfall (204.5 mm daily precipitation). daily precipitation).

1.1 Synoptic Circumstances Generally Favourable for Hail Events

Southern region:

1. A hailstorm is a. Passage of Western Anxiety, b. A stronger-than-usual subtropical western jet stream to the south c. Presence of warm, moist easterly winds

in the lower troposphere. 2. Upper-layer divergence driven by subtropical westerly jets coupled with the formation of a weak N/S windshield provided lower-layer convergence with a transient oceanic maximum. 3. The synoptic features listed above, alone or in combination, lead to intense convective activity in the form of destructive hail storms [11].

1.2 Objectives of the Study

- To study the synoptic, physical, and thermodynamic features that led to an unusual rainfall event.
- To investigate the circumstances surrounding the hail storm that was recorded over Telangana state.
- To see the diurnal temporal pattern of hailstorms or heavy rainfall

2. METHODOLOGY

- The state government's IADP rain gauge stations and rainfall data from IMD observatories in Telangana and Andhra Pradesh were used in the study. In AP, RS/RW stations are located in only two places, and in Telangana, it is only one place, so to represent the entire area, Wyoming University upper air sounding data is considered for the thermal indices of the lifted index/K indices and precipitable water. Real-time satellite images, S-band radar pictures, forecast products of total lightning flash count at 3 km resolution (indicated with red in Fig. 6(b), rainfall probability, and analysis of 850 wind products of IITM are used for the movement and nature of extreme hydrological events. Furthermore, surface and upper air observations from across India

Different indices are calculated based on the following formulas:

K-Factor: The K-Factor is a measure of the probability of a lightning strike based on vertical temperature gradient and low atmospheric moisture amount and vertical extent.

K = T(850mb) Td(850mb) - T(500mb) - DD(700mb)

Temperature in degrees Celsius (T is the temperature, Td is the dew point temperature, and DD is the drop in the dew point from the specified level).

Lifted index = T500 – T parcel
T500 = temperature in Celsius of the environment at 500mb

T parcel =500mb temperature in Celsius of a lifted parcel with the average pressure, temperature, and dew point of the layer 500m above the surface.

SWEAT =12*TD850 20*TERM2 2*SKT500 SKT500 SHEAR

TD850 = Dew point in Celsius at 850 mb
TERM2 =MAX(TOOL – 49,0)
TOTL =TOTAL TOTALS INDEX
SKT850 =850 mb wind speed in knots
SKT500 =500 mb wind speed in knots
Shear =125*[SIN (DIR500 – DIR850) .2]
DIR500 =500 mb wind direction
DIR850 =850 mb wind direction
K index = (T850 – T500) TD850- (T700 – TD700)
T850 = Temperature in Celsius at 850 mb
T500 = Temperature in Celsius at 500 mb
TD850 = Dew point in Celsius at 850 mb
T700 = Temperature in Celsius at 700 mb
Total Totals index
TTOT = (T850 – T500) TD850 – T500)
T850 = Temperature in Celsius at 850 mb
TD850 = Dew point in Celsius at 850 mb
T500 = Temperature in Celsius at 500 mb
CAPE Convective Available Potential Energy (J/kg)
CAPE = GRAVITY* SUMP (DELZ * (TP – TE) / TE)
SUMP =sum over sounding layers from LFCT to EQLV for which (TP – TE) is greater than Zero
DELZ = Incremental depth
TP = Temperature of a parcel from the lowest 500 m of the atmosphere, raised dry adiabatically to the LCL and moist adiabatically there after
TE = Temperature of the environment
Convection suppression CIN (J/kg)
CIN = Sum of Gravity* (DELZ * (TP - TE) / TE
SUMN = Sum for the sounding layer from LFCT to EQLV on top of the mixing layer, where (TP – TE) is less than zero
DELZ = incremental depth
TP = parcel temperature at 500 m above sea level in a dry place.

Adiabatically with LCL, then adiabatically when wet

TE = ambient temperature
Richardson mass number

BFC = Settings / (0.5* U**2)
CAPE = available convective potential energy
U = movement amount (u2 - u1, v2-v1)
u1, v1 = average value of u, v at least 500m
u2, v2 = average value of u, v at least 6000m

3. RESULTS AND DISCUSSION

3.1 January 11, 2022

3.1.1 Synoptic Situation

a) A trough existed in the lower troposphere between south interior Karnataka and south Chhattisgarh, as well as a Cyclone circulation over and around the southwest part of the Bay of Bengal at an altitude of 1.5 km above mean sea level. Winds from the Arabian Sea and the BoB were expected to converge in the lower troposphere over eastern and adjacent Central India.

Here the heat index for the state of Andhra Pradesh is calculated. A representative region is Visakhapatnam, which was used as a reference. The indices are as follows: Showalter exponent is 5.39, Lifting exponent is -0.72, Pot exponent is 107.39, K exponent is 11.50, CAPE is 72.17, Free convection level is 539.70, Richardson mass number is 1.50 and Table. Table 2 shows the deposited water volume (mm) for all measurements at 28.30. The value of the elevated index/index K in the figure. 1(a) equals 33. In general, the higher the value of the K index in the ambient air or inflow, the higher the probability of heavy rain. However, beware of low (less than 30) K values. Since the K index includes the dew point drop (i.e., the difference between the temperature and the dew point temperature) at 700 mbar, dry air at this level will result in a low K value. However, humidity below 700 mbar, unstable air and lifting mechanisms, severe or severe organized thunderstorms and heavy rains may still occur. Diffuse diurnal convection that occurs in environments with high K (and PW) values can quickly explode very heavy rainfall. (US Northwest). Indicates that thunderstorms are more likely to occur with heavy rain. 30 mm of precipitation in the picture. 2(a) at 12z, 3-hour TS with lightning, severe weather in red for the Telangana region in the Fig. 4(a) and Fig. 7.

3.1.2 Realized weather on January 11

Heavy rains occurred in isolated locations in Warangal-Raral, Mahabubabad and Yadadri-Bhuvanagiri districts. According to the press, the hailstones occurred in remote locations in Telangana's districts of Hanumakonda, Waranganal, Jangaon and Kumarambhim."

Rainfall in Telangana in (cm) is Atmakur (dist Warangal_rural) 8, Chennaraopet (dist Warangal_rural) 7, Gudurwrgl (dist Mahabubabad) 7, Bhuvanagiri (dist Y. Bhuvanagiri) 7, Kothaguda (dist Mahabubabad) 6, Khanapur (dist Warangal_rural) 6, Jammikunta (dist Karimnagar) 6, Nallabelly (dist Warangal_rural) 6, Karimnagar (dist Karimnagar) 6, Jangaon (dist Jangaon) 5, Narsampet (dist Warangal_rural) 5, Shayampet (dist Warangal_rural) 5, Karimnagar(a) (dist Karimnagar) 5, Bhongir(arg) (dist Y. Bhuvanagiri) 5, Mogullapalle (dist J. Bhupalpally) 5, Dharmasagar (dist Warangal_urban) 5, Parkal (dist Warangal_rural) 5.

3.2 January 12, 2022

3.2.1 Synoptic situation

The valley between the interior of southern Karnataka and southern Chhattisgarh is at an altitude of 0.9 km above mean sea level and continues to have a cyclone circulation over and around the southwest Bay of Bengal, extending to 1.5 km. Oceans above mean sea level. At an average elevation of 0.9 km above sea level, cyclonic circulation occurred and also existed in southern Tamil Nadu and its surroundings (IMD press release, 12 Jan 2022).

The thermal index of the index K is equal to 33 according to the figure. In Fig. 1(b), the precipitated water is shown in Fig. 1(b). 2(b) in 12Z and index K 30 in Table 1 indicates heavy rainfall over Telangana. CAPE was also higher on January 12 in Table 2, and the 3-hour thunderstorm threat is shown in red for the Telangana region in Fig. 2. 4(b). On January 12, 2022, areas with possible severe weather in the Telangana region were indicated (Fig. 1). 5(a).

3.2.1 Realized weather on January 12th

Thunderstorms accompanied by hail were observed in isolated places over EMP VID Chhattisgarh, Gangetic West Bengal, and Telangana.

11th and 12th JAN: Isolated rain in Telangana: A hailstorm occurred in Telangana's Hanumkonda, Warangal, Janagao, and Kumarambheem districts. In coastal Andhra Pradesh: Komarada (Vizianagaram), 3 cm. Thunderstorms with hail were observed in isolated locations over EMP VID Chhattisgarh, Gangetic West Bengal and Telangana.

January 11 and 12: Isolated rain in Telangana. Hailstones hit the districts of Hanumkonda, Warangal, Janagao and Kumarambhim in Telangana. Andhra Pradesh Coastal State: Komarada (Vizianagaram), 3 cm.

3.3 January 13, 2022

3.3.1 Synoptic situation

The trogh were at an average elevation of 0.9 km above sea level on 12 January between the interior of southern Karnataka and southern Chhattisgarh, and on 13 January between the interior of northern Karnataka and the interior of northern Odisha, continuing in and around southern Konkan. At an altitude of 1.5 km above average sea level. In addition, the southwest part of the Bay of Bengal and its surroundings has cyclonic circulations extending up to 1.5 km at mean sea level. The elevated index /K in the figure. 1(c) is 33, Fig. 2(c) of 12Z was 40 mm, with moderate precipitation probabilities for Telangana and Andhra Pradesh (Fig. 1). 3(c)). In table 2 in Fig. 2, the index K 32.6. 9 clearly shows the confluence of the Arabian Sea and World War II winds in the lower troposphere, very likely over the east and adjacent central India.

Chart 1. Weather forecasting

K below 30	Thunderstorms with heavy rain or severe weather possible (see note below).
K over 30	Better potential for thunderstorms with heavy rain.
K = 40	Best potential for thunderstorms with very heavy rain.

3.3.2 Realized Weather on January 13, 2022

The southern state of Tamil Nadu and its surrounding areas maintain cyclonic circulation at an altitude of 0.9 km above mean sea level. Parts of the state have experienced unseasonal rain over the past two or three days. The Hyderabad Meteorological Centre of the Indian Meteorological Department (IMD) attributed the off-season rainfall to a valley that runs from the interior of northern Karnataka to northern Odisha. Over the past two days, heavy rain and hail have damaged crops and homes in parts of New York State. High winds also pulled power poles in several locations. (From 13 January, according to news reports) Parts of Greater Hyderabad also had rain at 13:00 AM. Districts such as Alwal, Rajendranagar, Chilkalguda, Maredpalli, Abids, Sultan Bazaar, Himayat Nagar, Bashirbagh, Kochi, Liberty and Khairatabad experienced heavy rainfall leading to road flooding in some areas. Parvatagiri, in the rural area of Warangal, recorded the highest amount of precipitation (10 cm). Nootankal in Suryapet recorded 8 cm of precipitation, Kollapur in Nagarkurnool recorded 7 cm and Garla in Mahabubabad district recorded 7 cm of precipitation. In Andhra Pradesh, S. Kota (Visianagaram) is 5 cm.

3.4 January 14, 2022

3.4.1 Synoptic situation

The trough between north interior Karnataka and north interior Odisha at 0.9 km above mean sea level persists. The cyclonic circulation over the south Konkan and its neighbourhood at 1.5 km above mean sea level persists. The cyclonic circulation over Southwest Bay of Bengal and its surroundings extends up to 1.5 km above mean sea level over Southwest and adjoining Southeast Bay of Bengal. The cyclonic circulation over south Tamil Nadu and its neighbourhoods at 0.9 km above mean sea level persists. The cyclonic circulation over the south Konkan and its neighbourhood persists, and it was seen between 1.5 km and 2.1 km above mean sea level. Possible severe weather region 5(d) shows a thunderstorm with 5-10 cm of rain. dbz values in the figure. A 7 on the radar image is greater than 55, indicating severe weather.

3.4.2 Realized weather on January 14, 2022

The normal precipitation in January in Vizianagaram was 9.9 mm (Table 1), but due to the synoptic conditions of Andhra Pradesh and its surroundings, Vizianagaram recorded the highest precipitation at 16 cm (IMD). This was a feature of the very rare precipitation that fell in the Vizianagaram district on the north coast of Andhra Pradesh in January.

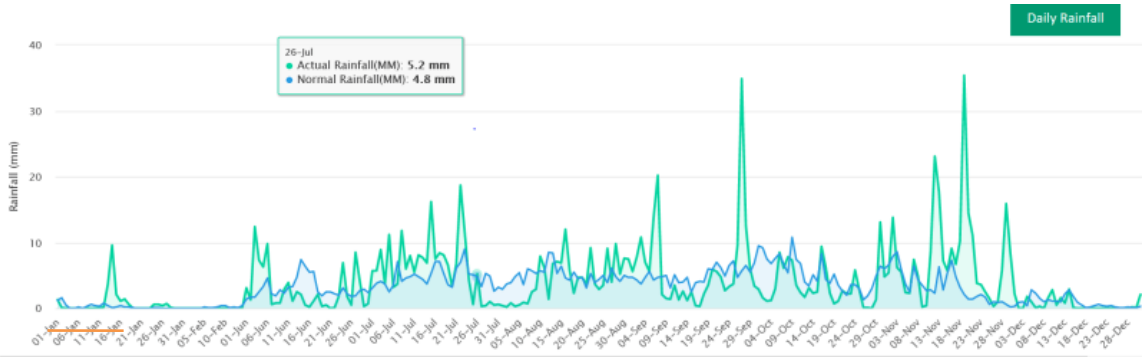
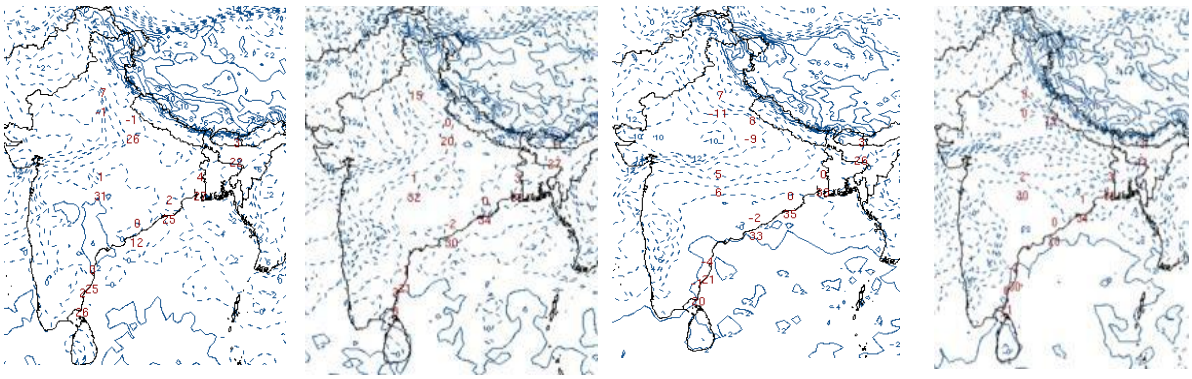


Chart 1. Rainfall of Andhra Pradesh from June2021 to Feb14 2022

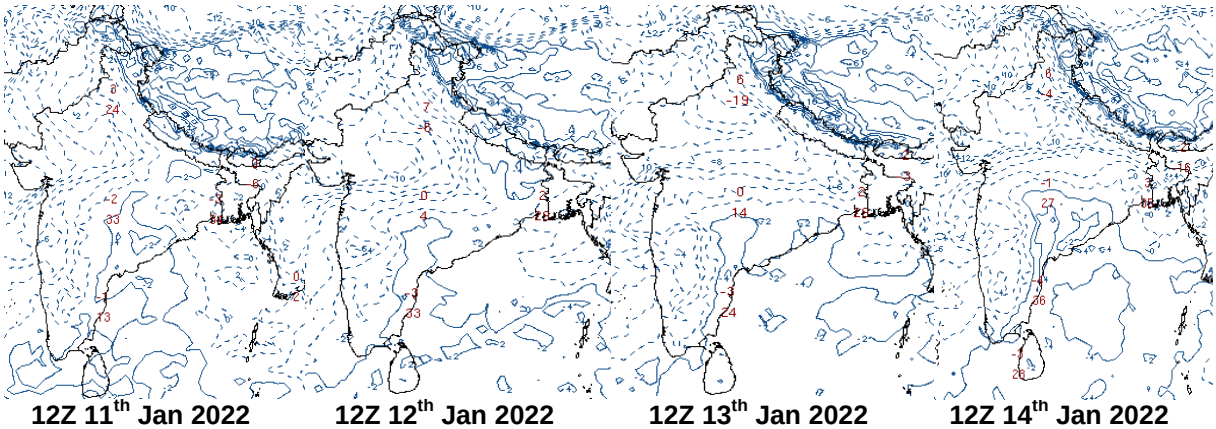
Table 1. District wise Monthly Seasonal Rainfall (mm) data from 01/06/2020 to 31/05/2021

Districtwise Monthly Seasonal Rainfall (mm) data from 01/06/2020 to 31/05/2021 A:Actual N:Normal

District	South-West Monsoon								North-East Monsoon						Winter Period				Hot Weather Period					
	Jun N	Jun A	July N	July A	Aug N	Aug A	Sept N	Sept A	Oct N	Oct A	Nov N	Nov A	Dec N	Dec A	Jan N	Jan A	Feb N	Feb A	Mar N	Mar A	April N	April A	May N	May A
Srikakulam	134.9	129.5	189.4	131.4	185.1	116.3	196.3	135.2	182.8	216.4	90.6	47.3	2.6	0.0	6.1	10.8	19.8	0.0	20.8	0.0	30.5	33.0	102.7	68.7
Vizianagaram	128.4	142.4	178.7	175.5	195.1	92.6	190.5	171.4	167.9	225.0	73.3	53.7	4.6	0.0	9.9	2.9	15.6	0.4	21.8	0.5	30.7	53.0	114.2	92.5
Vishakapatnam	128.8	142.2	197.3	192.8	196.5	181.9	190.0	193.6	205.3	294.8	87.3	103.7	4.6	0.0	10.0	1.8	12.3	1.3	20.7	4.9	35.0	50.6	114.5	110.1
East Godavari	123.7	132.9	239.1	319.2	218.9	239.6	186.3	284.2	206.7	350.7	88.4	152.7	10.3	0.1	8.7	2.0	11.0	1.3	13.5	0.8	17.5	28.4	93.5	67.4
West Godavari	114.7	121.6	250.2	391.5	249.2	229.3	177.8	280.9	165.7	300.2	63.4	121.6	10.3	0.0	10.2	0.0	7.5	1.0	14.4	0.1	18.4	18.5	71.2	78.6
Krishna	97.8	134.4	210.6	306.0	212.8	171.9	163.9	219.5	162.7	243.2	70.7	111.9	16.0	0.6	8.4	0.0	7.4	4.3	10.7	0.0	14.5	17.1	58.0	59.1
Guntur	86.3	103.4	142.1	239.2	152.0	145.0	145.4	210.1	130.5	137.9	82.0	117.6	16.4	0.1	9.2	0.0	9.2	3.2	8.7	0.0	11.4	11.0	59.8	58.3
Prakasham	58.0	81.7	89.7	140.9	107.0	92.2	133.6	233.5	206.5	106.2	143.7	242.4	43.5	9.1	11.8	3.1	4.5	15.9	9.5	0.0	11.8	16.5	51.9	70.4
Nellore	56.8	69.0	86.3	138.3	86.1	125.7	102.1	156.1	239.0	84.9	313.4	487.0	109.0	158.6	14.2	64.0	5.7	21.5	4.0	0.0	10.1	8.8	53.7	12.8
Chittoor	78.7	99.3	101.9	272.1	117.4	128.6	141.4	172.7	162.7	138.0	162.6	255.8	70.1	90.2	2.2	32.1	1.2	8.3	3.7	0.0	17.6	35.2	61.7	56.3
Kadapa	69.2	91.2	96.7	153.2	114.0	139.0	113.7	308.2	131.9	125.6	93.4	229.2	25.7	53.3	2.7	8.9	1.9	8.2	5.7	0.1	11.2	22.6	36.7	72.4
Anantapur	63.9	106.8	67.4	166.8	88.7	56.6	118.4	236.8	110.7	113.0	34.7	48.5	9.9	19.1	1.6	14.4	1.3	12.1	3.3	0.0	12.8	33.4	39.6	79.5
Kurnool	77.2	134.9	117.2	238.1	135.0	117.6	125.7	267.3	114.5	123.2	27.6	38.4	7.5	2.7	7.8	31.1	4.3	11.6	7.7	0.0	17.0	22.3	38.5	77.8
State	**93.7**	**113.1**	**151.3**	**225.1**	**158.3**	**141.8**	**152.7**	**224.8**	**168.2**	**185.9**	**102.4**	**157.7**	**25.4**	**26.7**	**7.9**	**13.3**	**7.8**	**7.3**	**11.1**	**0.4**	**18.3**	**26.2**	**68.9**	**68.7**

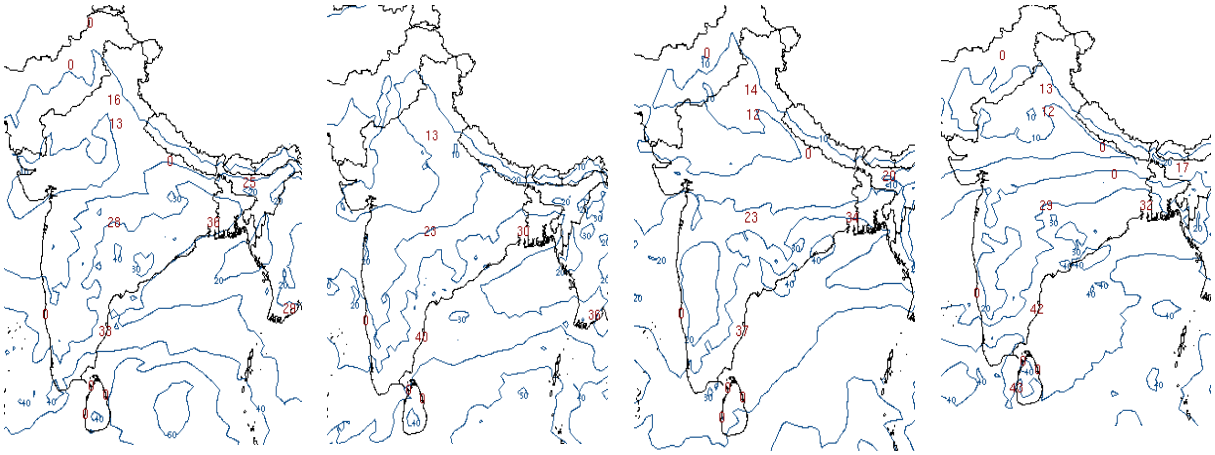


00 Z 11 Jan2022 (a) 00 Z 12 Jan2022 (b) 00 Z 13 Jan2022 00 Z 14 Jan2022



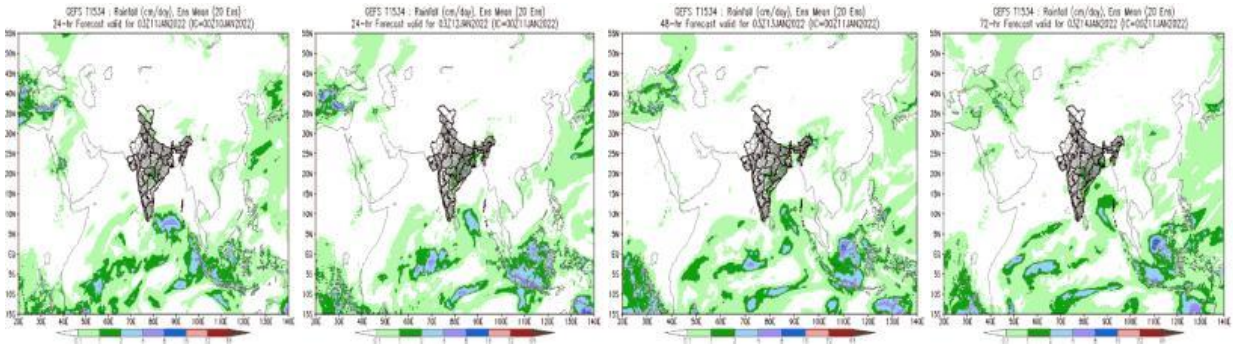
12Z 11th Jan 2022 (a) 12Z 12th Jan 2022 (b) 12Z 13th Jan 2022 (c) 12Z 14th Jan 2022 (d)

Fig. 1. Lifted / K Indices over India region from 11th to 14th January 2022



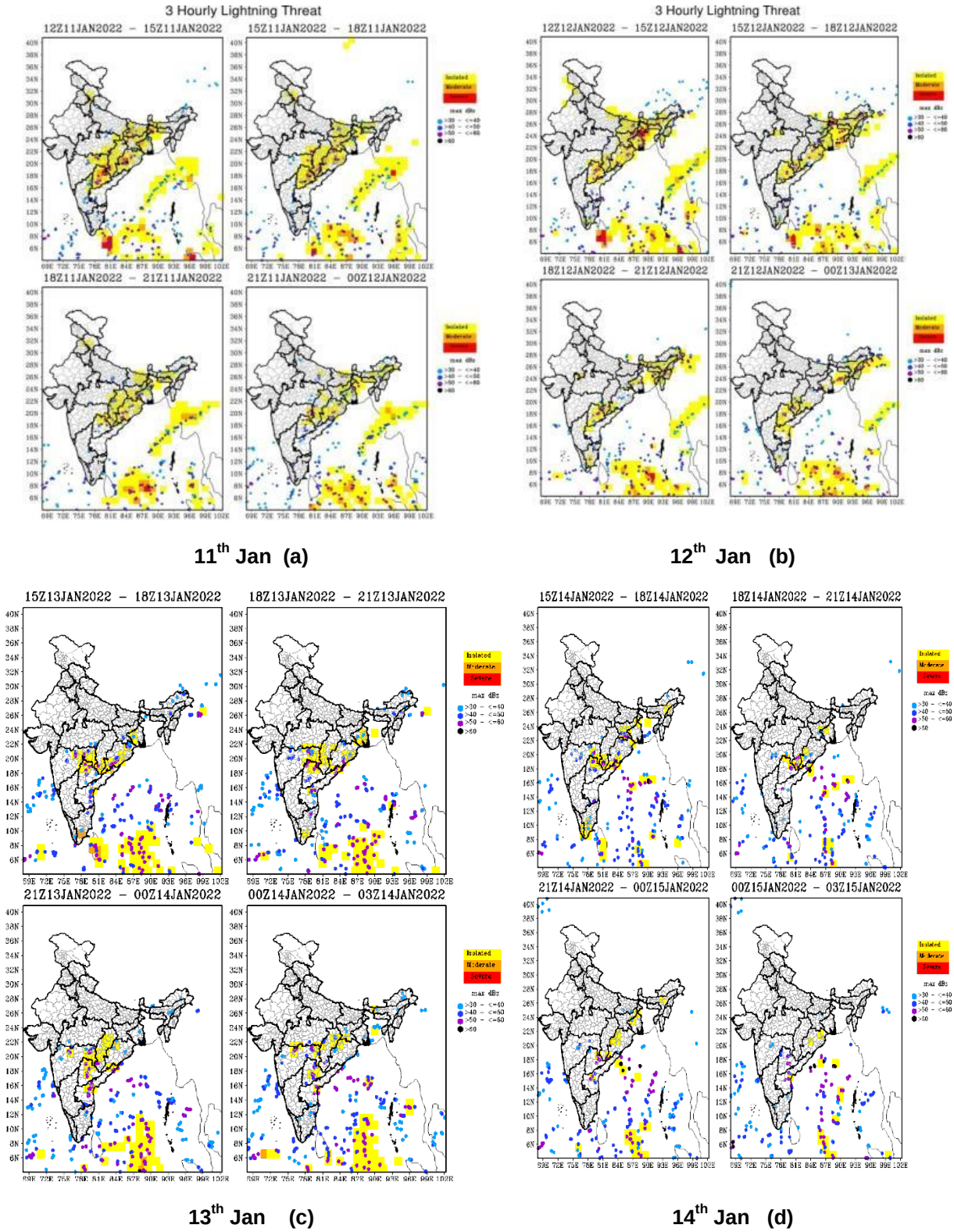
12Z 11th Jan 2022 (a) 12Z 12th Jan 2022 (b) 12Z 13th Jan2022 (c) 12Z 14th Jan 2022 (d)

Fig. 2. Precipitable Water analysis over India Region 11th to 14th January 2022



11th Jan 2022 (a) 12th Jan 2022 (b) 13th Jan 2022 (c) 14th Jan 2022 (d)

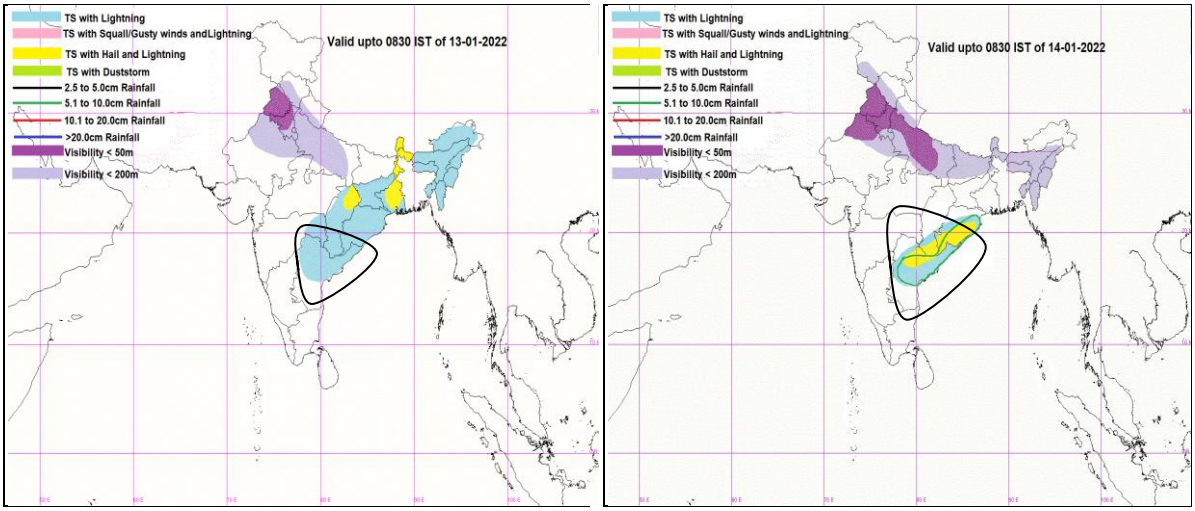
Fig. 3. GEFS forecast products from 11th to 14th January 2022



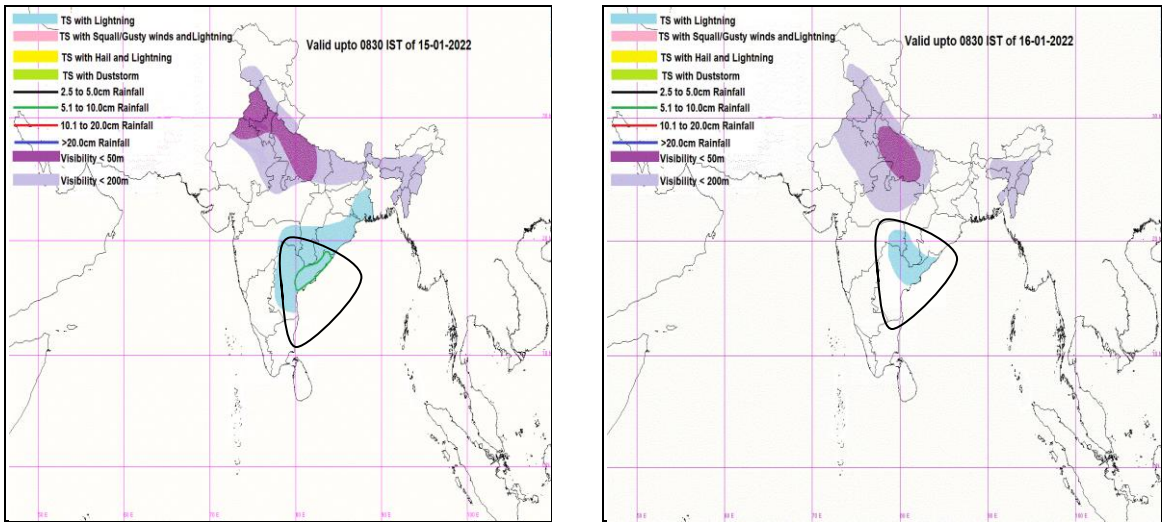
11th Jan (a) **12th Jan (b)**

13th Jan (c) **14th Jan (d)**

Fig. 4. 3 hourly Lightning Threat for the study period



Issued on 12th January **Issued on 13th January**

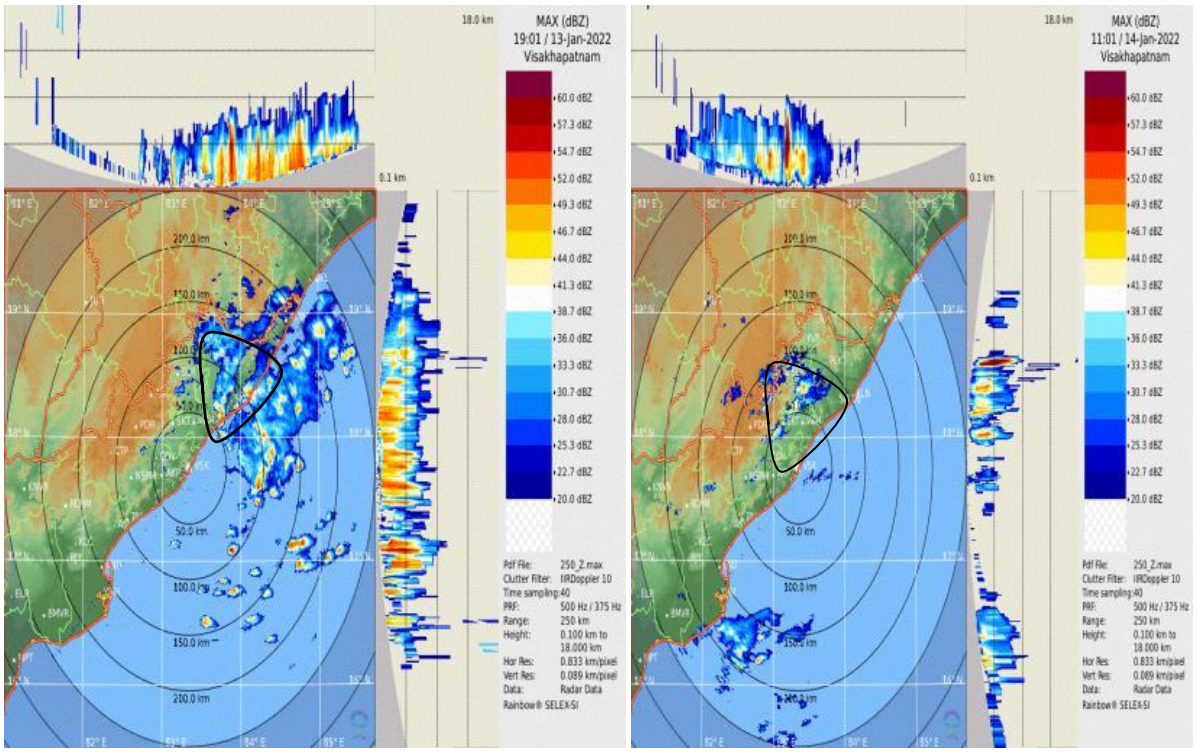


Issued on 14th January **Issued on 15th January**

Fig. 5. Potential Areas of Severe Weather over India 12th to 15th January 2022

Table 2. Thermodynamic parameters at reference station Visakhapatnam 43150

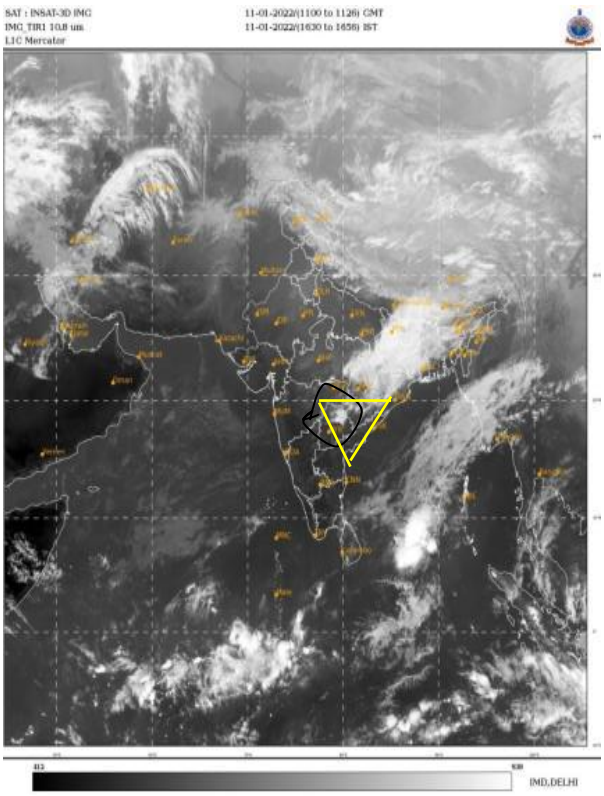
Parameter	11/00	12/00	13/00	14/00
Lifted index	-0.72	-2.9	-2.9	-0.04
SWEAT Index	107.39	187.2	172.6	191.1
K Index	11.5	30	32.6	28.4
Totals Totals index	40.60	47.3	47.4	44.7
CAPE	72.17	430	386.7	69.8
CI	-217.62	-6.22	-48.96	-91.9
EL	398.89	383.4	408.2	457.4
LFC	539	918.53	768.5	774.9
LCL	927	943	953.3	949.66
Bulk Richardson no	1.50	5.3	10.5	1.59
Precipitable Water mm	28.3	35.98	38.81	35.52



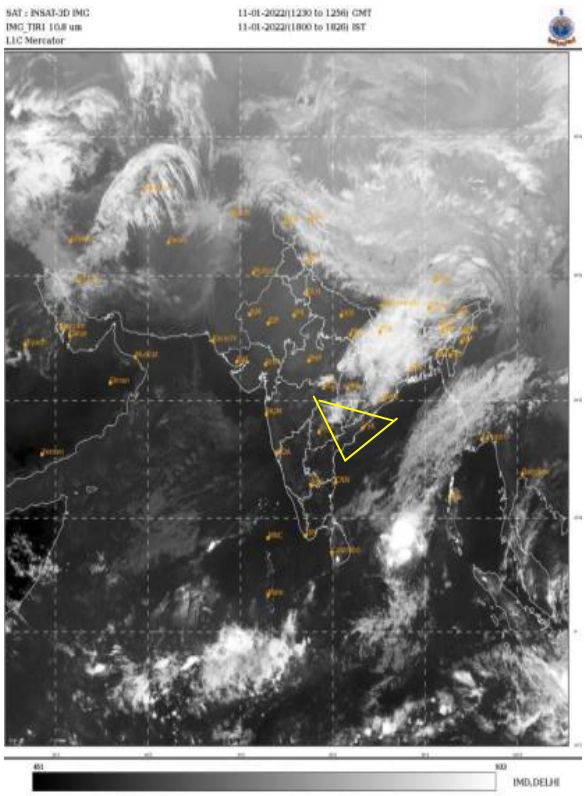
13th January **14th January**

14th January **15th January**

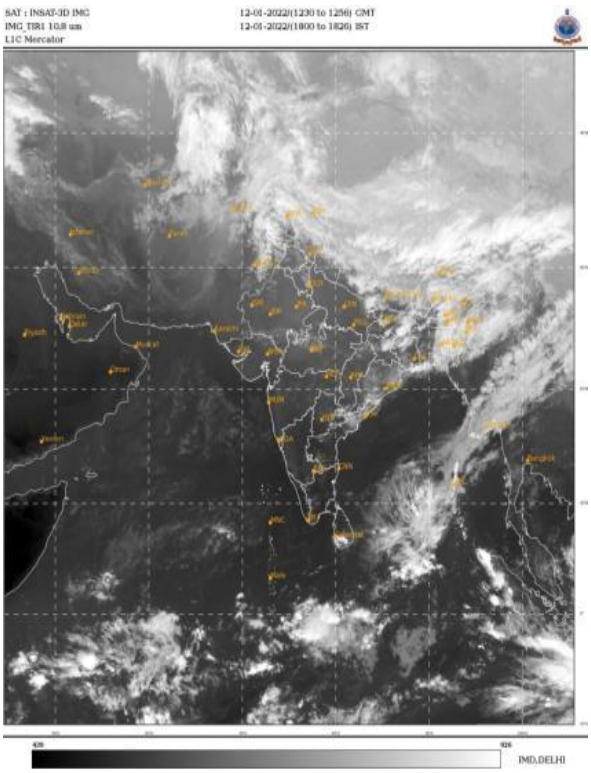
Fig. 6. Radar observations over North coastal Andhra Pradesh from 13th to 15th January 2022



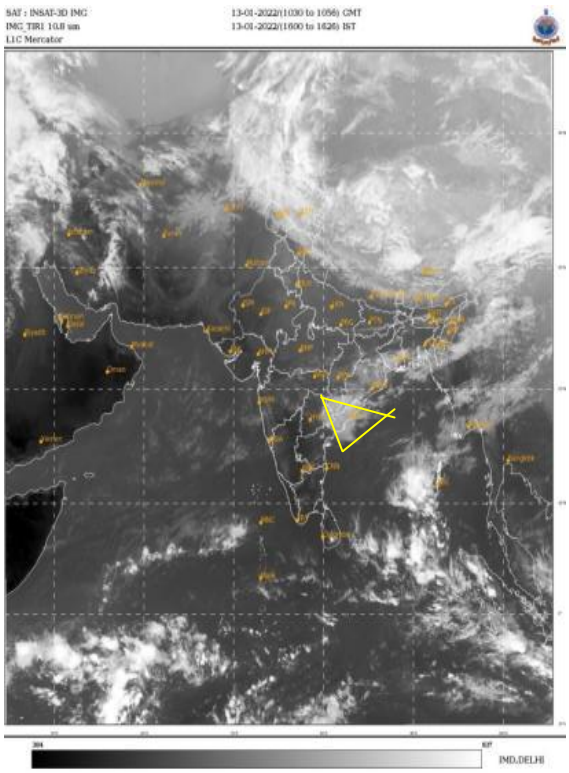
11th Jan 1630 IST



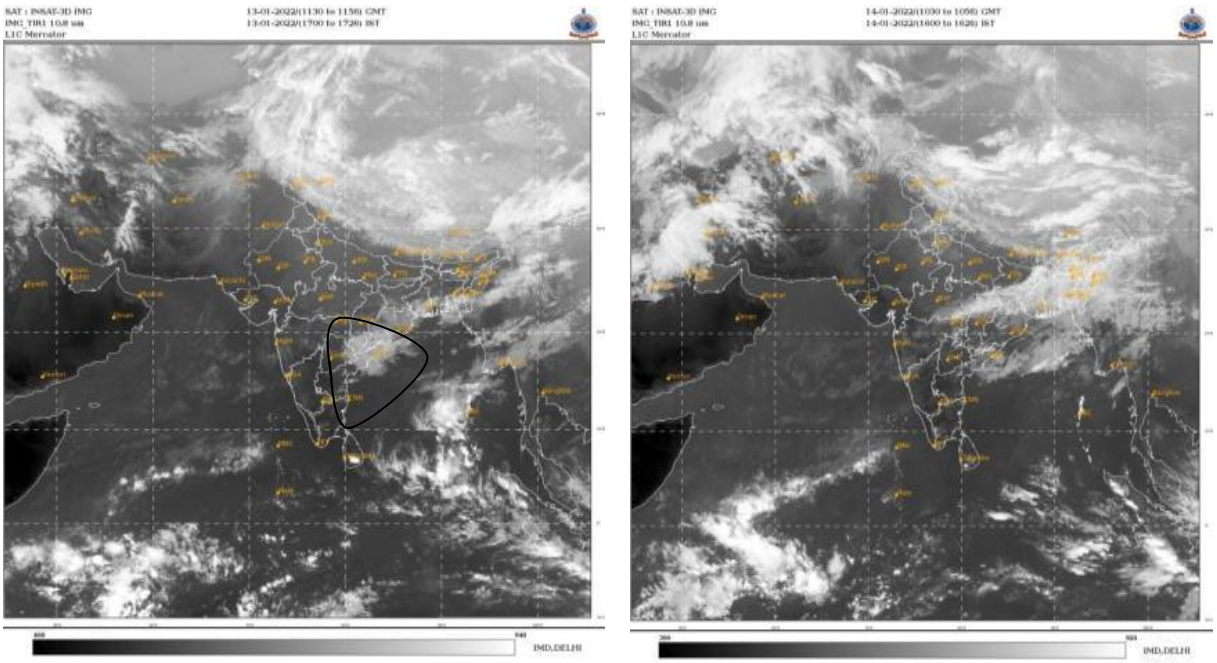
11th Jan 1830 IST



12th Jan 1830 IST

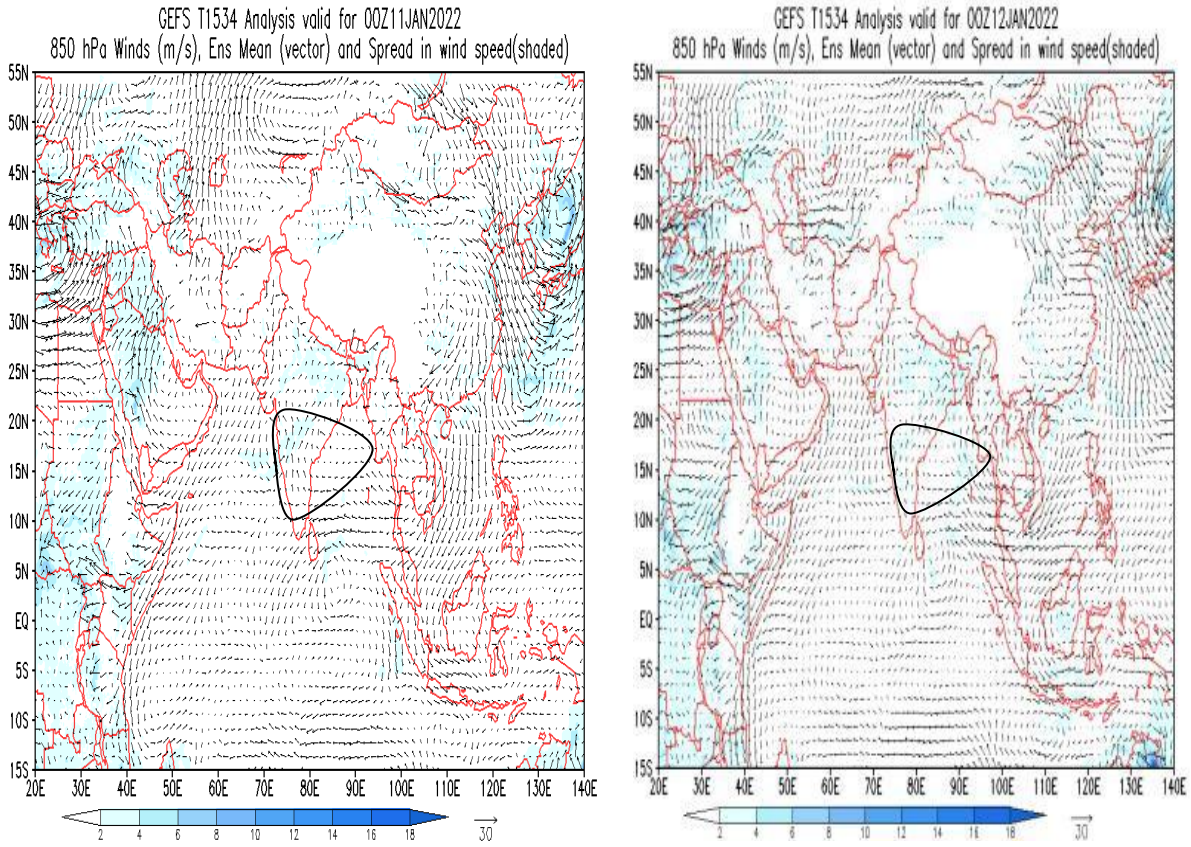


13th Jan 1630 IST

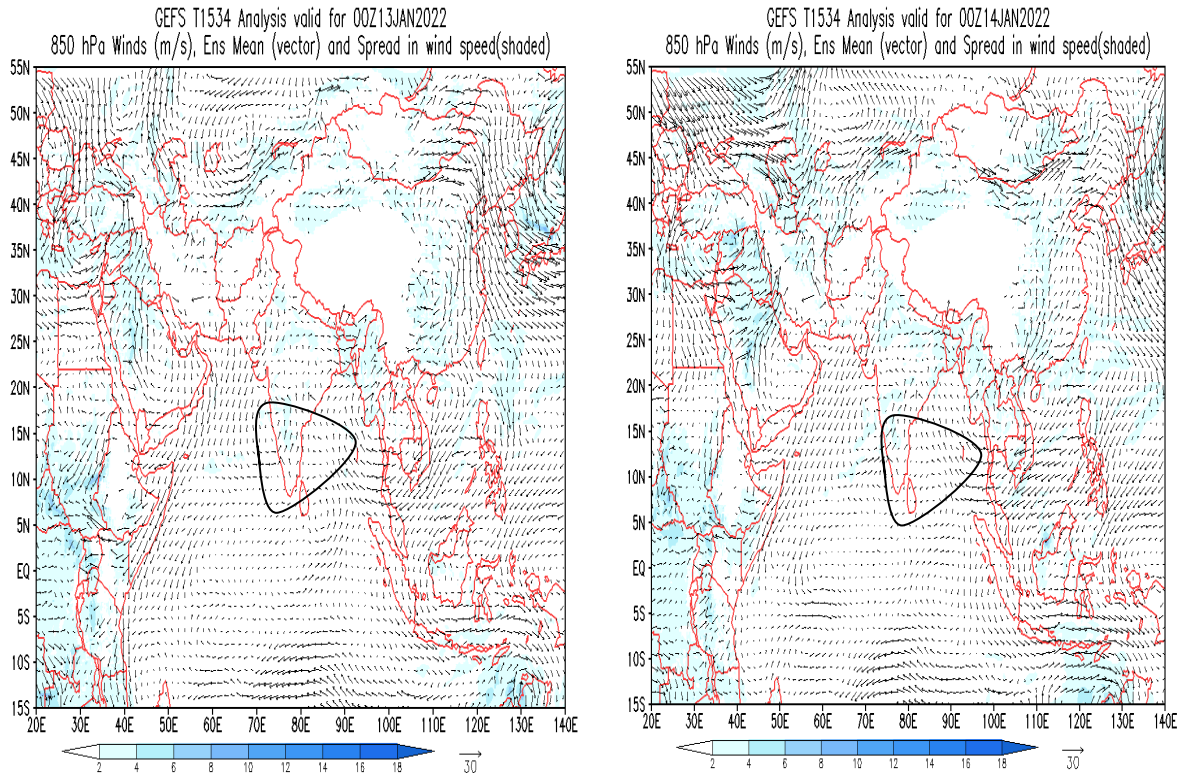


13th Jan 1730 IST **14th Jan 1630 IST**

Fig. 7. Insat 3D TIRI Satillite pictures observed during study period from 11th to 14th January 2022

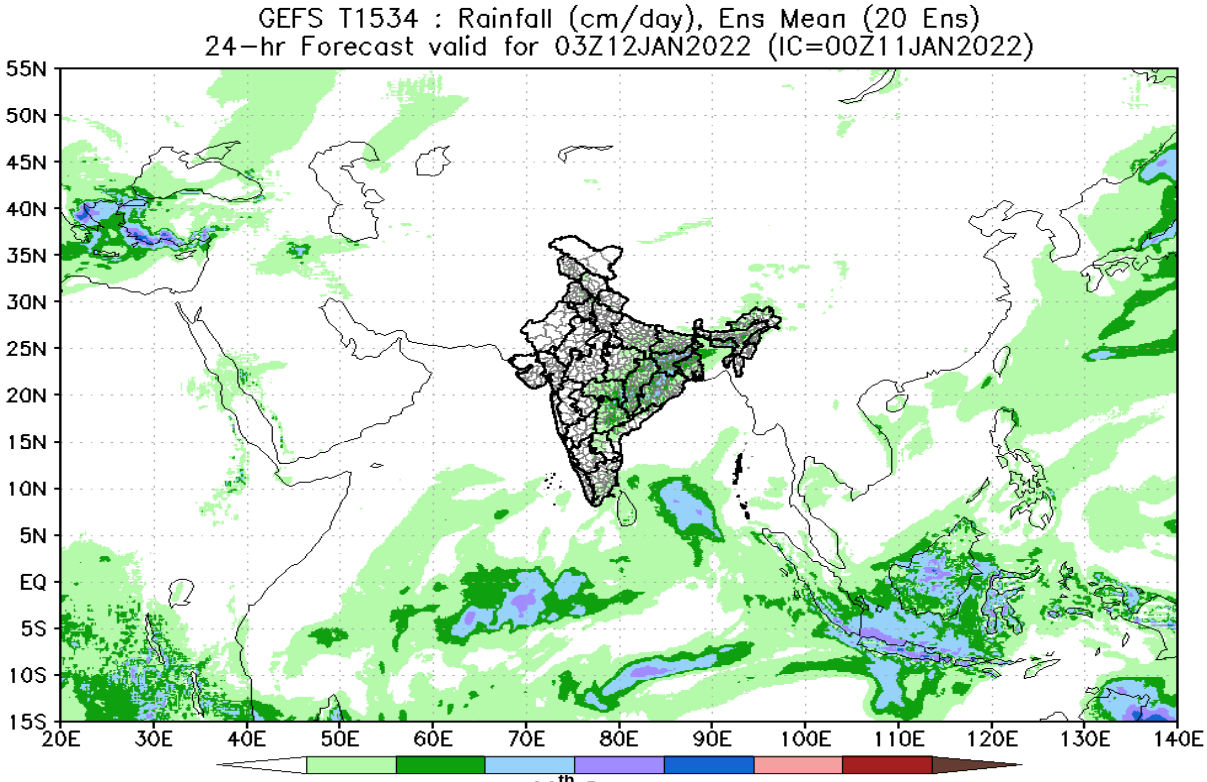


January 11 **January 12**

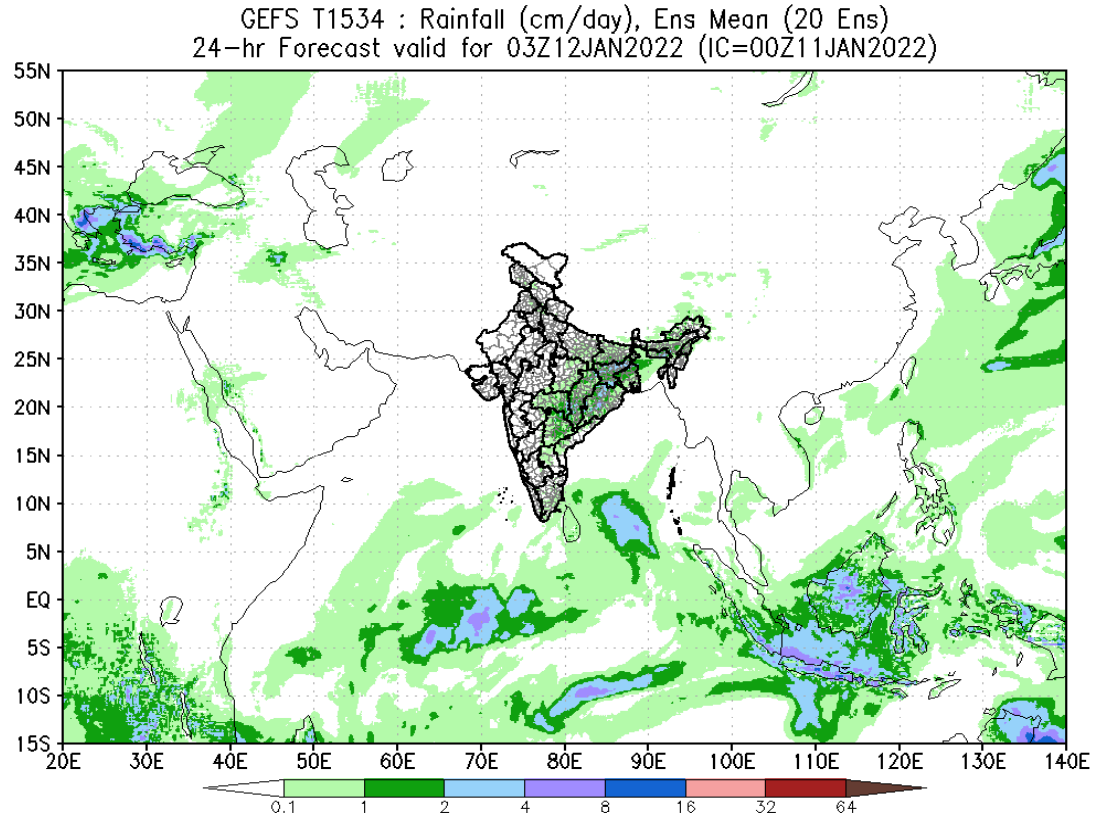


January 13 **January 14**

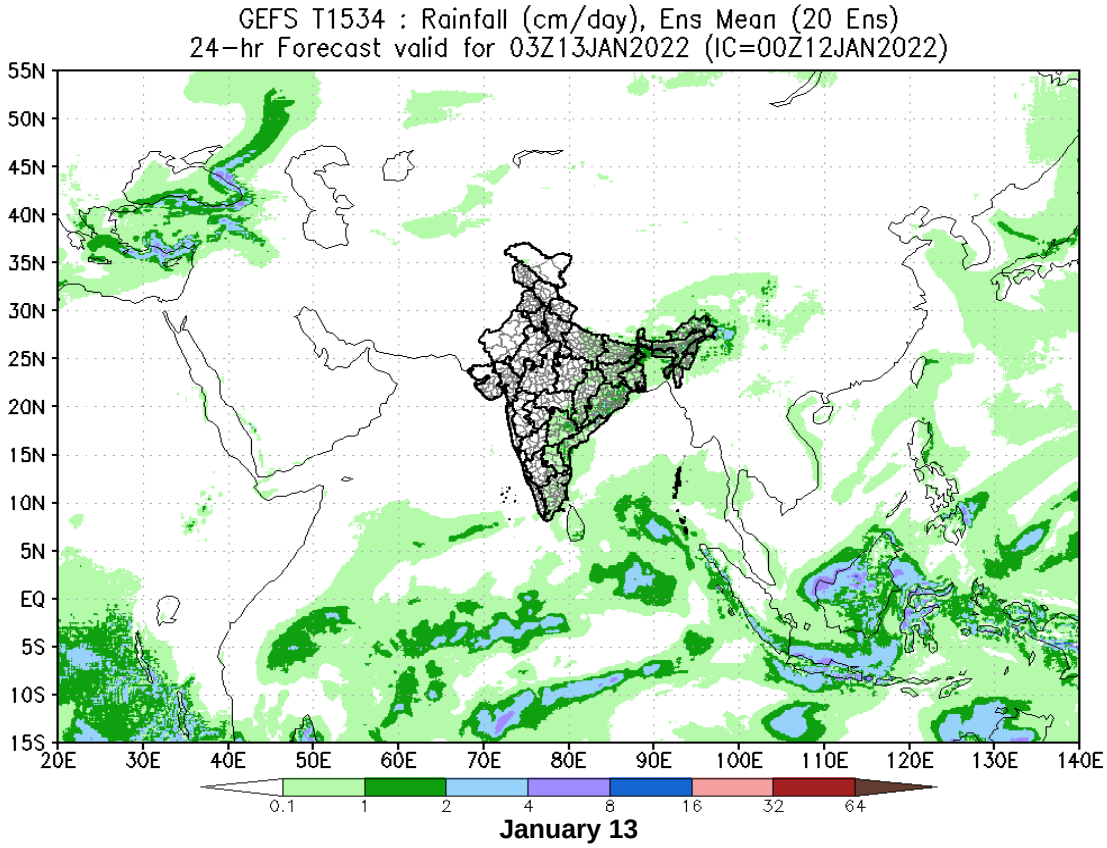
Fig. 8. GEFS Ti534 Analysis forecast products from 11th to 14th January 2022



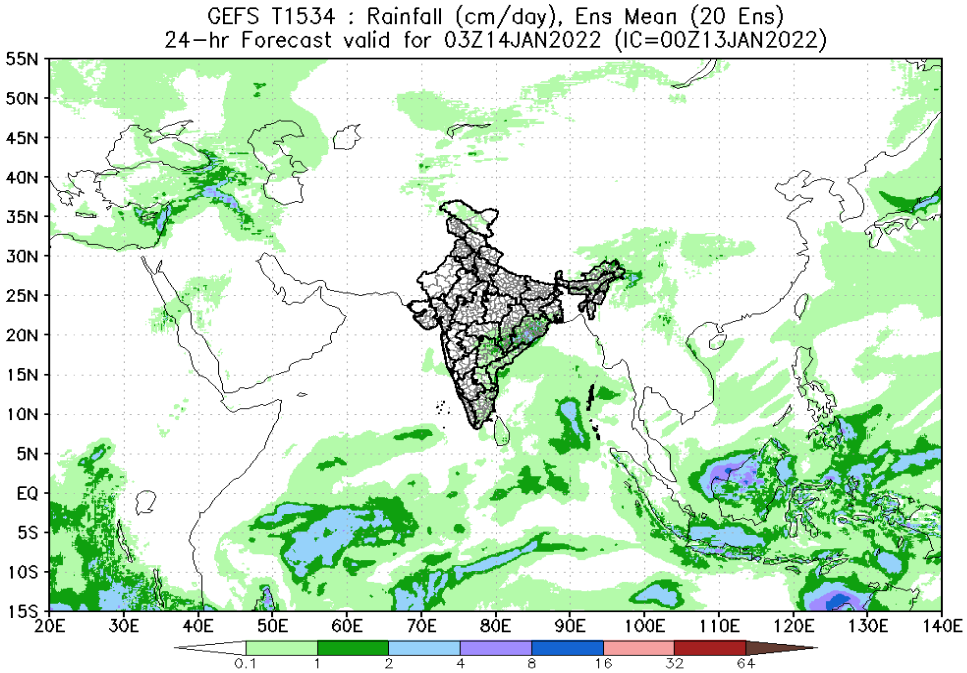
11th January



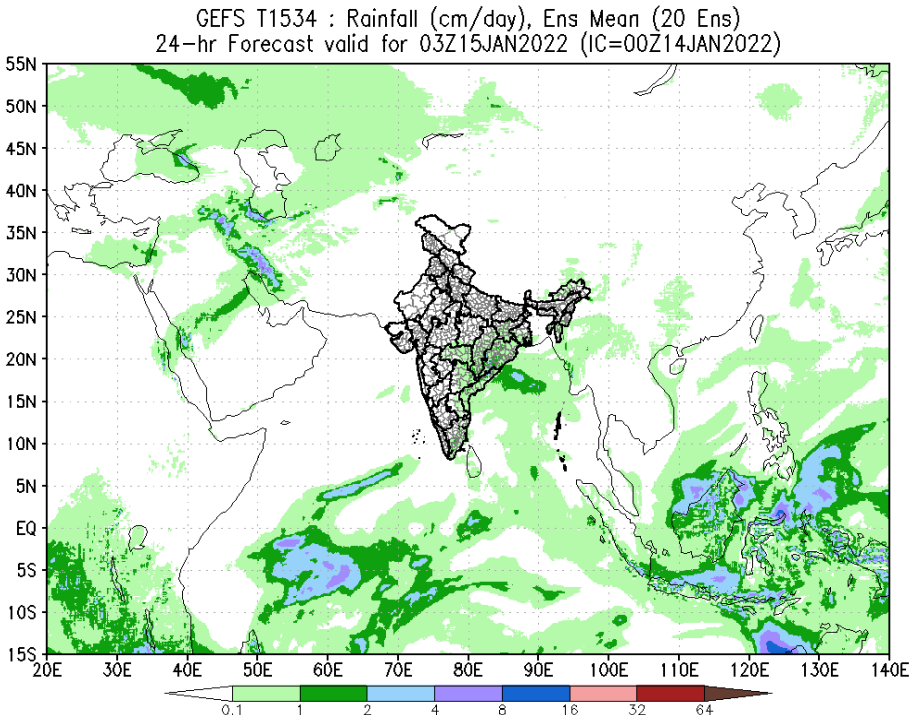
January 12



January 13



January14



January 15

Fig. 9. Forecast scenario from January 11 to January 15 2022

It rained in several places in Telangana, with the heaviest amount being 6cm in Jajireddigudem (Suryapet).

Paravatipuram 16 cm, Sithanagaram 9 cm, Garugubilli 7 cm, Bobbili, Balajipeta 5 cm each, Bondapalle, Jiyamawalsa 4 cm each, all located in Vizianagaram district.

Amaravati, Teneali, Mangalgiri (Guntur) 5 cm each.

On January 15, 2022, precipitation of more than 2 cm was recorded by many stations in the VZM and VSK regions.

In January 2022, hail storms and heavy rains were recorded in the state of Telangana and heavy rains were recorded in the coastal state of Andhra Pradesh. The results show that indices related to convection and potential instability are better suited to distinguish thunderstorms. The results show that these regions have higher instability of thunderstorm events on thunderstorm days and higher moisture availability in the region during the entire pre-monsoon season. Suppression is higher on non-stormy days and limits the occurrence of convective activity on certain days [12-17].

3.5 Forecast for the Period

The weather conditions shown above are rather unusual for the central and adjacent northern parts of the Indian peninsula at this time of year. So you can capture the first event in your daily weather forecast. The spatial distribution and intensity of precipitation were well predicted. In addition, subsequent events were predicted well in advance (two days is the maximum time that can be reached with currently available resources). The Met office has issued a yellow alert for the next three days, including Thursday. It is stated that hail and heavy rain are likely to occur in isolated areas in the districts of Mulugu, Bhadradri Kothagudem, Hammam, Nalgonda, Suryapet, Mahabubabad, Warangal (rural), Warangal (urban), Janagaon, Yadadri Bhuwangiri and Nagarkurnul. (The Times, 14 January 2022).

4. CONCLUSION

- During the period 5–8 January 2022, the southern tip of the trench at the lower and middle levels of the troposphere associated with the system was located south of 20° N deep in the Arabian Sea and pumped large volumes. Moisture enters the system from the Arabian Sea. Large amounts of water entering the lower tropospheric system have also been observed in the Bay of Bengal.
- The diurnal and temporal pattern of the hail storm and heavy rainfall over the Andhra Pradesh and Telangana states shows that late evenings are most conducive for the occurrence of extreme rainfall events due to the accumulation of precipitable water.
- Deep convection requires high relative humidity in the lower and upper troposphere and lower relative humidity in the middle troposphere, which is observed in this phenomenon. By combining continuous rainfall and hailstorm monitoring with the availability of radar and lightning products and satellite observations, the nowcasting of hailstorm and heavy rainfall events is possible with a lead time of half to an hour. The lead time of the nowcast of heavy rain can be increased by 1-2 hours with the availability of reflectivity products from GEFS. The favourable synoptic and thermodynamic conditions in association with NWP model outputs can help much more.
- In order to forecast hail storms across wide areas, countries require effective radar networks. Farmers will be able to safeguard crops, reduce losses, and apply integrated management methods for early crop and tree recovery thanks to Agromet's prompt release of alerts and guidance before and after hailstorms.

4.1 Advantages

- A timely forecast of adverse weather will save lives and human properties.
- Farmers can protect their crops and produce while minimising losses by adopting integrated management practices.
- The study will help to assess the occurrence of adverse weather.
- The study improves the adjustment of planning, scheduling, and management of crops and general public activities.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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