

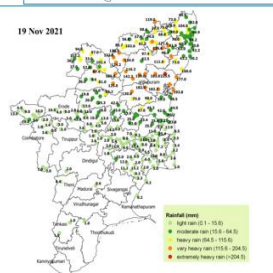
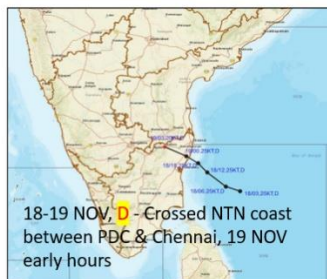
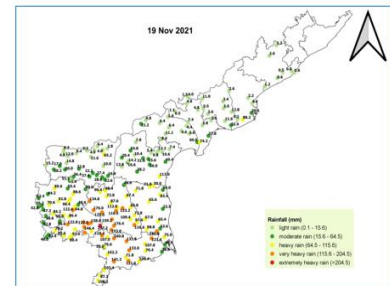
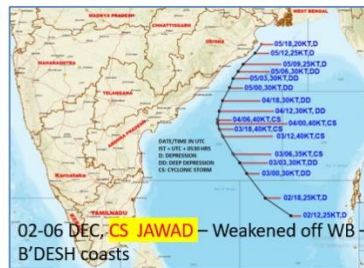
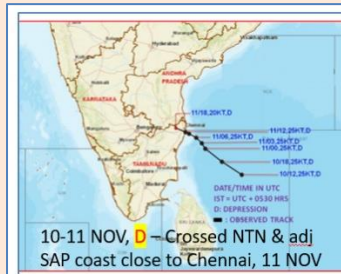
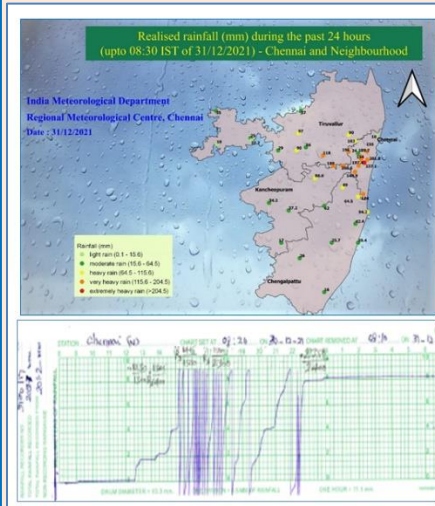
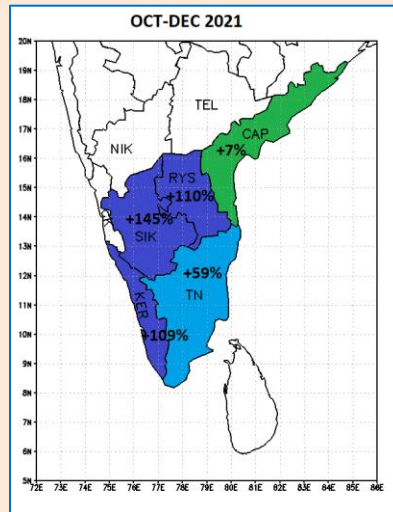


Government of India  
Earth System Science Organisation  
Ministry of Earth Sciences  
India Meteorological Department



IMD Chennai Scientific Report No. IMDC-SR/12

## REPORT ON NORTHEAST MONSOON – 2021



Regional Meteorological Centre, Chennai

March 2022

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## Executive Summary

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## **Abstract**

During the year 2021, the southwest monsoon withdrew from the Indian region on 25<sup>th</sup> October and simultaneously, the Northeast monsoon (NEM) of 2021 commenced over the southeastern parts of peninsular India on 25<sup>th</sup> October against the normal date of 20<sup>th</sup> October. Excepting Coastal Andhra Pradesh (CAP) that received *normal* rainfall during the season, the other four sub divisions benefitted by the NEM [Tamil Nadu (TN (including Puducherry & Karaikal), Kerala (KER), Rayalaseema (RYS) and South Interior Karnataka (SIK)] received *excess to large excess* rainfall during the NEM season (October-December) with KER, SIK, RYS recording more than 100% excess (*large excess*) rainfall. There were 30 days of *active to vigorous* monsoon conditions over TN & KER during the season. There were 65 days of *isolated heavy* rainfall activity with 33 days of *isolated very heavy* rain including 09 days of *isolated extremely heavy rainfall* activity over TN. Two **Depressions** that formed over the North Indian Ocean during November contributed significantly to NEM rainfall over the peninsular India. Cyclonic Storm (CS) **Jawad** over Bay of Bengal (BOB) during 02-06 December tracked northwards towards West Bengal-Bangladesh coasts and did not contribute towards NEM rainfall. There were two days of *extremely heavy rainfall* activity over Chennai (i) 06<sup>th</sup> November night & (ii) 30<sup>th</sup> December 2021. Recurrent heavy rainfall over the coastal and adjoining districts from last week of October to November, led to filling up of water bodies and inland and riverine flooding occurred over several areas of TN and RYS. NEM 2021 extended into January 2022 and cessation of NEM 2021 rainfall over peninsular India was declared on 22.01.2022.



## 1. Background

The Indian southwest monsoon (SWM) season of June to September is the chief rainy season for India and about 75% of the country's annual rainfall is realised during this season. Subsequent to the withdrawal of SWM, the northeast monsoon (NEM), a small scale monsoon confined to parts of southern peninsular India comprising of the meteorological sub-divisions of Tamil Nadu, Puducherry & Karaikal (TN), Kerala & Mahe (KER), Coastal Andhra Pradesh & Yanam (CAP), Rayalaseema (RYS) and South Interior Karnataka (SIK) occurs. For the subdivision of TN, the normal SWM seasonal rainfall realised is only about 36% (336.1 mm) of its annual rainfall (939.3 mm) as this subdivision comes under the rain-shadow region during the SWM. The northeast monsoon (NEM) season of October to December (OND) is the chief rainy season for this subdivision with 48% (449.7 mm) of its annual rainfall realised during this season and hence its performance is a key factor for this regional agricultural activities.

Further, the NEM season is also the primary cyclone season for the North Indian Ocean (NIO) basin comprising of the Bay of Bengal (BOB) and the Arabian Sea (AS) and cyclonic disturbances (CDs; low pressure systems (LPS) with maximum sustained surface wind speed (MSW) of 17 knots or more) forming over BOB and moving west/northwest-wards affect the coastal areas of southeastern peninsular India and also contribute significantly to NEM rainfall. As such, the NEM season assumes importance from the agricultural as well as cyclone disaster management perspectives.

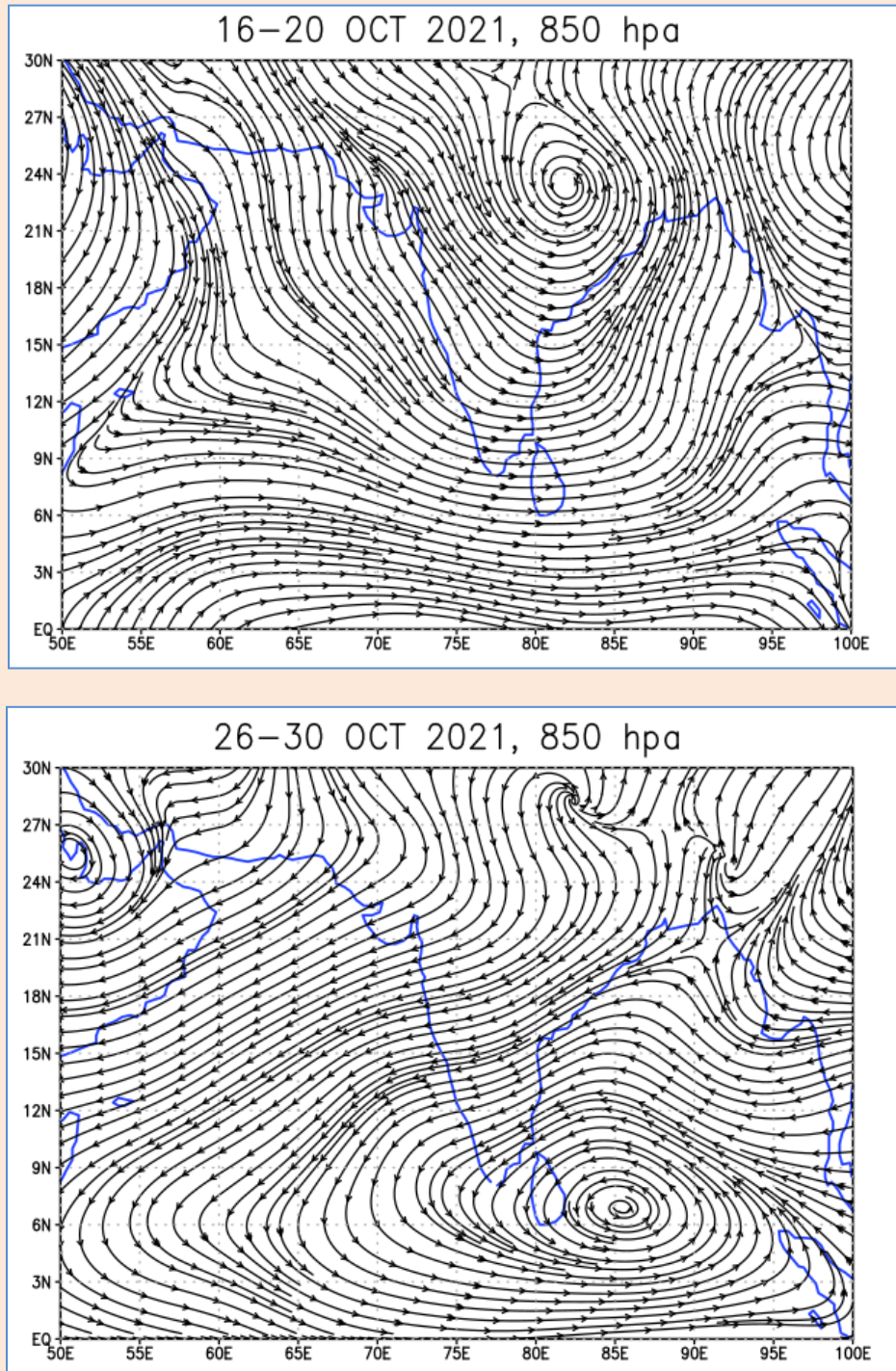
Prior to the commencement of NEM rains, after the withdrawal of SWM upto 15°N, reversal of low level winds from southwesterly to northeasterly occurs. The normal date of setting in of easterlies over the southeastern peninsular India is 14<sup>th</sup> October. The normal date of onset of NEM over Coastal TN (CTN) and south CAP is 20<sup>th</sup> October. The normal rainfall received over the five NEM sub-divisions during OND is TN-449.7 mm, KER-491.6 mm, CAP-338.1 mm, RYS-223.3 mm and SIK-204.1 mm. However, the NEM seasonal rainfall shows a high degree of variability with 27% co-efficient of variation.

The NEM rainfall is influenced by global climate parameters such as ENSO (El Nino/La Nina & Southern Oscillation Index), Indian Ocean Dipole (IOD) and Madden-Julian Oscillation (MJO). El Nino, positive IOD and MJO in phase 2-4 with amplitude greater than one are generally associated with good NEM rainfall.

## 2. Onsetphase

During October 2021, La Nina conditions prevailed over the equatorial Pacific Ocean and IOD was negative which were not favourable for good NEM activity. MJO was in phase-5 during the first half of October and became insignificant during the second half of the month. Under the influence of La Nina, MJO in phase-5 and favourable synoptic situations such as formation of a Low pressure area (LOPAR)s, cyclonic circulations over the southern peninsular region and active east-west shear zone roughly along 15°N over the Indian region on many days

during the month, SWM extended up to the 25<sup>th</sup> October 2021. Pentad mean wind flow pattern depicting the reversal of wind from westerlies to easterlies during the last pentad of October 2021 are presented in Fig.1a.



**Fig.1a: NCEP reanalysis 850 hPa streamline pattern indicating reversal wind from westerly to easterly over peninsular India during the last pentad (25<sup>th</sup>-30<sup>th</sup>) of October 2021**

**(i) Pre-onset (Extended southwest monsoon) period:** During October 2021, under the influence of favourable synoptic situations such as formation of a Low pressure area (LOPAR)s and cyclonic circulations over the southern peninsular region and active east-west shear zone roughly along 15°N over the peninsular region on many days, SWM extended up to the 25<sup>th</sup> October 2021. During the period 01<sup>st</sup> October to 24<sup>th</sup> October, fairly widespread (FWS) to widespread (WS) rainfall occurred over Kerala for 23 days & over SIK for 16 days. Active to vigorous monsoon conditions prevailed over Kerala for 11 days and over SIK and TN for 9 days. Tables 1a&b present the spatial rainfall distribution and frequency of heavy rainfall days over the five subdivisions during this period. There were 8 days of *isolated very heavy* rainfall over KER including 2 days of *isolated extremely heavy* falls; 7 days of *isolated very heavy* rainfall over TN including 2 days of *extremely heavy* falls during this period. *Extremely heavy* rainfall was reported over Kerala, on 12<sup>th</sup> October [Karipur Airport (Malappuram district) – 25 cm, Mannarkkad (Palakkad district) – 24 cm, Kozhikode-22 cm]] and 17<sup>th</sup> October [Peermedu (Idukki district) –29 cm, Kanjirappally (Kottayam district) – 27 cm)]; over Tamilnadu on 17<sup>th</sup> October [Papanasam (Tirunelveli district) – 27 cm, Pechiparai (Kanyakumari district) – 22 cm] and 21<sup>st</sup> October [Yethappur (Salem district) – 21 cm]. There were 3,2 & 1 day(s) of isolated very heavy rainfall activity over SIK, CAP & RYS respectively during this period.

Surface isobaric analysis as on 0830 IST and upper air streamline analysis as on 0530 IST of 16<sup>th</sup> October depicting the LOPAR that prevailed over westcentral Bay of Bengal off North Andhra Pradesh-south Odisha coasts during 14<sup>th</sup>-16<sup>th</sup> October and another LOPAR over southeast Arabian Sea off Kerala coast during 16<sup>th</sup>-17<sup>th</sup> October with associated upper air cyclonic circulations are presented in Fig.1b. Fig.1c presents plots of GPM-gauge merged rainfall depicting very-extremely heavy rainfall as on 12<sup>th</sup>& 17<sup>th</sup> October over the southern region.

**Table 1a: Spatial distribution of rainfall over various subdivisions during 01-24 Oct 2021**

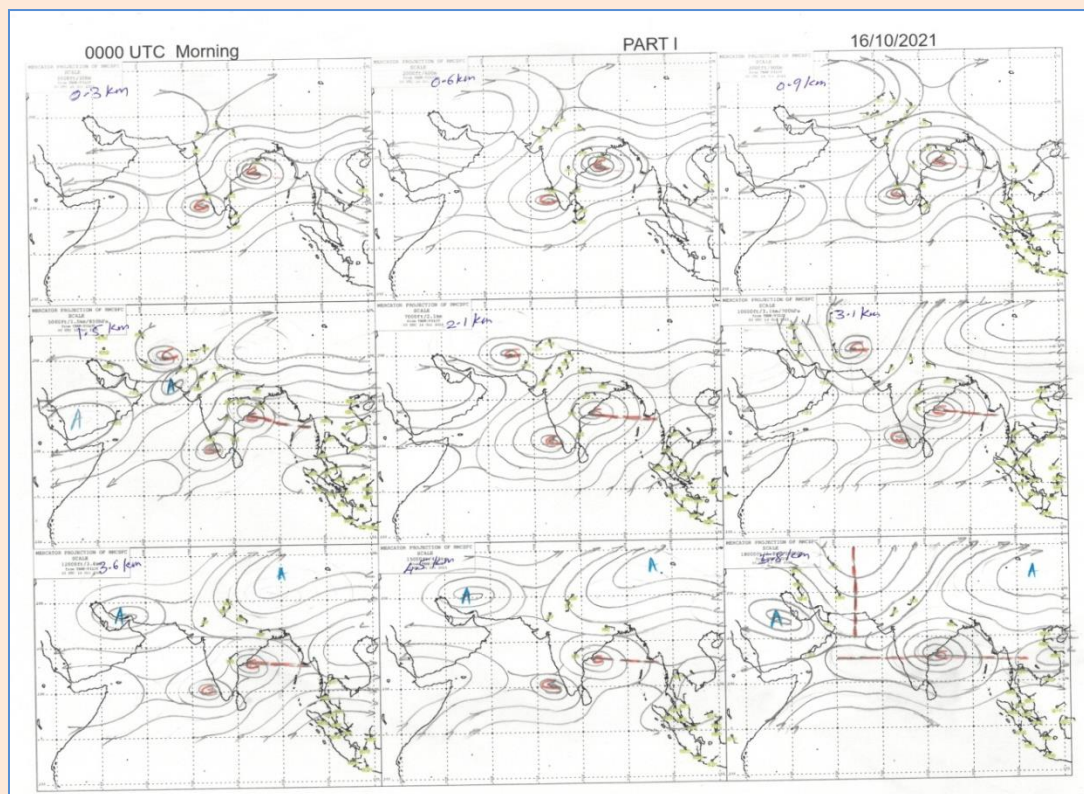
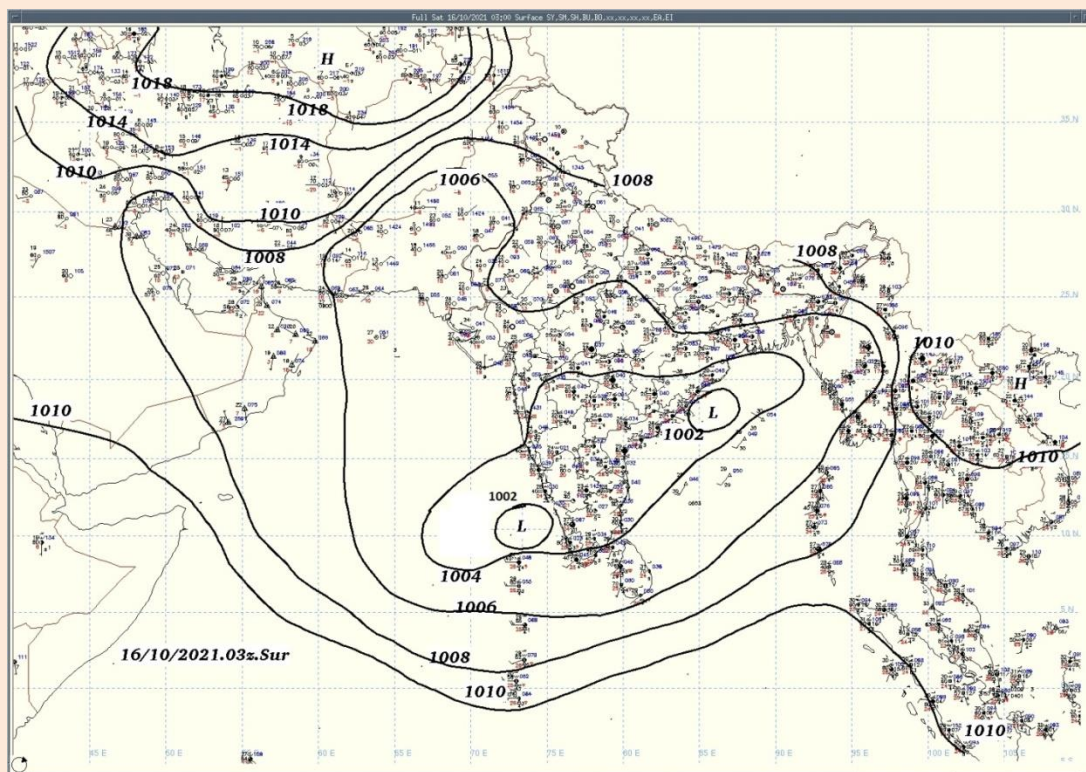
Spatial distribution	No. of days				
	TN	CAP	RYS	KER	SIK
WS	2	0	2	18	8
FWS	9	3	4	5	8
SCT	9	4	7	0	6
ISOL	4	17	10	1	2
DRY	0	0	1	0	0

**Table 1b: No. of days of heavy rainfall events during 01-24 Oct 2021**

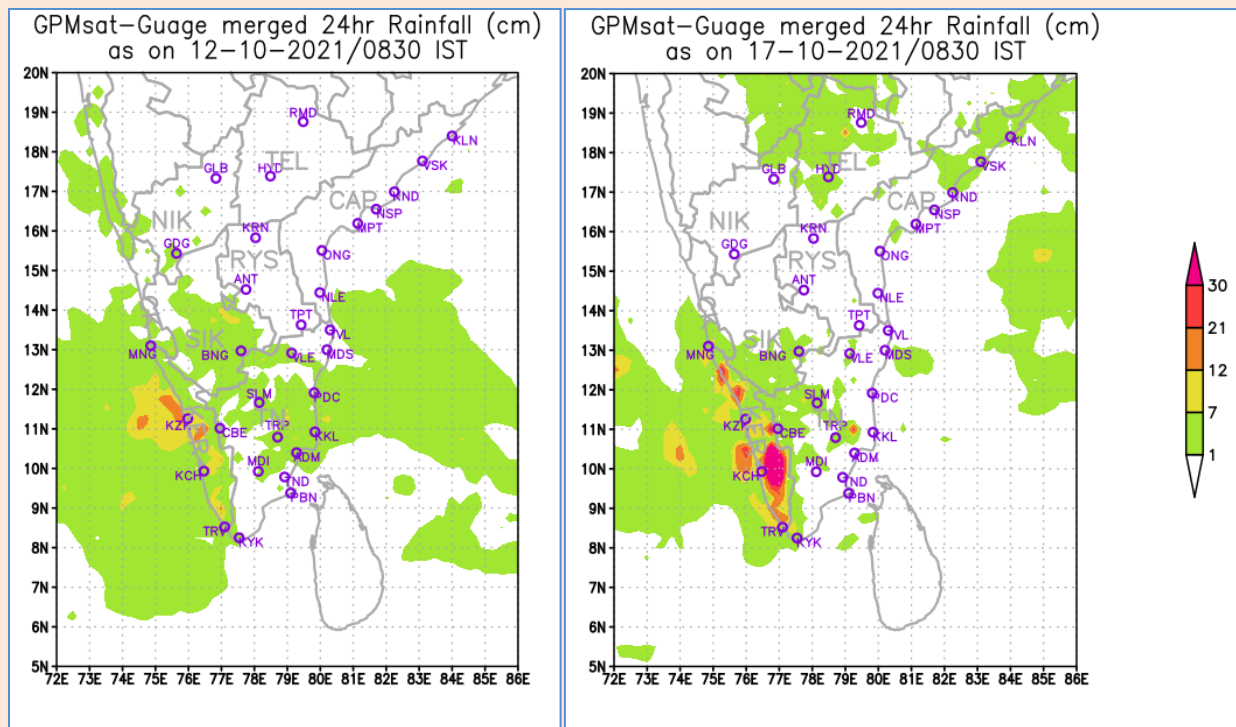
Rainfall Intensity	No. of days				
	TN	CAP	RYS	KER	SIK
H (≥ 7 cm/day)	23	7	10	16	13
VH (≥ 12 cm/day)	7	2	1	8	3
EH (≥ 21 cm/day)	2	0	0	2	0

(Note: Kindly see Appendix (i) and (ii) for description of terminologies used for spatial rainfall distribution and rainfall intensity)





**Fig.1b: Surface isobaric analysis based on 0830 IST and upper air (lower levels) streamline analysis based on 0530 IST of 16<sup>th</sup> October 2021**

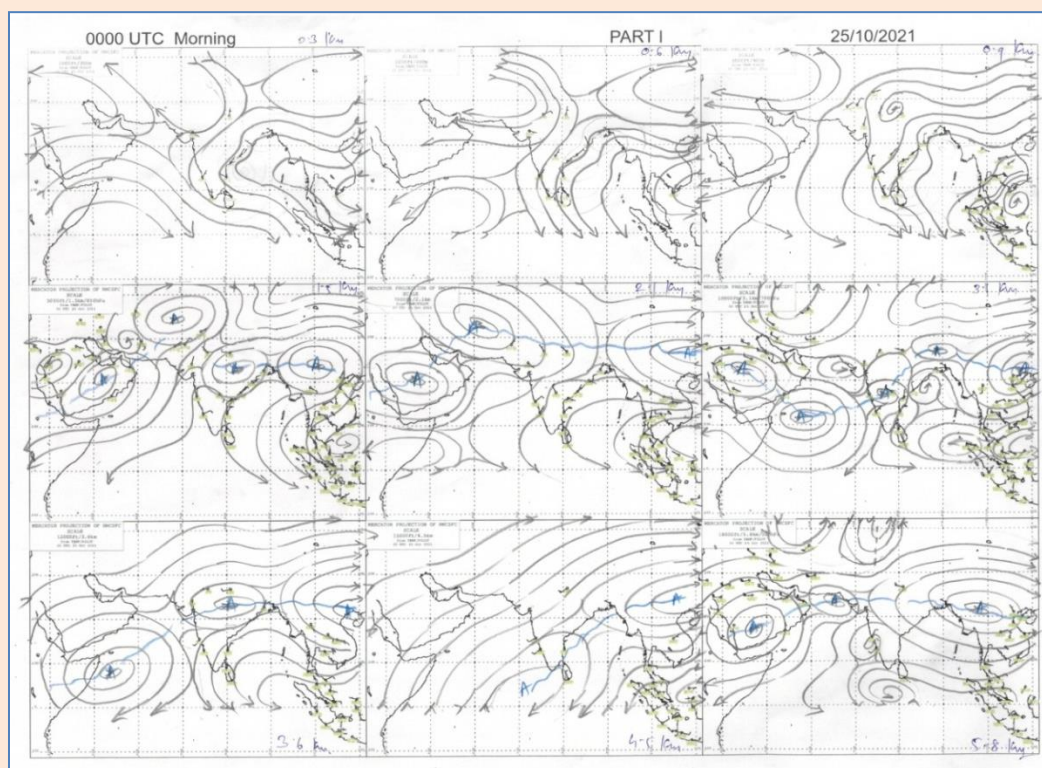
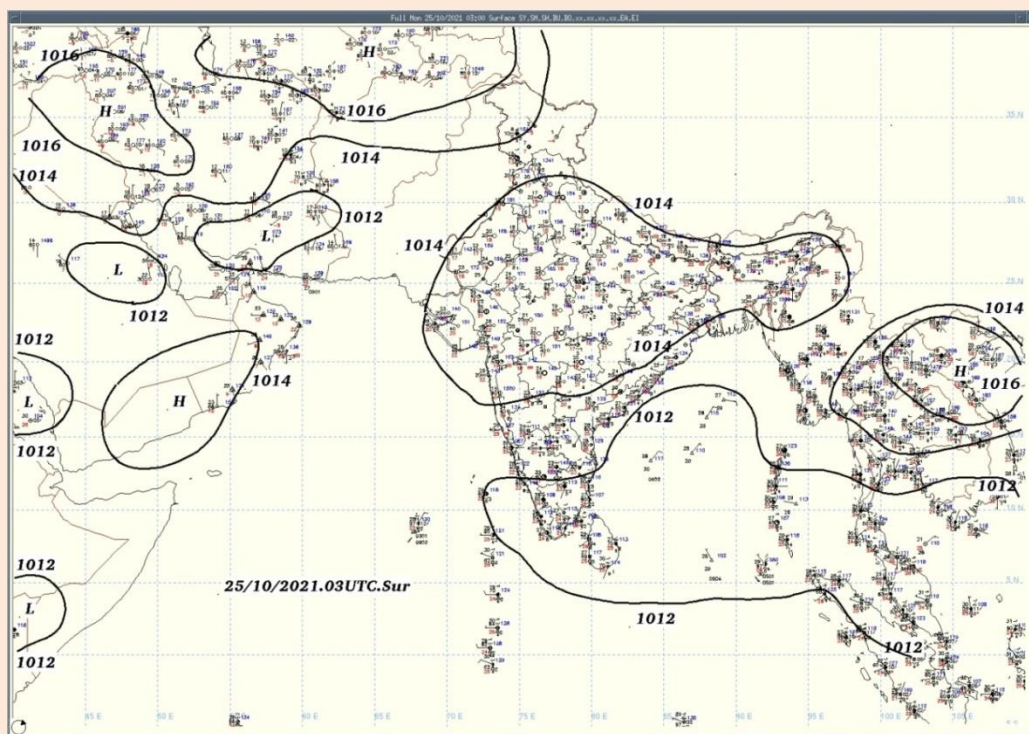


**Fig.1c: GPM satellite+Gauge merged 24-hr rainfall (in cm) as on 0830 IST of 12 & 17 Oct 2021.**

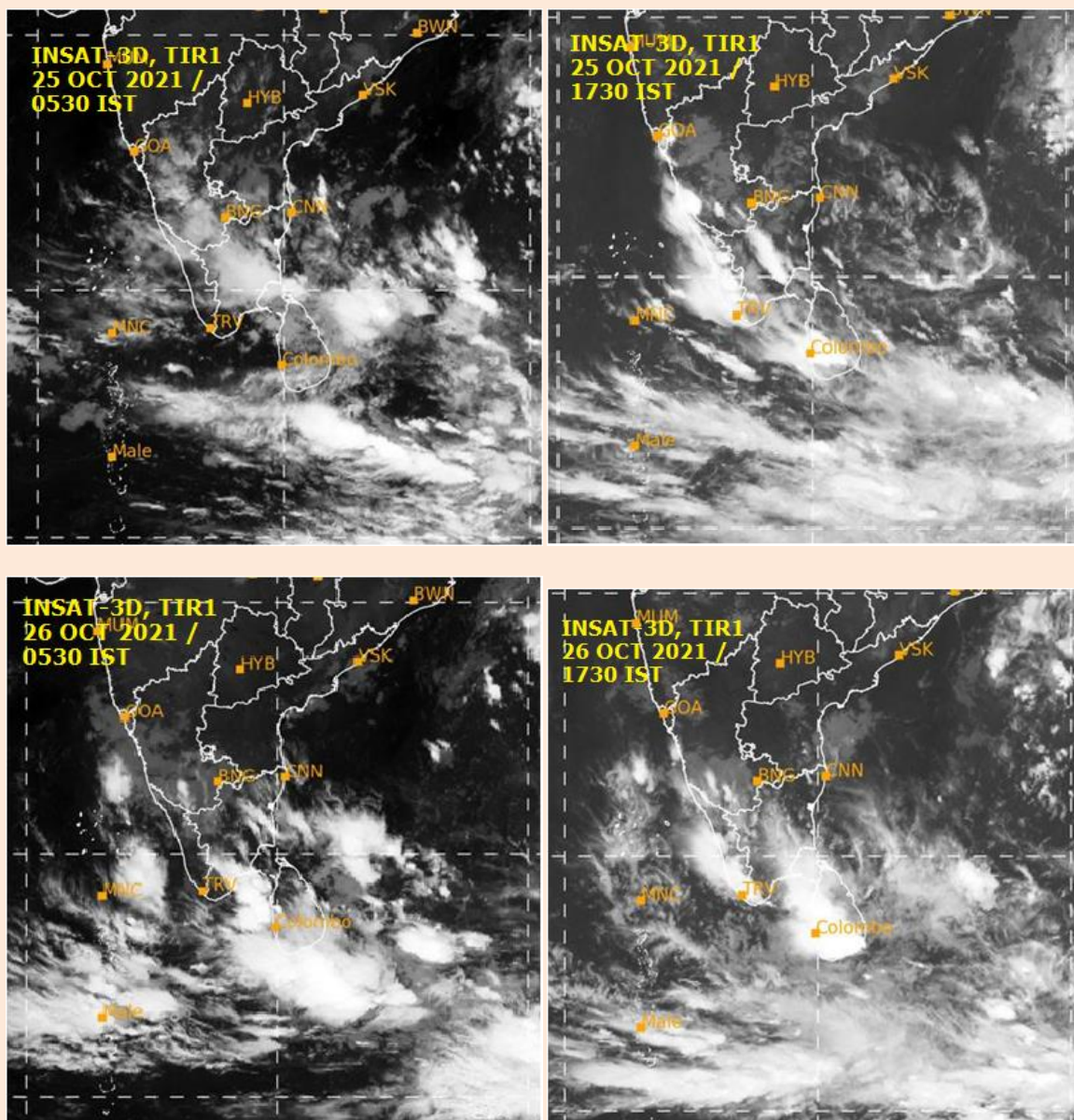
**(ii) Commencement of NEM rains:** With the setting in of northeasterly winds by 25<sup>th</sup> October, SWM withdrew from the entire country on 25<sup>th</sup> October with simultaneous commencement of NEM rains over the southern peninsula with effect from 25<sup>th</sup> October 2021. Surface isobaric analysis based on 0830 IST and upper air streamline analysis based on 0530 IST observations of 25<sup>th</sup> October depicting the synoptic features associated with the onset of NEM 2021 are presented on Fig.1d. It is noted that under the influence of cyclonic circulation over the south Bay of Bengal and neighbourhood in the lower tropospheric levels (up to 3.1 km above mean sea level) and trough in easterlies off Kerala-Karnataka coasts extending upto 1.5 km above mean sea level, *fairly widespread* rainfall occurred over TN and SIK on 25<sup>th</sup> October.

INSAT-3D based cloudiness as on 0830, and 1730 IST of 25<sup>th</sup> and as on 0530 & 1730 IST of 26<sup>th</sup> October depicting the cloudiness over the southern peninsula during the onset period are presented in Fig.1e. Spatial rainfall distribution over the NEM region depicted by the satellite based GPM-Gauge merged rainfall and that over TN subdivision based on gauge observation as on 24-hr ending 0830 IST of 25<sup>th</sup> October 2021 are presented in Fig.1f(i-ii) respectively.

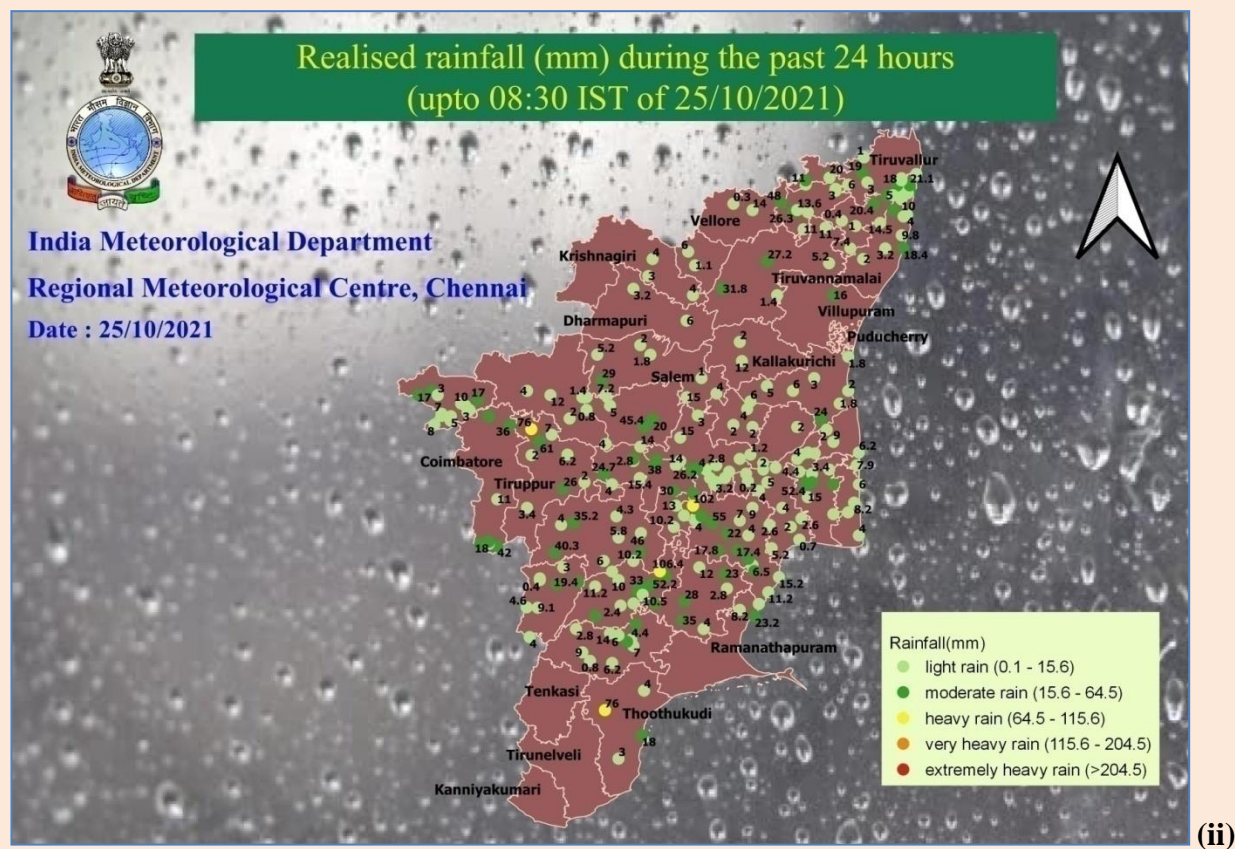
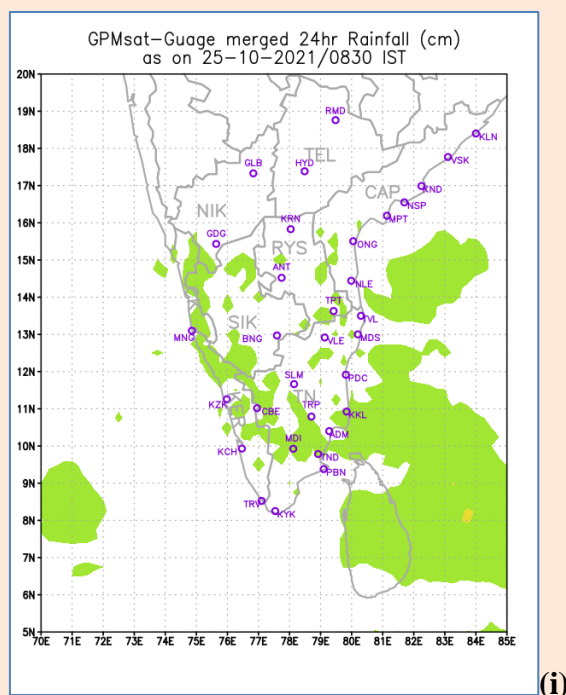








**Fig.1e: INSAT-3D infra-red imageries as on 0530 & 1730 IST of 25<sup>th</sup> & 26<sup>th</sup>Oct 2021**



**Fig.1f: Past 24-hr accumulated rainfall based on (i) GPM satellite+Gauge merged 24-hr rainfall (in cm) over the southern peninsular region and (ii) point rainfall observation (raingauge)over TN (in mm) as on 0830 IST of 25 Oct 2021.**

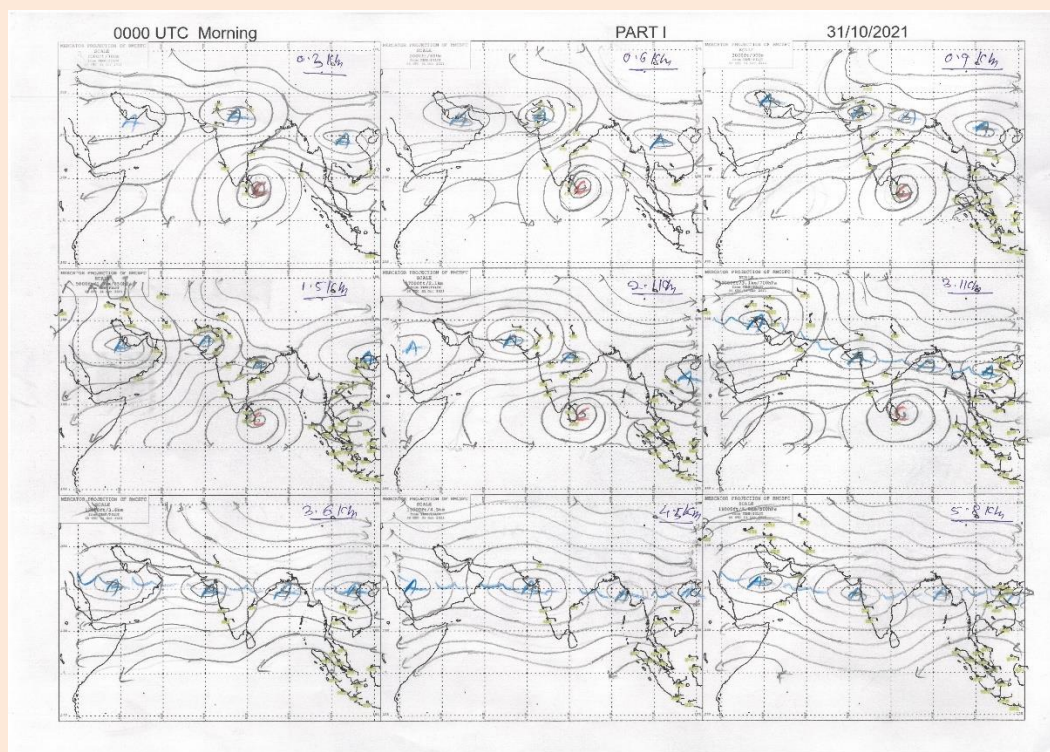
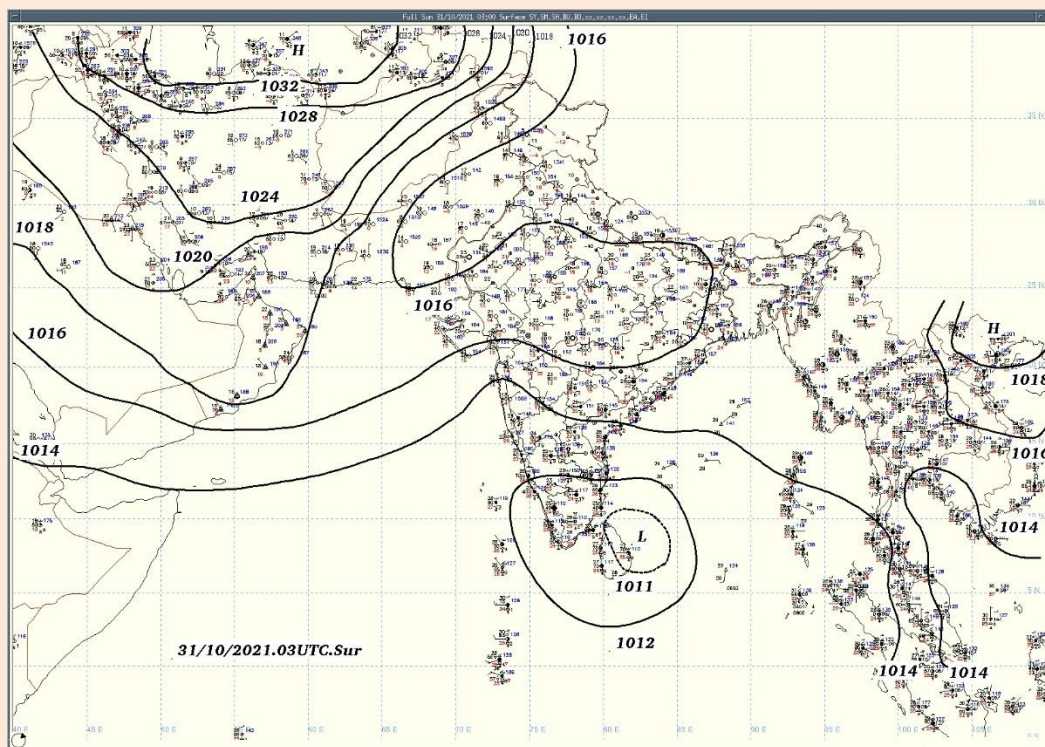
### 3.1 Major synoptic scale systems during the NEM 2021 season

#### (i) Low Pressure area over Bay of Bengal during 27<sup>th</sup> October – 04<sup>th</sup> November 2021

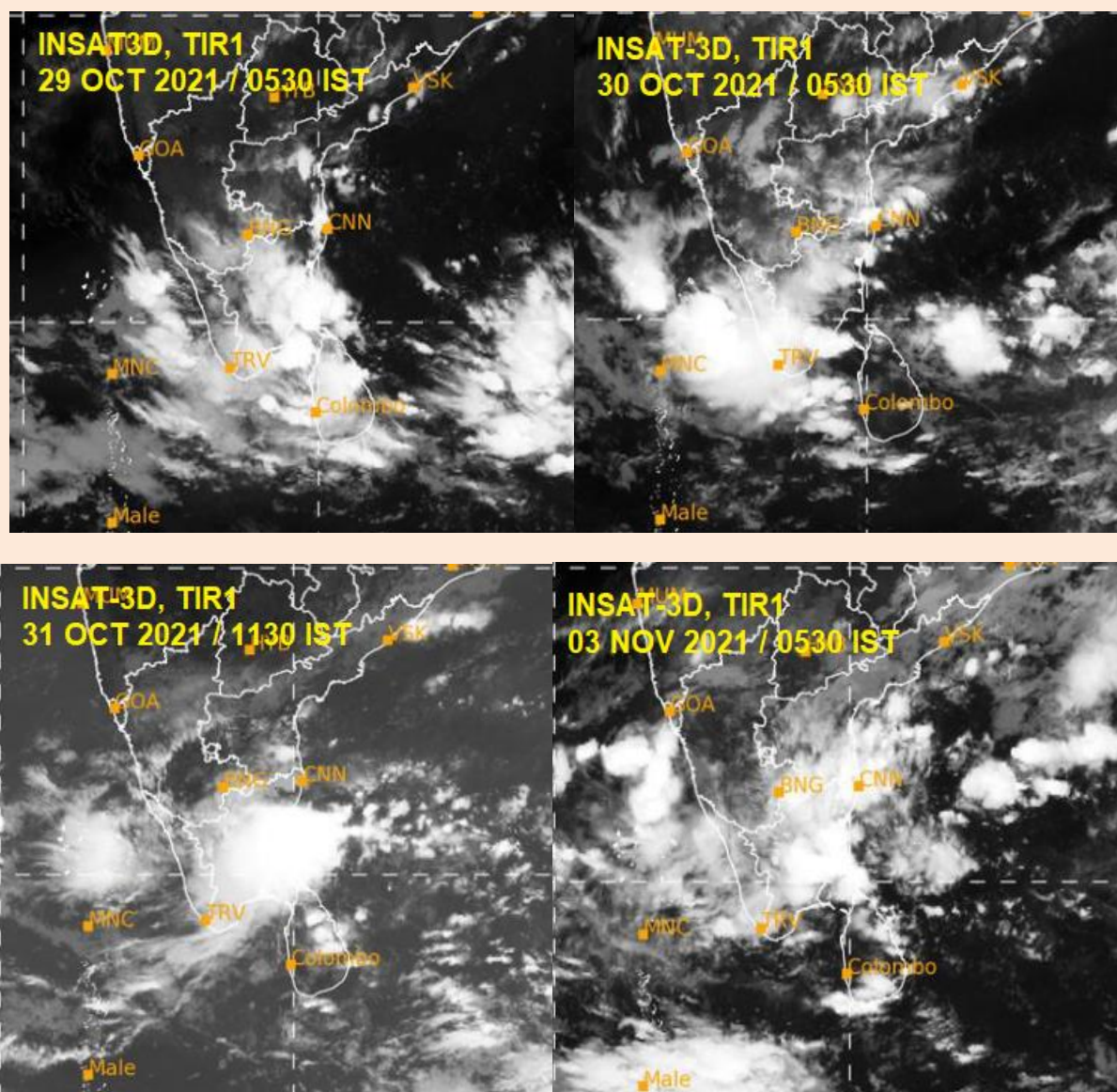
Under the influence of a LOPAR that formed over the central parts of south Bay of Bengal on 27<sup>th</sup> October 2021 and moved slowly westwards across Sri Lanka, Comorin area and Lakshadweep area during 27<sup>th</sup> October - 04<sup>th</sup> November 2021, *fairly widespread* to *widespread* rainfall occurred over TN & KER continuously for 9 days during the 24-hr ending 08:30 IST of 28<sup>th</sup> October to 05<sup>th</sup> November. *Heavy* (7-11 cm/day) to *very heavy* (12-20 cm/day) rainfall occurred at *isolated* places over TN on 29<sup>th</sup> & 30<sup>th</sup> October and from 01<sup>st</sup> to 04<sup>th</sup> November; over KER on 28<sup>th</sup> & 30<sup>th</sup> October and on 02<sup>nd</sup> November; and over CAP on 02<sup>nd</sup> November. Also, *heavy* rain occurred at *isolated* places over TN on 28<sup>th</sup> October and 05<sup>th</sup> November, over KER on 01<sup>st</sup>, 03<sup>rd</sup> & 04<sup>th</sup> November, over CAP on 01<sup>st</sup> November, over RYS on 03<sup>rd</sup> November and over SIK on 05<sup>th</sup> November. Highest rainfall amount of **20 cm** was recorded at Kothavacherry Marakkanam in Villupuram district on 02<sup>nd</sup> November. Several *heavy* to *very heavy* rainfall reports were received from TN on 03<sup>rd</sup> November from the delta and adjoining districts and the coastal belt between Chengalpattu and Ramanathapuram.

The LOPAR and associated upper cyclonic circulations as depicted by the surface isobaric analysis as on 08:30 IST and upper air (lower levels) streamline analysis as on 05:30 IST of 31<sup>st</sup> October are presented in Fig.2a. INSAT-3D infra-red imageries depicting the cloudiness associated with the system as on 29<sup>th</sup> & 30<sup>th</sup> October / 0530 IST, 31<sup>st</sup> October / 1130 IST and 03<sup>rd</sup> November / 0530 IST are presented in Fig.2b. Past 24-hr accumulated rainfall as on 0830 IST of 30<sup>th</sup> & 31<sup>st</sup> Oct 2021 over the southern peninsular region based on GPM satellite+Gauge merged 24-hr rainfall (in cm) and that over TN based on point rainfall observation (raingauge) (in mm) as on 0830 IST of 30<sup>th</sup> Oct & 03<sup>rd</sup> Nov 2021 are presented in Fig.2c(i) & (ii) respectively.



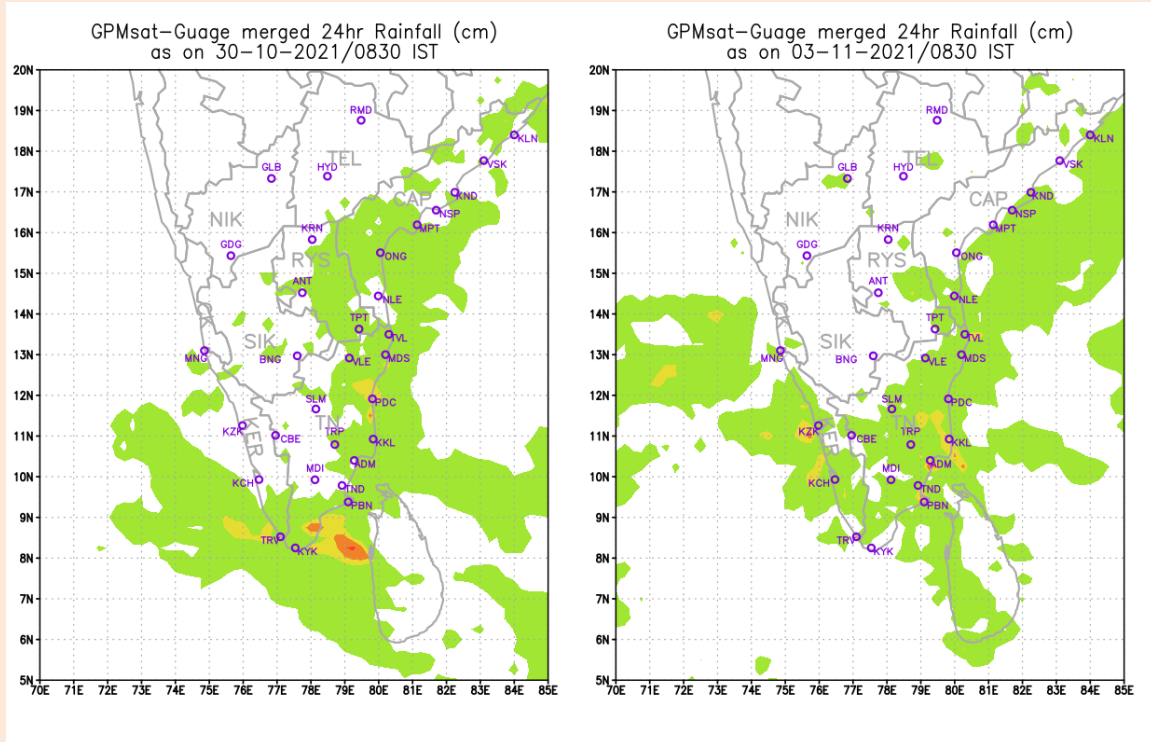


**Fig.2a: Surface isobaric analysis based on 0830 IST and upper air (lower levels) streamline analysis based on 0530 IST of 31<sup>st</sup> October 2021**



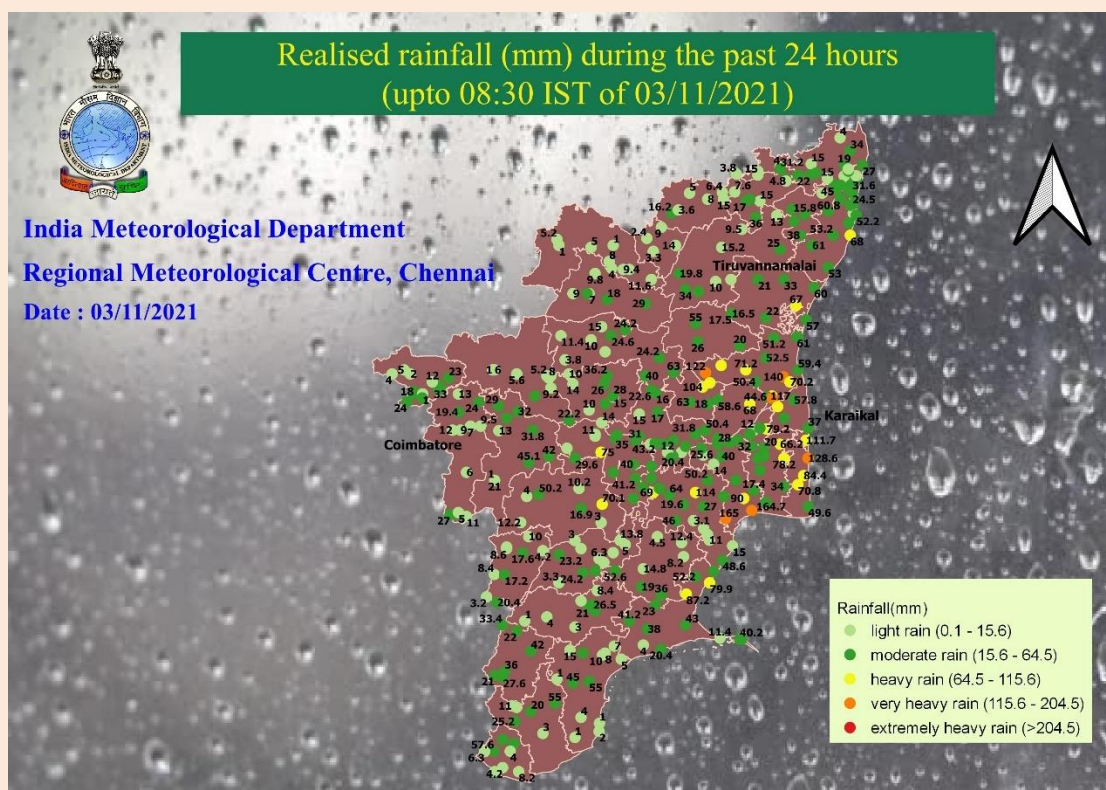
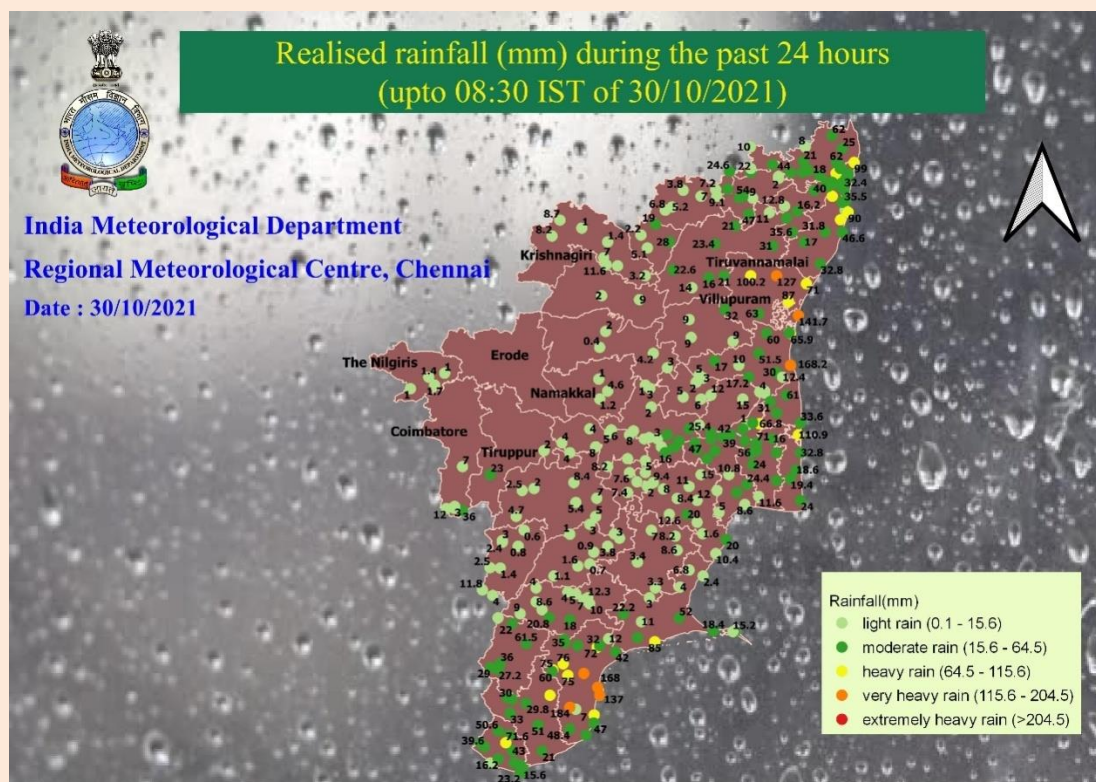
**Fig.2b: INSAT-3D infra-red imageries as on 0530 IST of 29<sup>th</sup>& 30<sup>th</sup>Oct, 1130 IST of 31<sup>st</sup> Oct and 0530 IST of 03<sup>rd</sup> Nov 2021**





**Fig.2c (i): Past 24-hr accumulated rainfall as on 0830 IST of 30<sup>th</sup>& 31<sup>st</sup> Oct 2021 over the southern peninsular region based on GPM satellite+Gauge merged 24-hr rainfall (in cm)**





**Fig.2c(ii): Past 24-hr accumulated rainfall over TN based on point rainfall observation (raingauge)(in mm) as on 0830 IST of 30<sup>th</sup>Oct & 03<sup>rd</sup> Nov 2021.**

## (ii) Depression over Bay of Bengal during 10<sup>th</sup>-11<sup>th</sup> November 2021

Under the influence of a cyclonic circulation over southeast Bay of Bengal and adjoining south Andaman sea extending up to 5.8 km above the mean sea level during 07<sup>th</sup>-08<sup>th</sup> November 2021, a low pressure area formed over the southeast Bay of Bengal and neighbourhood at 0830 IST of 9<sup>th</sup> November, 2021. It lay as a well marked low pressure area (WML) over southeast and adjoining southwest BOB at 0530 IST of 10<sup>th</sup> November. Moving west-northwestwards it concentrated into a **Depression** over southwest BOB at 1730 IST of 10<sup>th</sup> November. Moving further northwestwards, it crossed north Tamil Nadu & adjoining south Andhra Pradesh coasts close to Chennai, near latitude. 12.95°N and longitude 80.25°E during 1730 to 1830 IST with a maximum sustained wind speed of 45 – 55 kmph gusting to 65 kmph. It then weakened into a WML over north Tamilnadu & neighborhood at 0530 hrs IST of 12<sup>th</sup> November. The observed track of the system is presented in Fig.3a. Surface isobaric analysis as on 0830 IST and upper air streamline analysis as on 0530 IST of 11<sup>th</sup> November 2021 are shown in Fig.3b.

Associated with the formation and movement of the system, *fairly widespread to widespread* rainfall occurred over the TN subdivision during 08<sup>th</sup>-12<sup>th</sup> November. *Heavy to very heavy* rainfall at isolated places with *extremely heavy* falls ( $\geq 21$  cm/day) at one or two places occurred over TN subdivision on 10<sup>th</sup> & 11<sup>th</sup> November; also, *heavy to very heavy* rain occurred at isolated places over TN on 08<sup>th</sup>, 09<sup>th</sup> & 12<sup>th</sup>; over CAP & KER on 11<sup>th</sup> and over RYS on 12<sup>th</sup> November. Heavy rain also occurred at isolated places over RYS on 10<sup>th</sup> & 11<sup>th</sup> & over CAP on 12<sup>th</sup> November 2021.

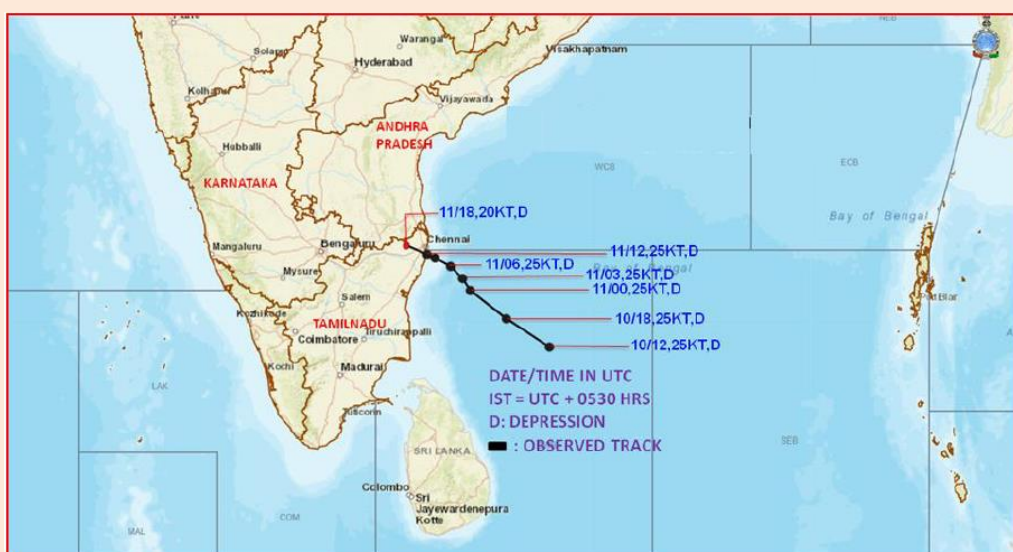
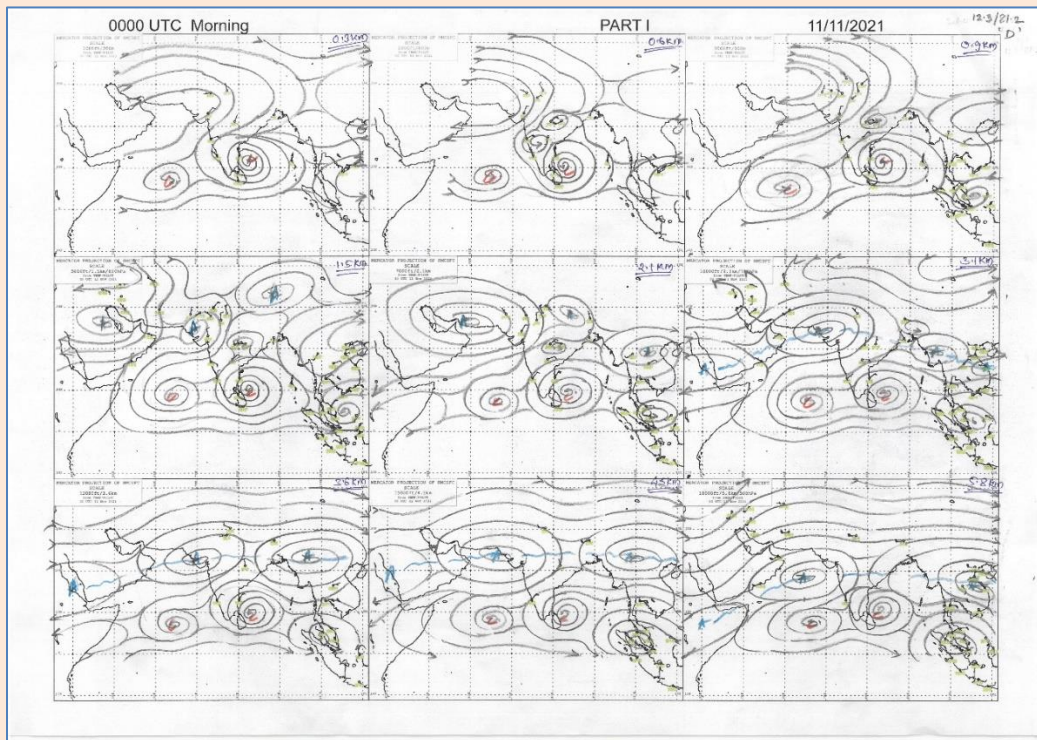
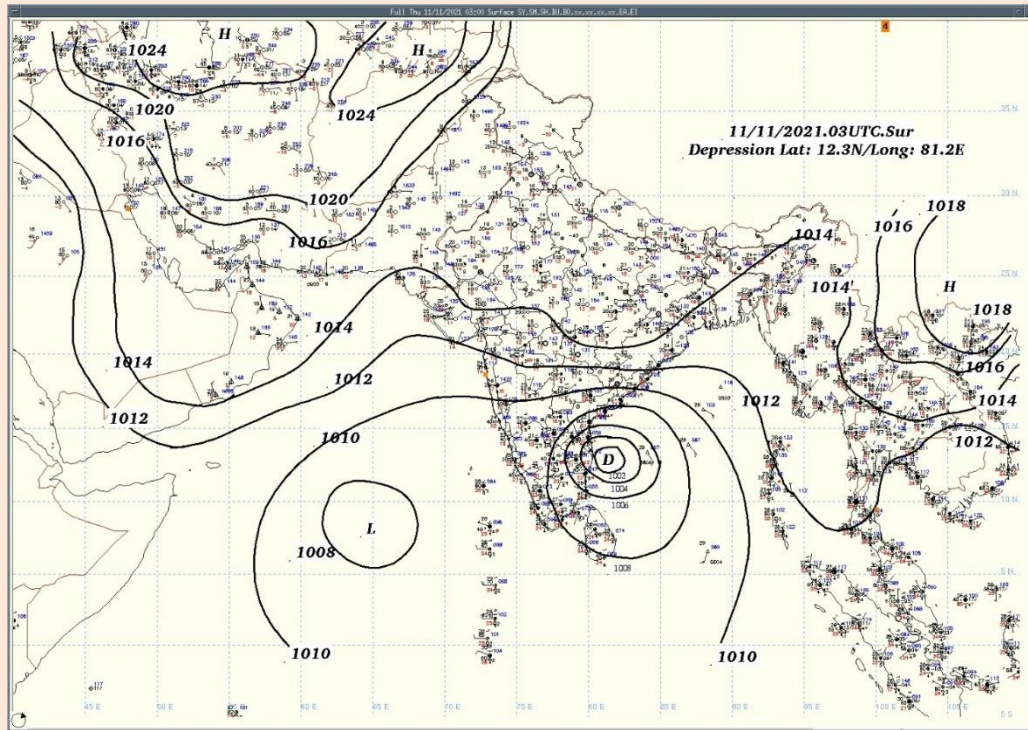


Fig.3a: Observed track of the Depression over Bay of Bengal during 10<sup>th</sup>-11<sup>th</sup> Nov 2021





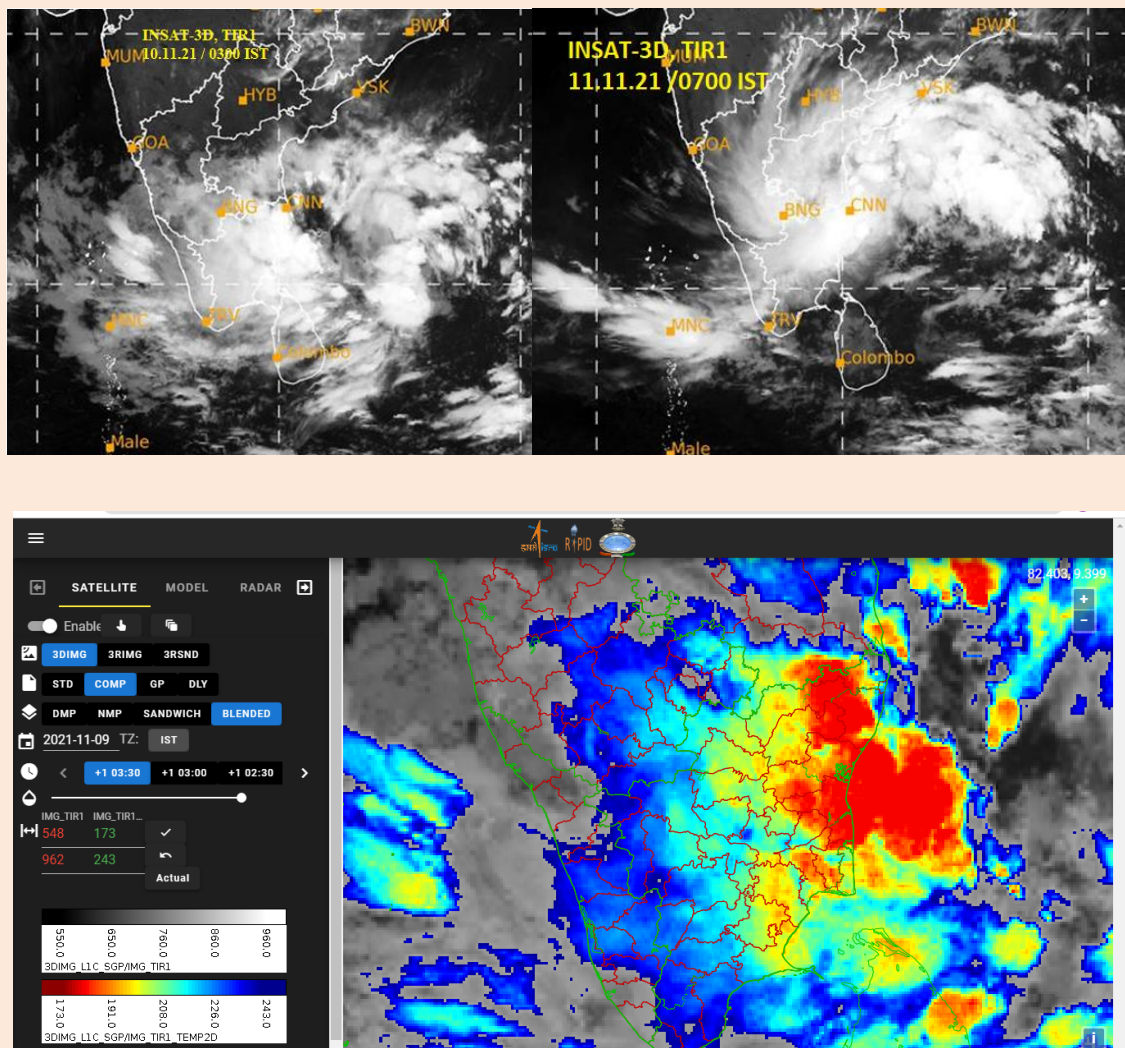
**Fig.3b: Surface isobaric analysis as on 0830 IST and upper air (lower levels) streamline analysis as on 0530 IST of 11<sup>th</sup> November 2021**

Sample satellite and Doppler Weather Radar imageries depicting the cloudiness and rainfall associated with the system are presented in Fig.3c &3d respectively. 24-hr accumulated rainfall plots as on 0830 IST of 10<sup>th</sup> & 11<sup>th</sup> over the TN subdivision and over CAP on 11<sup>th</sup> November are presented in Fig.3e (i-iii).

Highest rainfall amount of **31 cm** was recorded at Nagapattinam and Tirupoondi in Nagapattinam district on 10<sup>th</sup> November 2021. *Extremely heavy* rainfall events were reported from the delta region on 10<sup>th</sup> (Nagapattinam, Tiruvarur & Karaikal) and over Chengalpattu and Tiruvallur districts on 11<sup>th</sup> November 2021 as listed below:

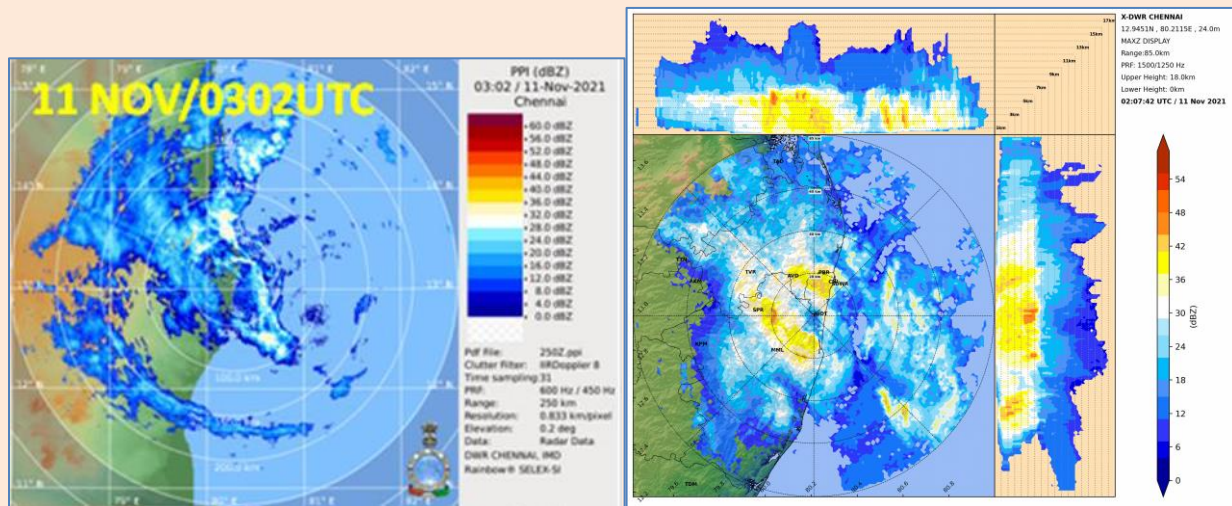
- 10.11.22: Nagapattinam (distNagapattinam), Tirupoondi (distNagapattinam) **31cm** each, Karaikal (dist Karaikal) **29 cm**, Vedaranyam (distNagapattinam) **25 cm**, Thalaigaiy (distNagapattinam) **24cm**, Thiruthurai (distTiruvarur) **22cm**
- 11.11.22: Tambaram (dist Chengalpattu) **23 cm**, Cholavaram (dist Tiruvallur) **22 cm**, Ennore (dist Tiruvallur) **21 cm**.

Several parts of Chennai and adjoining districts reported extensive inland and coastal flooding (Fig.3f).

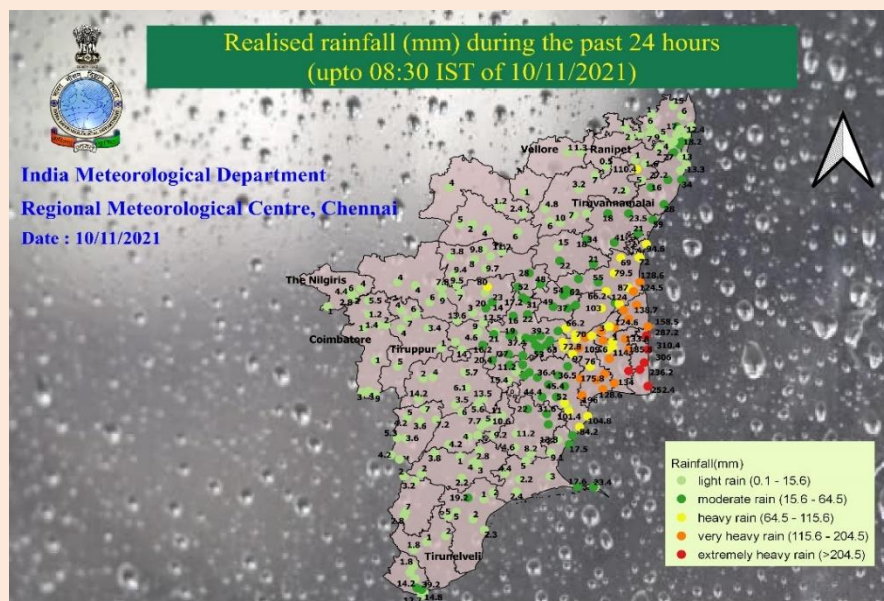


**Fig.3c: INSAT-3D infra-red imageries as on 10<sup>th</sup> Nov /0300 IST & 11<sup>th</sup> Nov / 0700 IST and INSAT-3D brightness temperature product as on 0330 IST of 10<sup>th</sup> November 2021.**

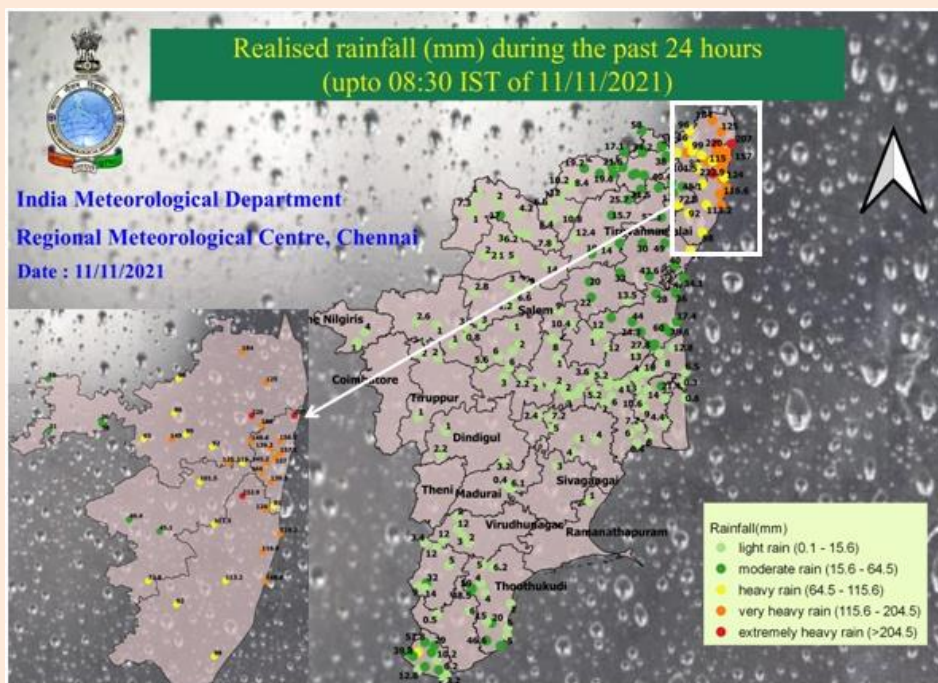




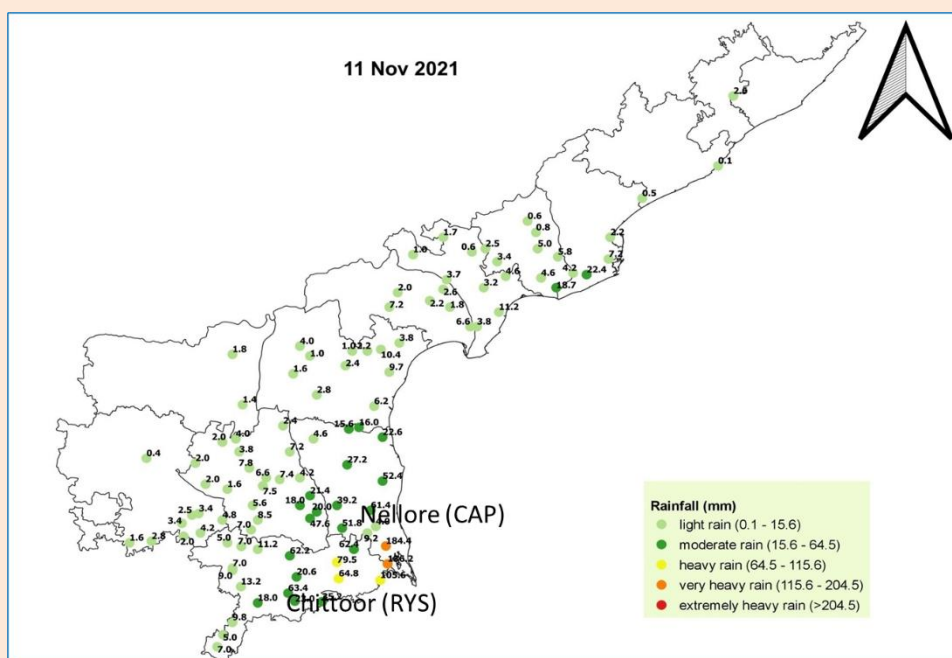
**Fig.3d: Doppler Weather Radar imageries as on 11<sup>th</sup> Nov 0830 IST (S-band DWR Chennai) & 11<sup>th</sup> Nov /0737 IST (X-Band DWR Chennai)**



**Fig.3e (i) : Past 24-hr accumulated rainfall over TN subdivision based on point rainfall observation (raingauge)(in mm) as on 0830 IST of 10<sup>th</sup> Nov 2021.**



**Fig.3e (ii): Past 24-hr accumulated rainfall over TN subdivision based on point rainfall observation (raingauge)(in mm) as on 0830 IST of 11<sup>th</sup> Nov 2021.**



**Fig.3e (iii) : Past 24-hr accumulated rainfall over CAP based on point rainfall observation (raingauge)(in mm) as on 0830 IST of 11<sup>th</sup> Nov 2021.**





**Fig.3f: Inland flooding in several parts of Chennai and neighbourhood**(Source: ANI reports in social media, 10<sup>th</sup> November, 2021 / 1830 IST)

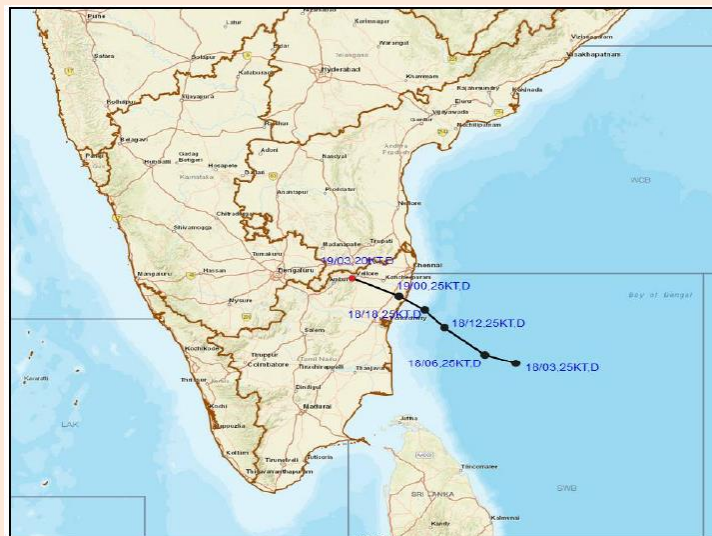
### **(iii) Depression over Bay of Bengal during 18<sup>th</sup>-19<sup>th</sup> November 2021**

A LOPAR formed over south Andaman Sea & adjoining Thailand coast around 0830 IST of 13<sup>th</sup> November 2021. It persisted as LOPAR over south Bay of Bengal for about 4 days. It then moved westwards and lay as a well marked low pressure area over southwest & adjoining westcentral BOB off north Tamil Nadu and South Andhra Pradesh coasts in the morning (0530

IST) of 18<sup>th</sup> Nov. Under favourable environmental conditions, it concentrated into a **Depression** over southwest BOB off North Tamil Nadu coast in the forenoon (0830 IST) of 18<sup>th</sup> November. Moving west-northwestwards it crossed north Tamil Nadu coast between Puducherry and Chennai near latitude 12.45°N and longitude 80.1°E during early hours of 19<sup>th</sup> Nov (0300-0400 IST) and then weakened into a well marked low pressure area over interior Tamil Nadu at early morning of 19<sup>th</sup> (0530 IST) and gradually became less marked over same region on 20<sup>th</sup> November 2021. Estimated maximum sustained surface wind was 40-50 kmph gusting to 60 kmph over north Tamil Nadu in the early hours of 19<sup>th</sup> November 2021 at the time of coastal crossing.

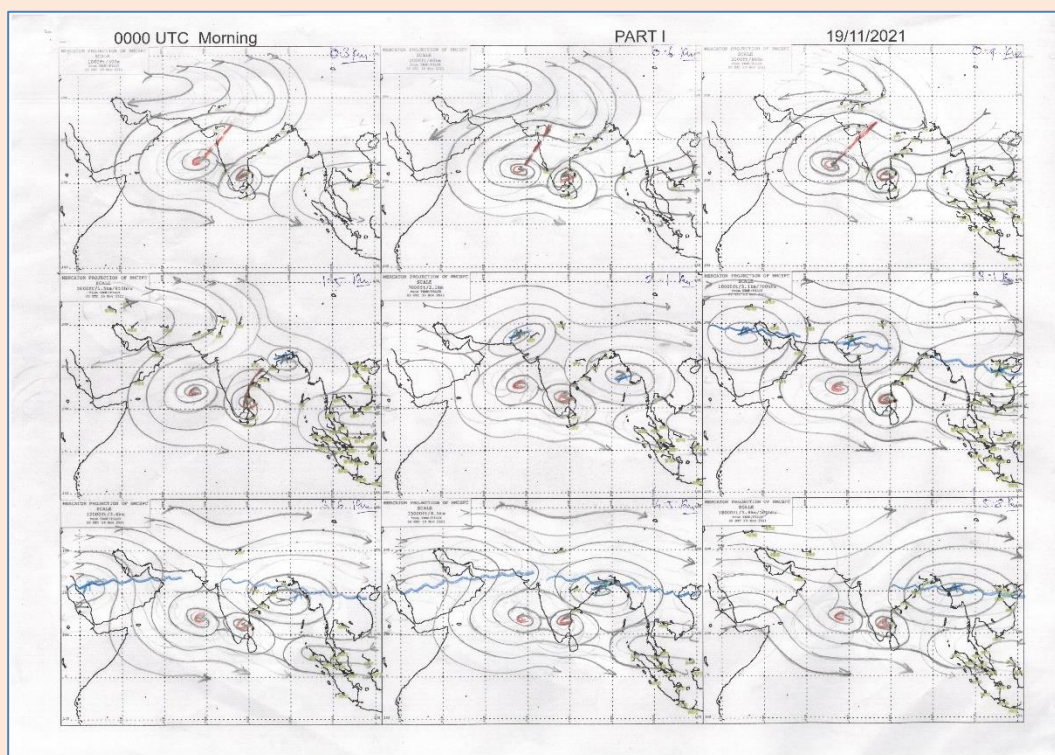
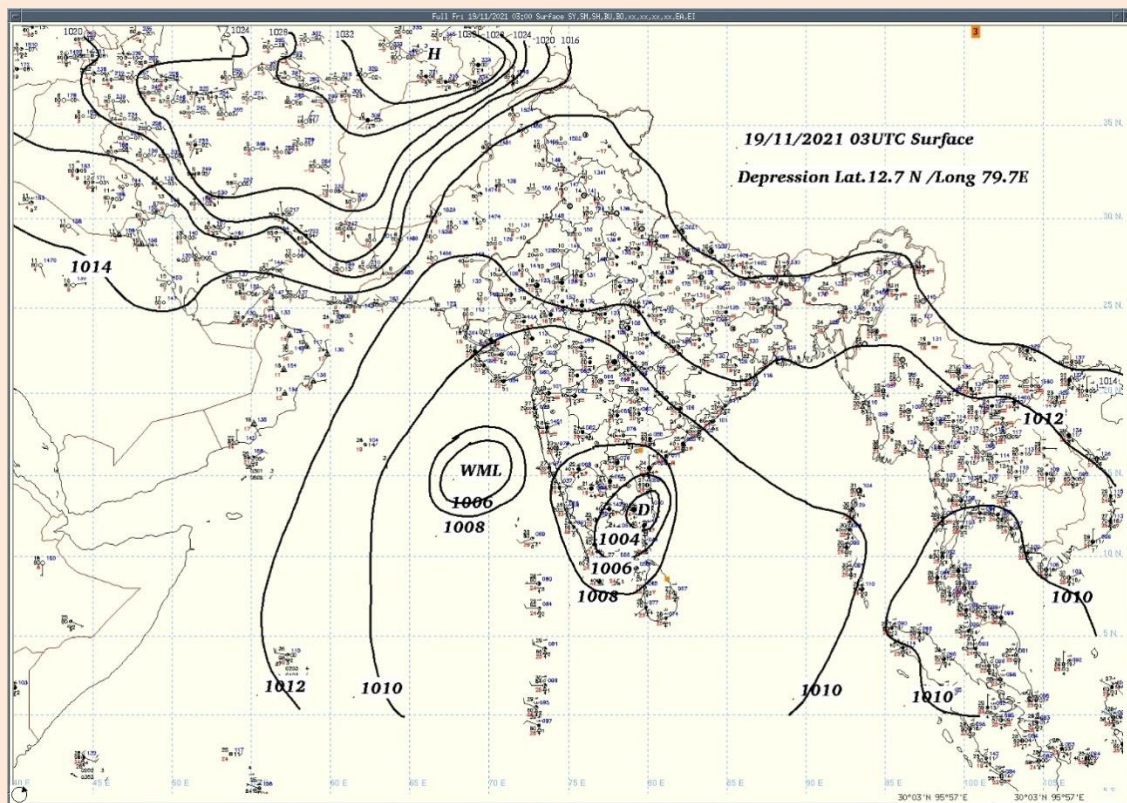
Associated with the passage of the system, *fairly widespread to widespread* rainfall occurred over the TN subdivision on 19<sup>th</sup> & 20<sup>th</sup> November. *Heavy to very heavy* rainfall at isolated places with *extremely heavy* falls ( $\geq 21$  cm/day) at one or two places occurred over TN & RYS subdivisions on 19<sup>th</sup> November. Heavy rain also occurred at isolated places over TN & CAP on 20<sup>th</sup>. Highest rainfall amount of **24 cm** was recorded at Nambulipulikunta in Anantapuramu district in RYS on 19<sup>th</sup> November. Tindivanam, Koliyanur, Vallam & Valavanur (all in Villupuram district) also recorded extremely heavy rainfall of **22 cm**, and Manampoondi (Villupuram district)-**21 cm** on the same day. Puducherry recorded 19 cm and in CAP, Kandukur in Prakasam district recorded 11 cm on the same day.

Fig.4a presents the observed track of the system during 18<sup>th</sup>– 19<sup>th</sup> November 2021. Surface isobaric analysis as on 0830 IST and upper air (lower levels) streamline analysis as on 0530 IST of 19<sup>th</sup> November 2021 are presented in Fig.4b.



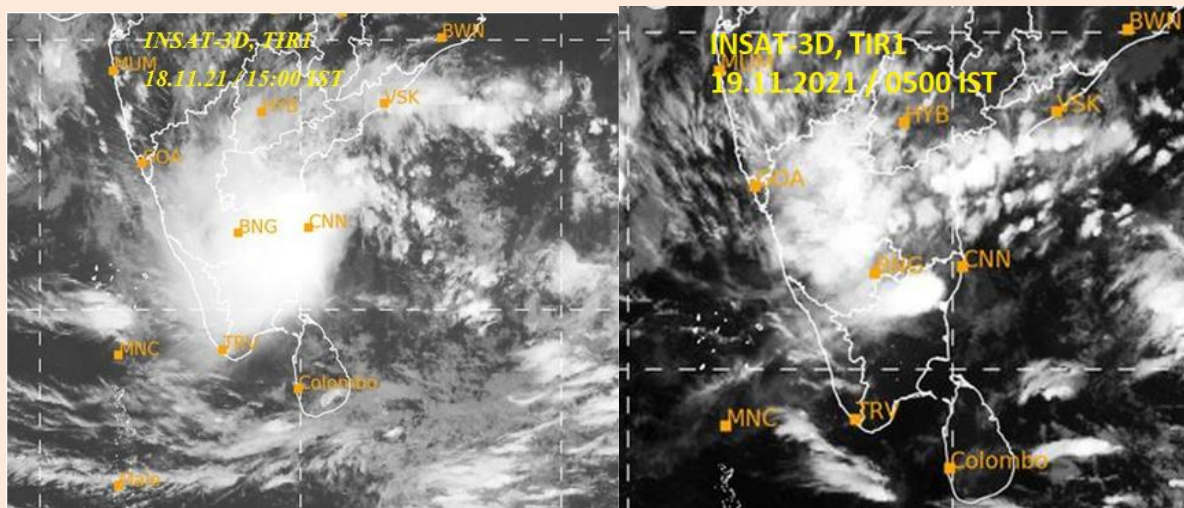
**Fig.4a: Observed track of the Depression over Bay of Bengal during 18<sup>th</sup>-19<sup>th</sup> Nov 2021**



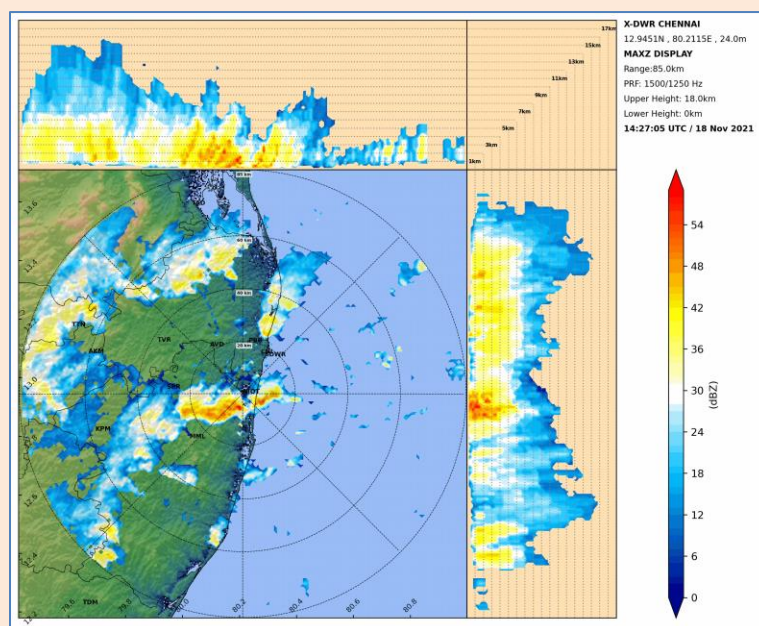


**Fig.4b: Surface isobaric analysis as on 0830 IST and upper air (lower levels) streamline analysis as on 0530 IST of 19<sup>th</sup> November 2021**

Sample INSAT-3D infra-red imageries as on 18<sup>th</sup>/1500 IST & 19<sup>th</sup>/0500 IST and Doppler Weather Radar (X-Band), Chennai maximum reflectivity product as on 18<sup>th</sup>/2000 IST of November 2021 are presented in Fig.4c-d. Past 24-hr accumulated rainfall over TN (including Puducherry & Karaikal), RYS & CAP subdivisions based on point rainfall observation (raingauge) as on 0830 IST of 19<sup>th</sup> Nov 2021 are depicted in Fig.4e. Some media reports depicting the inland and riverine flooding associated with incessant intense rainfall activity are presented in Fig.4f.

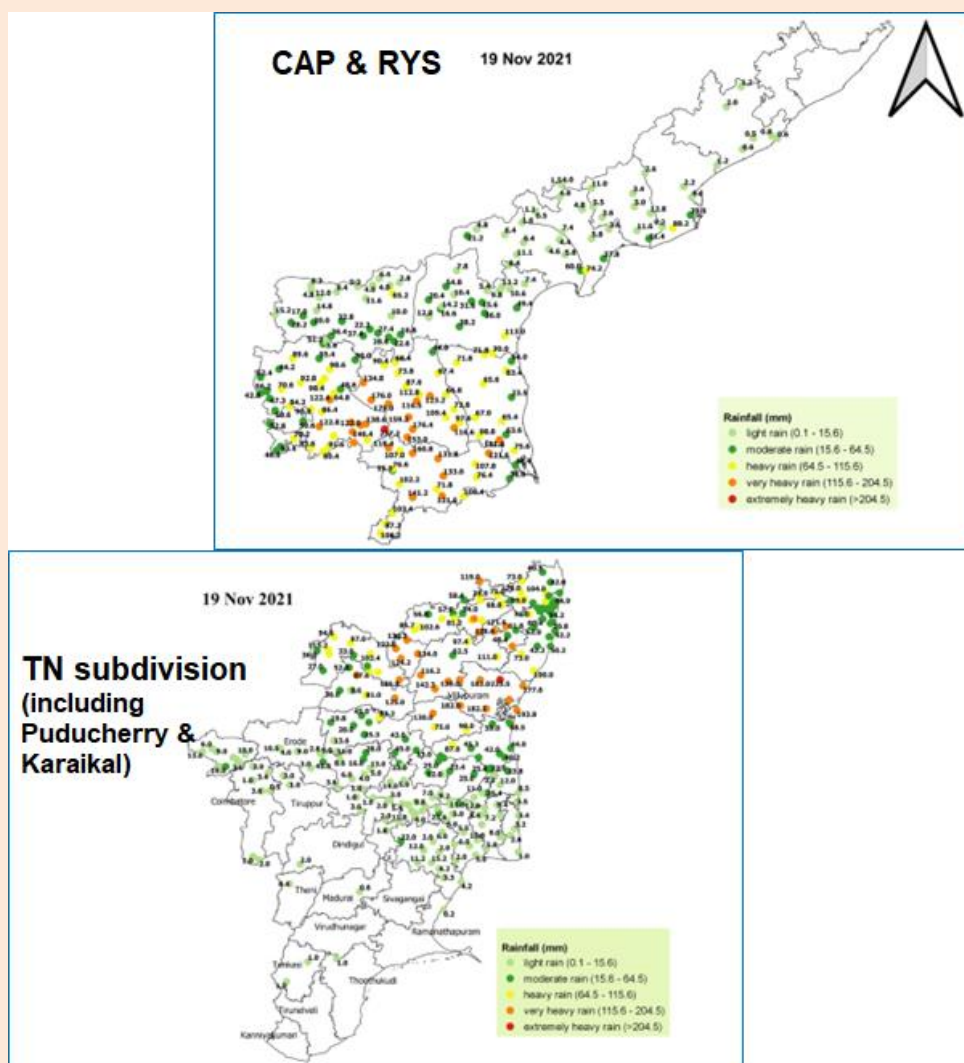


**Fig.4c: INSAT-3D infra-red imageries as on 18<sup>th</sup> /1500 IST & 19<sup>th</sup> / 0500 IST of Nov 2021**



**Fig.4d: Doppler Weather Radar, Chennai (X-Band)maximum reflectivity product as on 18<sup>th</sup>/2000 IST of Nov 2021**





**Fig.4e: Past 24-hr accumulated rainfall over TN (including Puducherry & Karaikal), RYS & CAP subdivisions based on point rainfall observation (raingauge)(in mm) as on 0830 IST of 19<sup>th</sup> Nov 2021.**

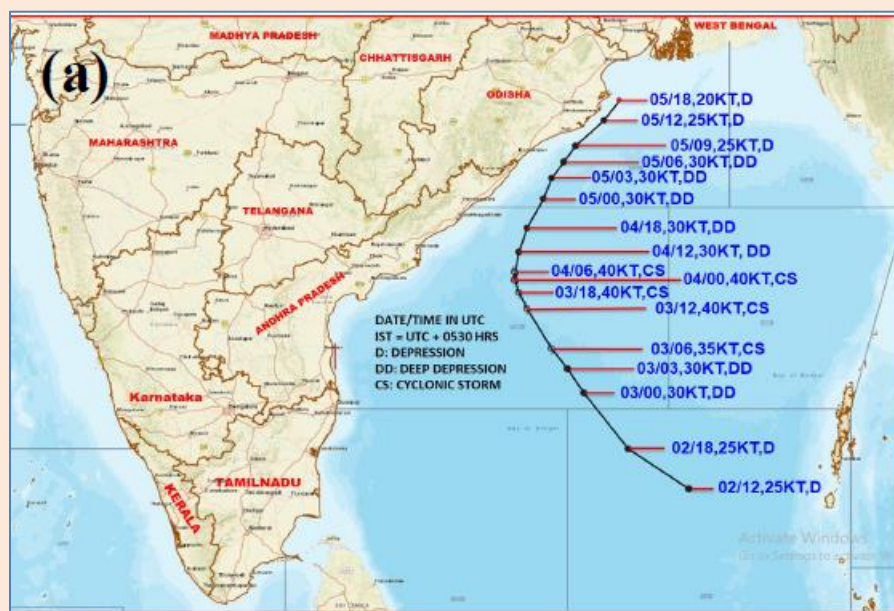


**Fig.4f: Inland flooding in Tirupati temple area and riverine flooding and associated damages along the banks of overflowing Palar river as on 19<sup>th</sup> November 2021 (Source: Polimer, Puthiyathalaimurai & Sun TVs).**



#### (iv) Cyclonic storm JAWAD during 02<sup>nd</sup>-05<sup>th</sup> December 2021

A LOPAR formed over South Thailand & neighbourhood in the forenoon (0830 IST) of 30<sup>th</sup> November 2021. It emerged into central parts of Andaman Sea in the same evening (1730 IST) and lay as a well marked low pressure area over southeast BOB & adjoining Andaman Sea in the morning (0530 IST) of 02<sup>nd</sup> December. Under favourable environmental conditions, it concentrated into a Depression over southeast BOB in the same evening (1730 IST). Moving north-northwestwards, it intensified into a Deep Depression over westcentral & adjoining south BOB in the morning (0530 IST) and into the Cyclonic Storm “JAWAD” (pronounced as JOWAD) over westcentral BOB in the forenoon (1130 IST) of 03<sup>rd</sup> December. It moved north-northwestwards till morning (0530 IST) of 04<sup>th</sup> December, northwards till the evening (1730 IST) of 04<sup>th</sup> and weakened into a deep depression over westcentral BOB at 1730 hours IST of 04<sup>th</sup> December. Thereafter, it moved north-northeastwards and reached very close to Odisha coast on 05<sup>th</sup>. Moving northeastwards it weakened into a well marked low pressure area over northwest BOB and adjoining West Bengal & Bangladesh coasts in the morning (0530 IST) and into a low pressure area over the same region in the forenoon (0830 IST) of 06<sup>th</sup> December, 2021. The system did not have much effect on the rainfall over the NEM region. The observed track of the system is presented in Fig.5.



**Fig.5: Observed track of Cyclonic Storm ‘JAWAD’ over the Bay of Bengal during 02<sup>nd</sup>-05<sup>th</sup> December 2021**

### 3.2 Other chief synoptic features

#### (i) Upper air cyclonic circulation over southeast Arabian sea during 12<sup>th</sup>-15<sup>th</sup> November 2021

Under the influence of an upper air cyclonic circulation over southeast Arabian sea during 12<sup>th</sup>-15<sup>th</sup> November 2021 (Fig.6a), widespread rainfall occurred over KER & SIK and *scattered to fairly widespread* rainfall occurred over TN during 12<sup>th</sup>-16<sup>th</sup> November. *Heavy to very heavy* rainfall occurred at *isolated* places over KER on all days during this period and over Kanyakumari district of Tamilnadu during 12<sup>th</sup>-14<sup>th</sup> November with *extremely heavy* falls at one or two places on 14<sup>th</sup>. *Isolated heavy* rain occurred over Kanyakumari district of TN on 15<sup>th</sup> also. Highest rainfall amount of 22 cm was recorded at Perunchani and Puthan dams followed by Kalial- 20cm (all in Kanyakumari district) on 14<sup>th</sup> November. In KER, 19 cm was recorded in C.I.A.L. Kochi & North Paravur AWS (both in Ernakulam district) on 14<sup>th</sup> November 2021. Recurrent heavy rainfall activity over Kanyakumari district of TN during 12<sup>th</sup>-15<sup>th</sup> November caused filling up / overflowing of reservoirs leading to extensive flooding over the region.

Heavy rainfall reports from Kanyakumari district during 12<sup>th</sup>-15<sup>th</sup> November are listed below:

12.11.2021: Suralacode -**15 cm**, Kannimar -**14 cm**, Perunchani Dam, Puthan Dam - **13 cm each**,

13.11.2021: Kannimar -**14 cm**, Suralacode, Thuckalay - **13 cm each**,

Sivalogam, Perunchani Dam - **12 cm each**, Puthan Dam -**11 cm**,

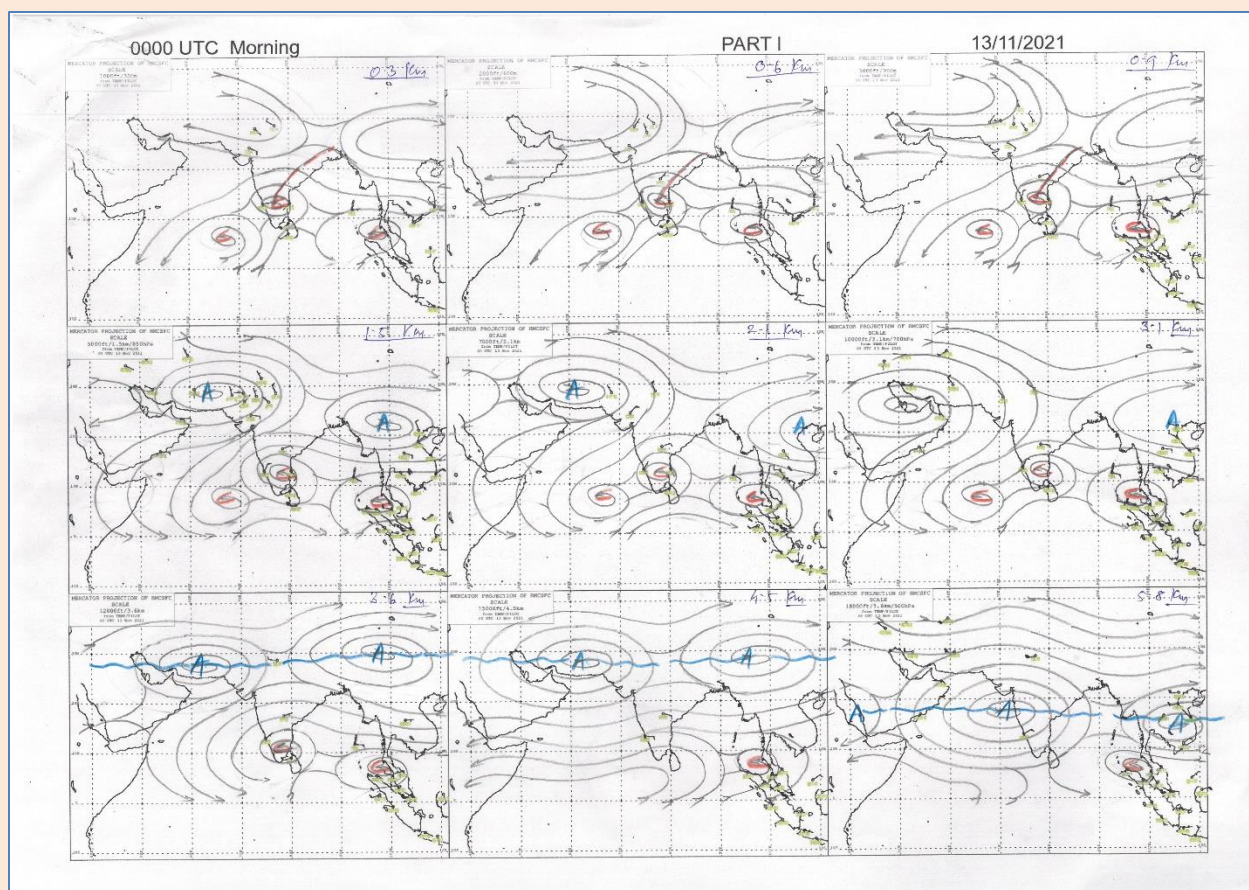
Eraniel, Kalial, Nagercoil -**10 cm each**, Kuzhithurai, Chittar, Kottaram, Pechiparai - **9 cm each**, Mylaudy, Bhoothapandy - **7 cm each**,

14.11.2021: Perunchani, Puthan Dam -**22 cm each**, Kalial - **20 cm**, Suralacode -**14 cm**, Pechiparai, Kannimar -**11 cm each**, Mylaudy -**10 cm**,

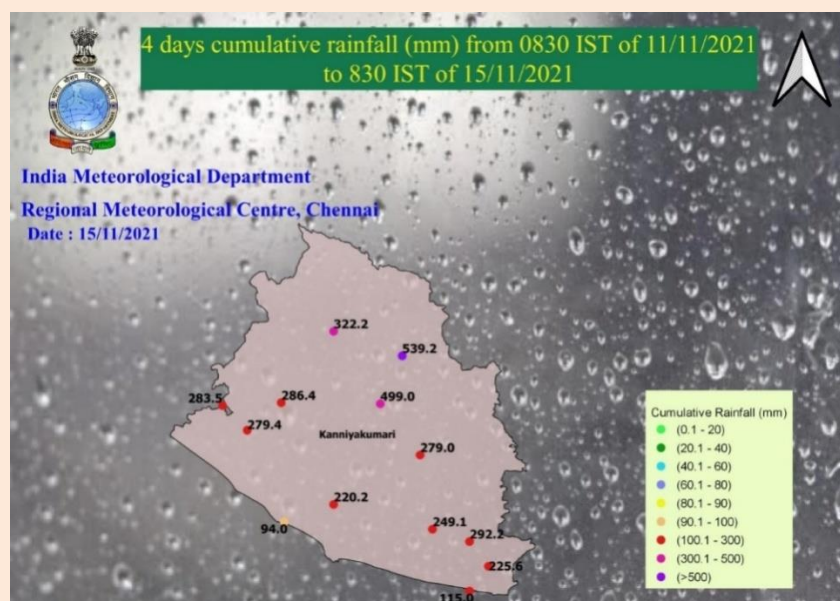
Kuzhithurai, Chittar, Sivalogam - **9 cm each**, Thuckalay, Bhoothapandy, Nagercoil - **8 cm each**,

15.11.2021: Kalial -**10 cm**; Puthan Dam - **8 cm**, Suralacode, Perunchani Dam, Pechiparai, Sivalogam - **7 cm each**.

Cumulative rainfall over various stations in Kanyakumari during the above four days is depicted in Fig.6b. **50-55 cm** of rain occurred over Perunchani and Puthan Dams and 25-35 cm of rain in the rest of Kanyakumari district during this period. Media report depicting the flood situation in Kanyakumari is presented in Fig.6c.



**Fig.6a: Upper air (lower levels) streamline analysis as on 0530 IST of 13<sup>th</sup> Nov 2021**



**Fig.6b: Cumulative rainfall for four days during the 24-hr ending 0830 IST of 12<sup>th</sup> to 15<sup>th</sup> November 2021 over various stations in Kanyakumari district of TN**





Residential areas at Thirupathisaram in Kanyakumari seen submerged | Express

By Express News Service

**TIRUNELVELI/KANNIYAKUMARI:** Even as Chennai and its neighbouring districts received a respite from the rains, the southern districts of the State including Kanyakumari and Tirunelveli were lashed with a heavy downpour on Saturday.

The incessant rains in the two districts flooded residential areas and roads mostly located near rivers and tanks. With the dams brimming, surplus water was discharged, bringing copious water to the rivers. In Tirunelveli, Radhapuram was most affected as water level reached the maximum in most of its ponds. Assembly Speaker M Appavu inspected the region.

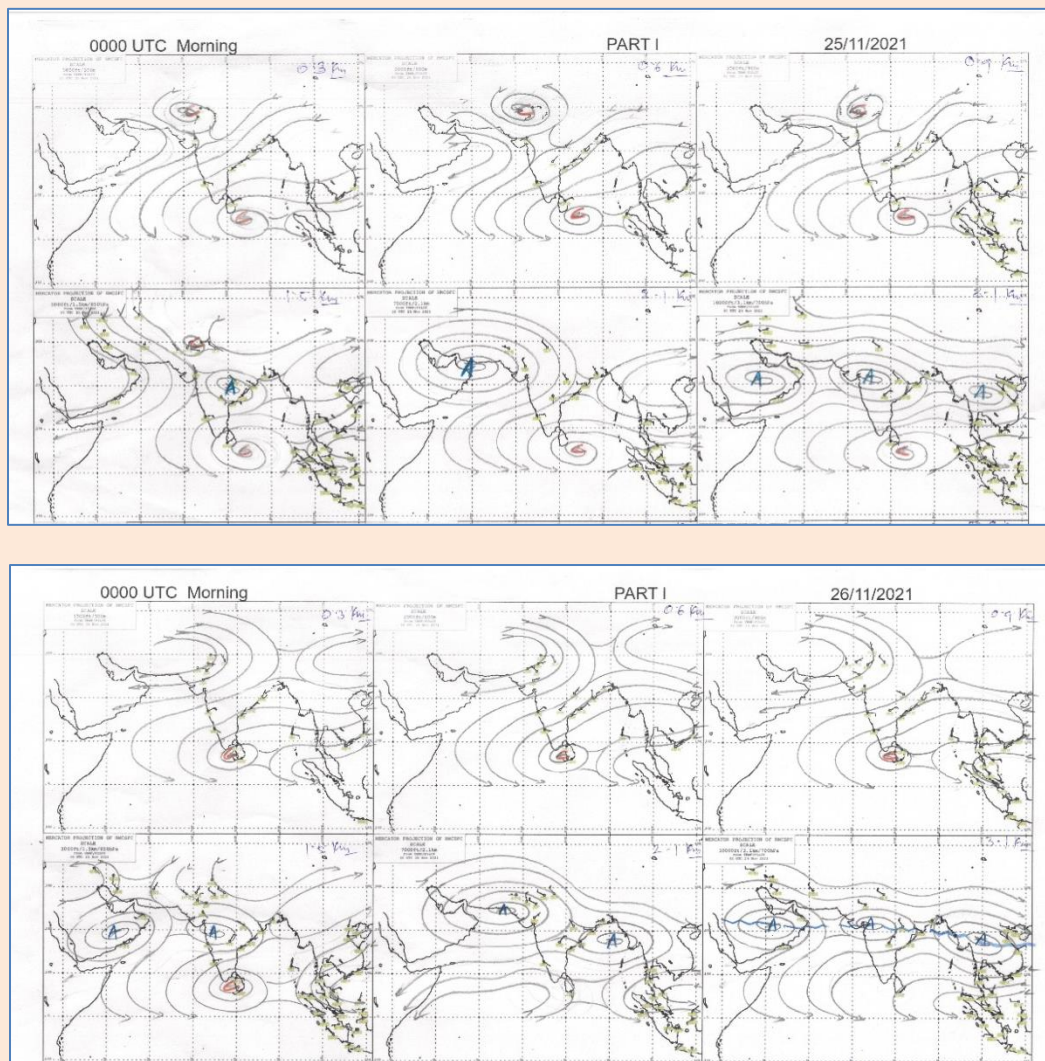
**Fig.6c: New Indian Express report dated 14<sup>th</sup> November / 0600 IST**

**(ii) Upper air cyclonic circulation over southwest Bay of Bengal and neighbourhood during 25<sup>th</sup>-30<sup>th</sup> November 2021**

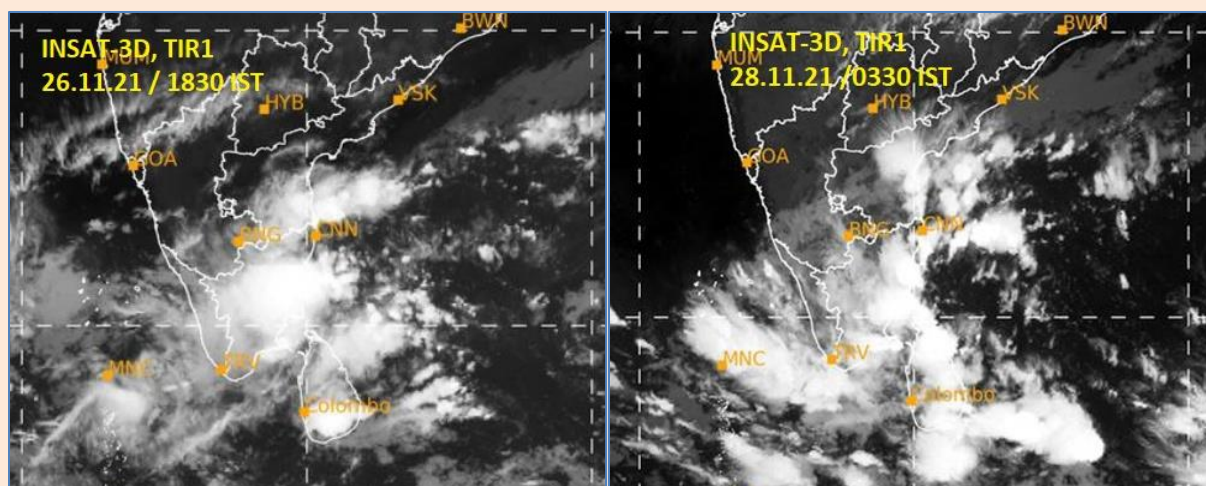
An upper air cyclonic circulation formed over southwest Bay of Bengal off Sri Lanka coast on 25<sup>th</sup> November 2021 and was seen up to the lower tropospheric levels with a trough extending from the cyclonic circulation to south Andhra Pradesh coast (Fig.7a). It slowly moved across Sri Lanka, Comorin area and Lakshadweep area during 25<sup>th</sup>-30<sup>th</sup> November 2021. Under its influence, *fairly widespread* to *widespread* rainfall occurred over the TN subdivision from 26<sup>th</sup>-30<sup>th</sup> with *active* to *vigorous* monsoon conditions on all the days; over KER on 26<sup>th</sup>, 28<sup>th</sup>-30<sup>th</sup> with *active* to *vigorous* monsoon conditions on those days; and over RYS on 29<sup>th</sup> & 30<sup>th</sup> with *vigorous* monsoon conditions on both the days. Satellite infra-red imageries as on 26<sup>th</sup>/1830 IST and 28<sup>th</sup>/0330 IST depicting the intense clouding and DWR (X-Band) Chennai Max(Z) product as on

26<sup>th</sup>/20:08 IST and DWR Karaikal reflectivity product as on 27<sup>th</sup>/21:10 IST associated with the system are presented in Fig. 7b&c.

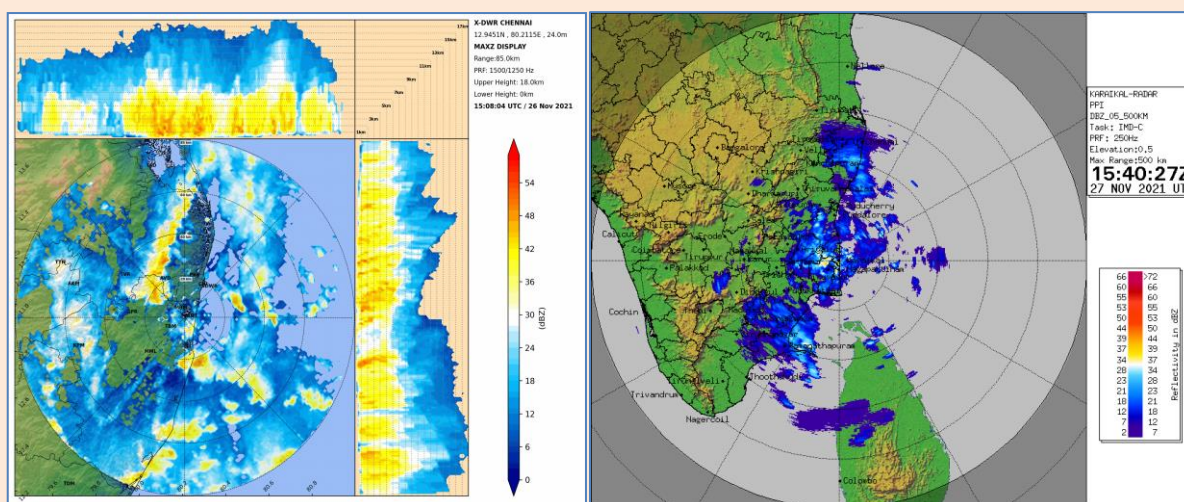
*Isolated heavy to very heavy rainfall occurred over TN subdivision on 26<sup>th</sup>, 27<sup>th</sup>, 29<sup>th</sup> & 30<sup>th</sup>; and over KER & CAP on 29<sup>th</sup> with extremely heavy falls at one or two places over TN on 26<sup>th</sup>. Isolated heavy rain occurred over TN on 28<sup>th</sup>, over KER on 26<sup>th</sup>, over RYS on 29<sup>th</sup> & 30<sup>th</sup> and over CAP on 28<sup>th</sup> & 30<sup>th</sup>. Highest rainfall amount of **31 cm** was recorded in Kayalpattinam in Toothukudi district, followed by Tuticorin (Toothukudi district) - **27 cm** and Tiruchendur (Toothukudi district) – **25 cm** on 26<sup>th</sup>.*





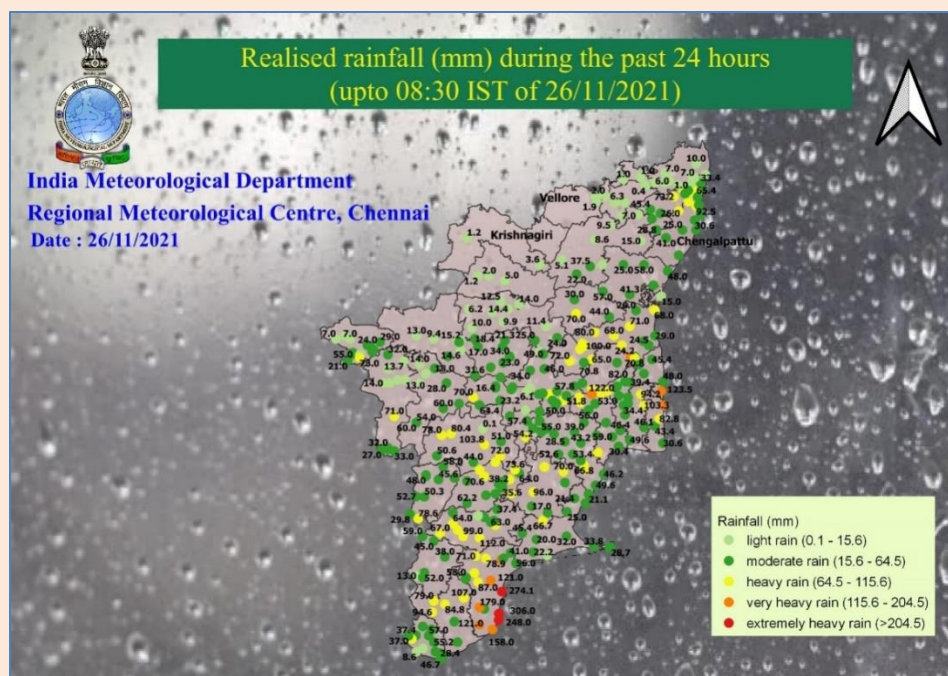


**Fig.7b: Satellite infra-red imageries as on 26<sup>th</sup>/1830 IST and 28<sup>th</sup>/0330 IST of Nov 2021**

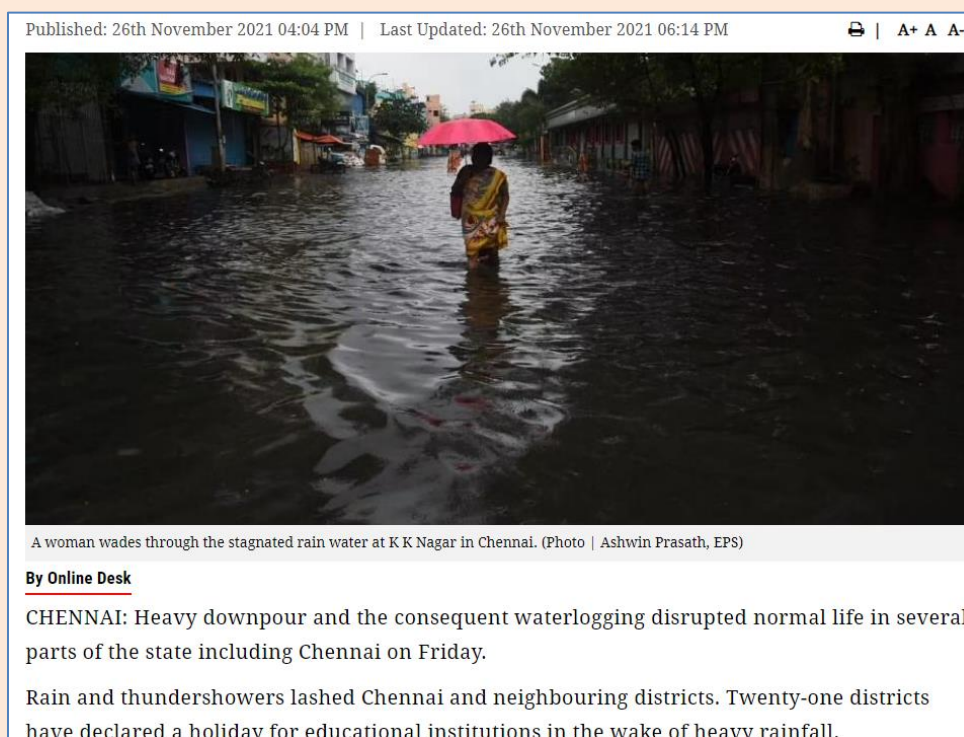


**Fig.7c: DWR (X-Band) Chennai Max(Z) product as on 26<sup>th</sup>/20:08 IST and DWR Karaikal reflectivity product as on 27<sup>th</sup>/21:10 IST**





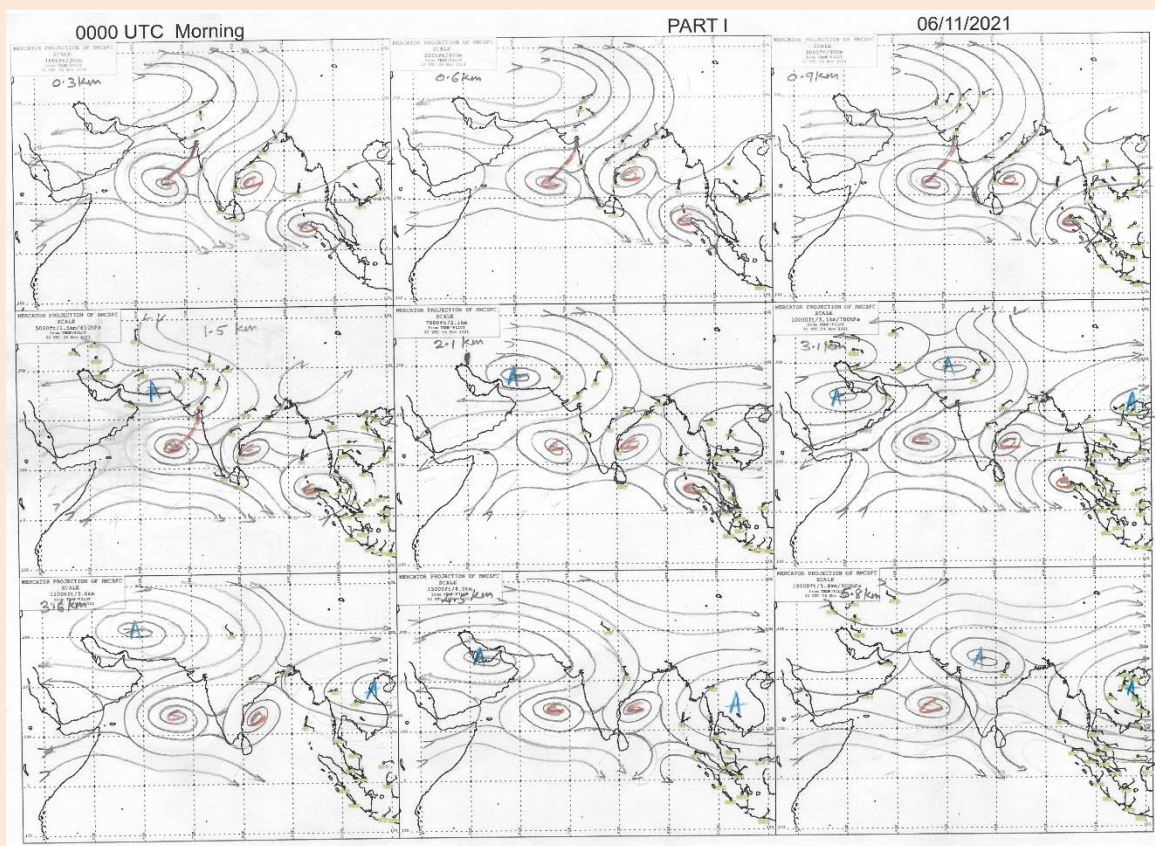
**Fig.7e: Past 24-hr accumulated rainfall (in mm) over TN subdivision (including Puducherry & Karaikal) as on 0830 IST of 26<sup>th</sup> Nov 2021.**



**Fig.7f: The New Indian Express report on 26<sup>th</sup> November 2021 / 18:04 IST**

### 3.3 (i) Extremely heavy rainfall event over Chennai and neighbourhood as on 24-hr ending 0830 IST of 07<sup>th</sup> November 2021

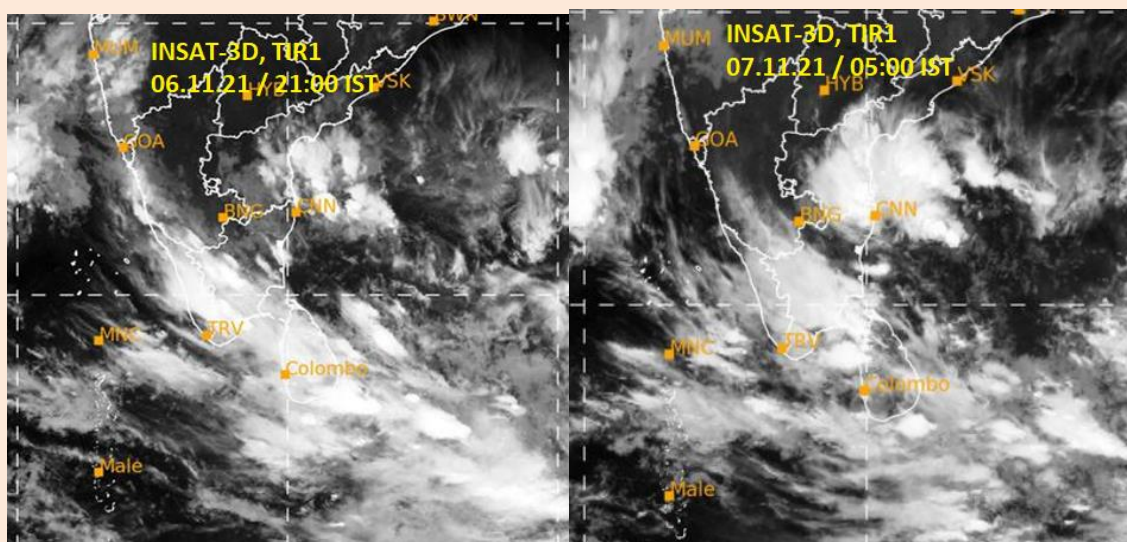
Under the influence of a cyclonic circulation over westcentral and adjoining southwest Bay of Bengal off South Andhra Pradesh – North Tamil Nadu coast extending upto 4.5 km above mean sea level (Fig.8a) *fairly widespread* rainfall occurred over the Tamil Nadu subdivision (Tamil Nadu, Puducherry & Karaikal) during the 24-hr ending 08:30 IST of 07.11.21 and active northeast monsoon conditions prevailed over the subdivision. Isolated *heavy to very heavy* rainfall occurred over the subdivision with *extremely heavy falls* at one or two places over Chennai and neighbourhood during this period.



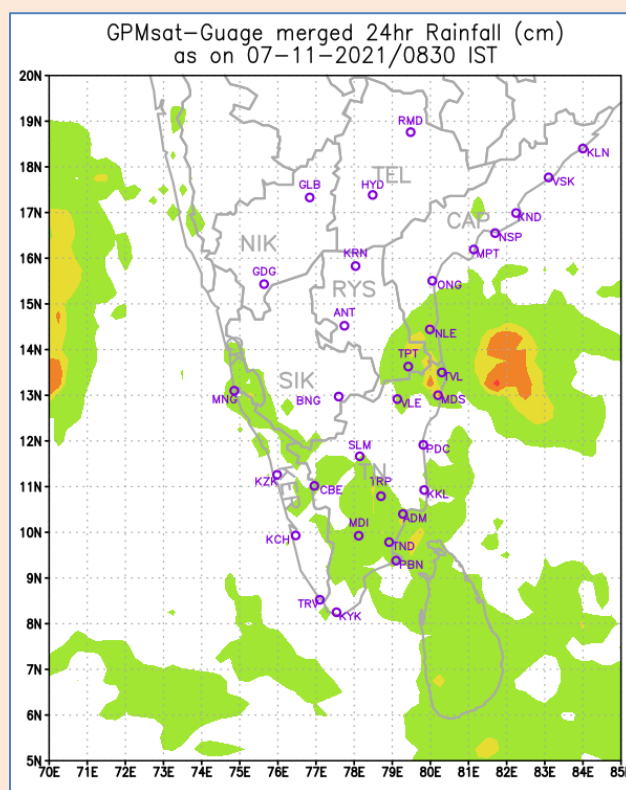
**Fig.8a:Upper air (lower levels) streamline analysis as on 0530 IST of 06<sup>th</sup>Nov 2021**

Satellite imageries depicting the associated cloudiness are presented in Fig.8b. Spatial distribution and intensity of 24-hr rainfall ending 08:30 IST of 07<sup>th</sup> November 2021 as depicted by (i) GPM satellite + gauge merged rainfall over the southern peninsula and (ii) point observations based on rain gauge reports are presented in Fig.8c(i-ii).



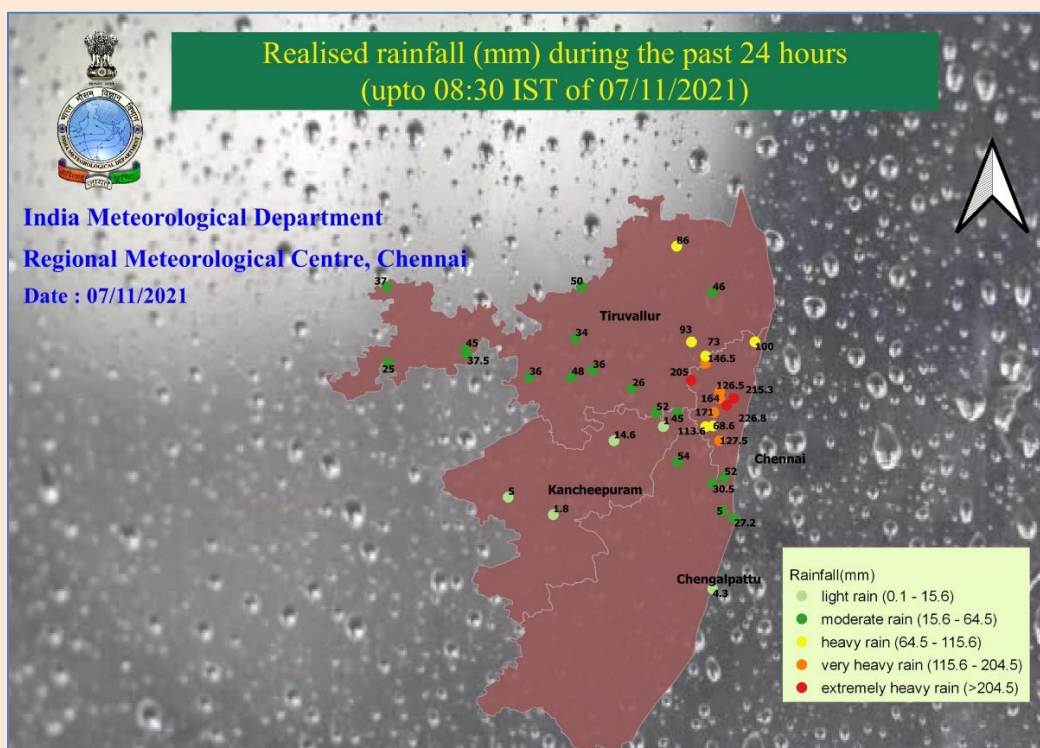
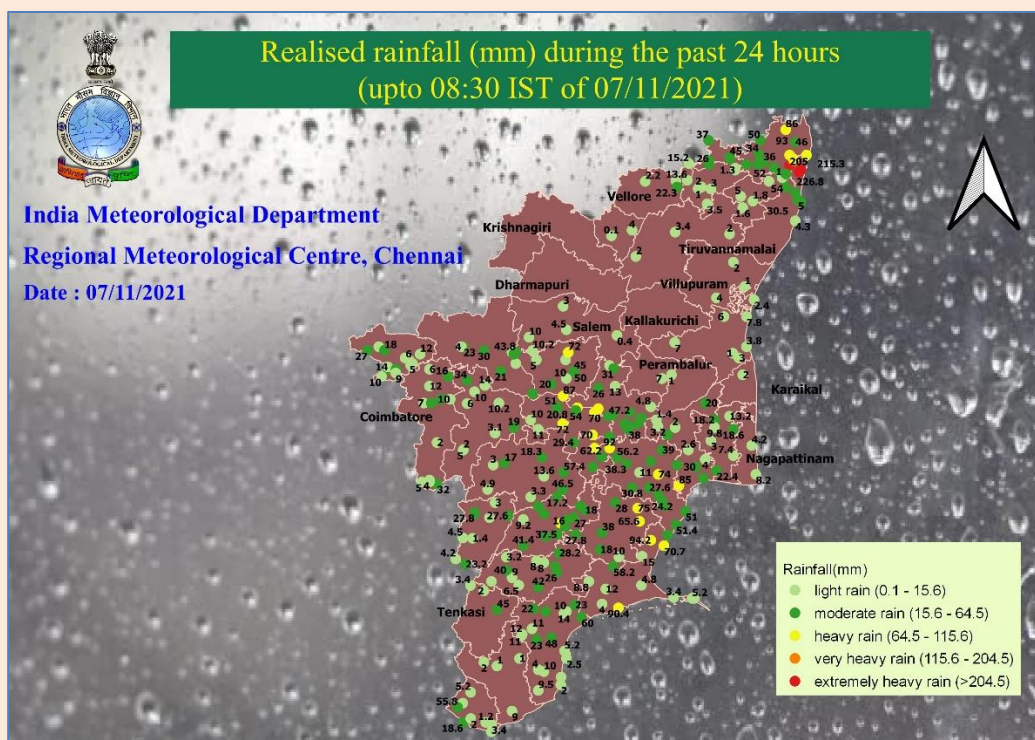


**Fig.8b: Satellite infra-red imageries as on 06<sup>th</sup>/2100 IST and 07<sup>th</sup>/0500 IST of Nov 2021**



**Fig.8c(i) GPM satellite+Gauge merged 24-hr rainfall (in cm) as on 0830 IST of 07 Nov 2021.**





**Fig.8c(ii):Past 24-hr accumulated rainfall (in mm) over TN subdivision (including Puducherry & Karaikal) & Chennai & neighbourhood as on 0830 IST of 07<sup>th</sup> Nov 2021.**

As seen, *very heavy* to *extremely heavy* rainfall occurred over Chennai. List of *heavy-extremely heavy rainfall* reports (in cm) realized as on 24-hr ending 08:30 IST of 07.11.21 is given below:

**Extremely heavy rainfall:**

Dgp Office (dist Chennai) 23,  
Chennai(NBK) (dist Chennai), Ambathur (dist Tiruvallur) 21 each

**Very heavy rainfall:**

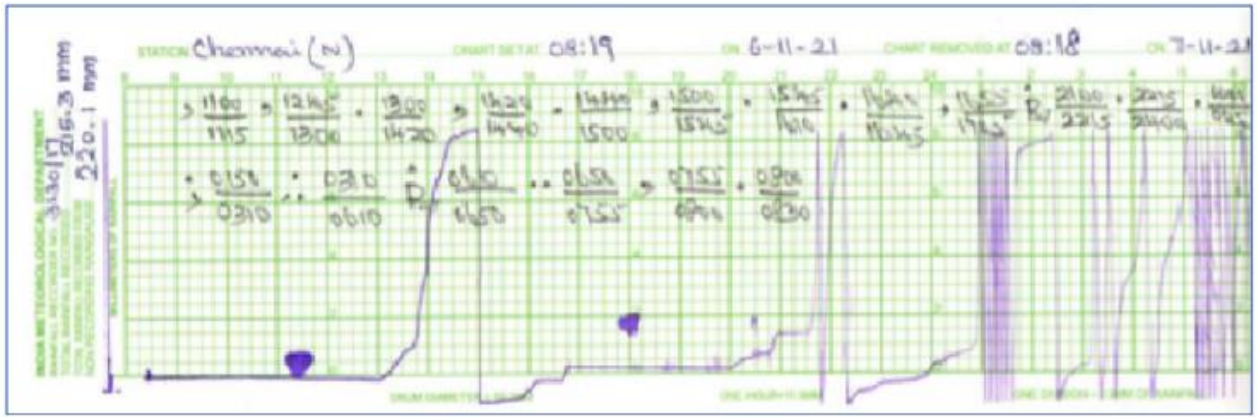
Ayanavaram Taluk Office (dist Chennai) 18  
Mgr Nagar (dist Chennai) 17,  
Anna Uty Arg (dist Chennai) 16,  
Puzhal Arg (dist Tiruvallur) 15,  
Perambur Corporation Park (dist Chennai) 14,  
CD Hospital Tondaipet (dist Chennai), Taramani Arg (dist Chennai), Anna University (dist Chennai) 13 each,  
Sirungamani (dist Trichy) 12,

**Heavy rainfall:**

Chennai Ap (dist Chennai), Government HS School MGR Nagar (dist Chennai) 11 each,  
Ennore Aws (dist Tiruvallur) 10,  
Tiruvadana (dist Ramanathapuram), Cholavaram (dist Tiruvallur), Viralimalai (dist Pudukkottai), Valinokam (dist Ramanathapuram), Mohanur (dist Namakkal), Musiri (dist Trichy), Gummidipoondi (dist Tiruvallur), Peravurani (dist Thanjavur), Madurai South (dist Madurai) 9 each,  
Karaikudi (dist Sivaganga), Malaiyur (dist Pudukkottai), Alangudi (dist Pudukkottai), Theerthandathanam (dist Ramanathapuram), Red Hills (dist Tiruvallur), Chennai Collectorate Building (dist Chennai), Panchapatti (dist Karur), Rasipuram (dist Namakkal), Navalurkottapattu (dist Trichy), Tondi (dist Ramanathapuram), Krishnarayapuram (dist Karur), Thogamalai (dist Karur), Kulithalai (dist Karur), Manapparai (dist Trichy), Alandur (dist Chennai), Devakottai (dist Sivaganga), Mylapatti (dist Karur) 7 each

The extremely heavy rainfall event over Chennai (NBK) occurred after the midnight of 06<sup>th</sup> and within a short span of about 6-7 hours. The self-recording rain gauge (SRRG) chart of Chennai (NBK) dated 06-07 November 2021 depicting the same is shown in Fig.8d. Associated with this event, extensive inland flooding occurred over Chennai and neighbourhood as reported by the media (Fig.8e).





**Fig.8d: Autographic chart (SRRG) of Chennai (Nungambakkam) for the period 06.11.21/0830 IST to 07.11.21/0830 IST**

## Water Scarcity to Water Scares City: How Chennai Can Get Off the Drought-to-Floods Rollercoaster



Commuters waded through a flooded area following heavy rain in Chennai, on November 7, 2021. (PTI)

Experts say decades-old encroachments near lakes have cut off natural drainage of rainwater into waterbodies. The solution needs political will and may also help Chennai during droughts, they say.

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ARCHANA R

Published: 07th November 2021 04:11 PM | Last Updated: 08th November 2021 08:53 AM



With the Chennai city receiving heavy rains last night, the highest since 2015, residents in many parts of the capital woke up to inundation on Sunday morning. (Photo | R Satish Babu, EPS)

**Fig.8e: News18 & The New Indian Express reports dated 07 November 2021**



### 3.3 (ii) Extremely heavy rainfall event over Chennai and neighbourhood as on 24-hr ending 0830 IST of 31<sup>st</sup> December 2021

Under the influence of trough in easterlies in the lower levels off north TN-south CAP coast *fairly widespread* rainfall with *heavy to extremely heavy rainfall* occurred over the TN subdivision during the 24-hr ending 0830 IST of 31<sup>st</sup> December 2021. A deep amplitude westerly trough over the northern parts of India along 80°E extending into lower latitudes in the mid tropospheric levels (Fig.9a) advecting cold air in the mid levels over Chennai and adjoining areas and enhancing the instability over these areas, lead to another episode of *very-extremely heavy rainfall* over Chennai and neighbourhood during the 24-hr ending 0830 IST on 31<sup>st</sup> December 2021. Spatial rainfall distribution over the TN subdivision and Chennai & neighbourhood are presented in Fig.9b and the *heavy* rainfall reports(in cm) during the 24-hr ending 0830 IST of 31<sup>st</sup> December 2021 are listed below:

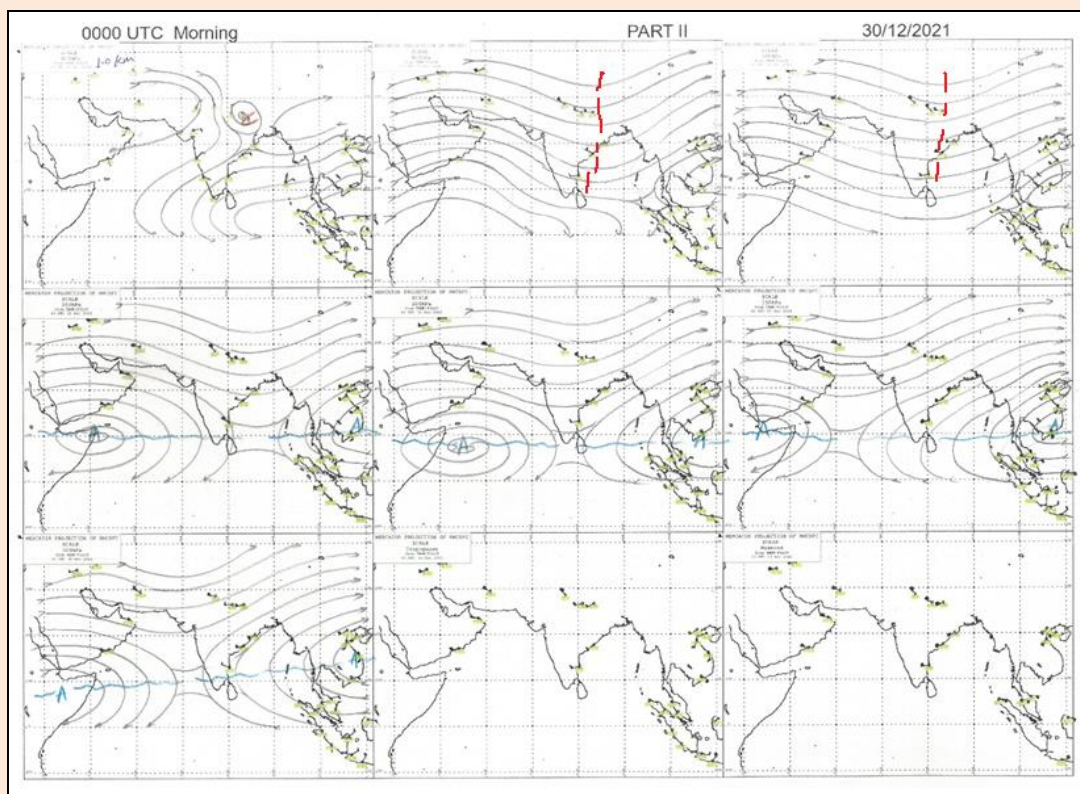
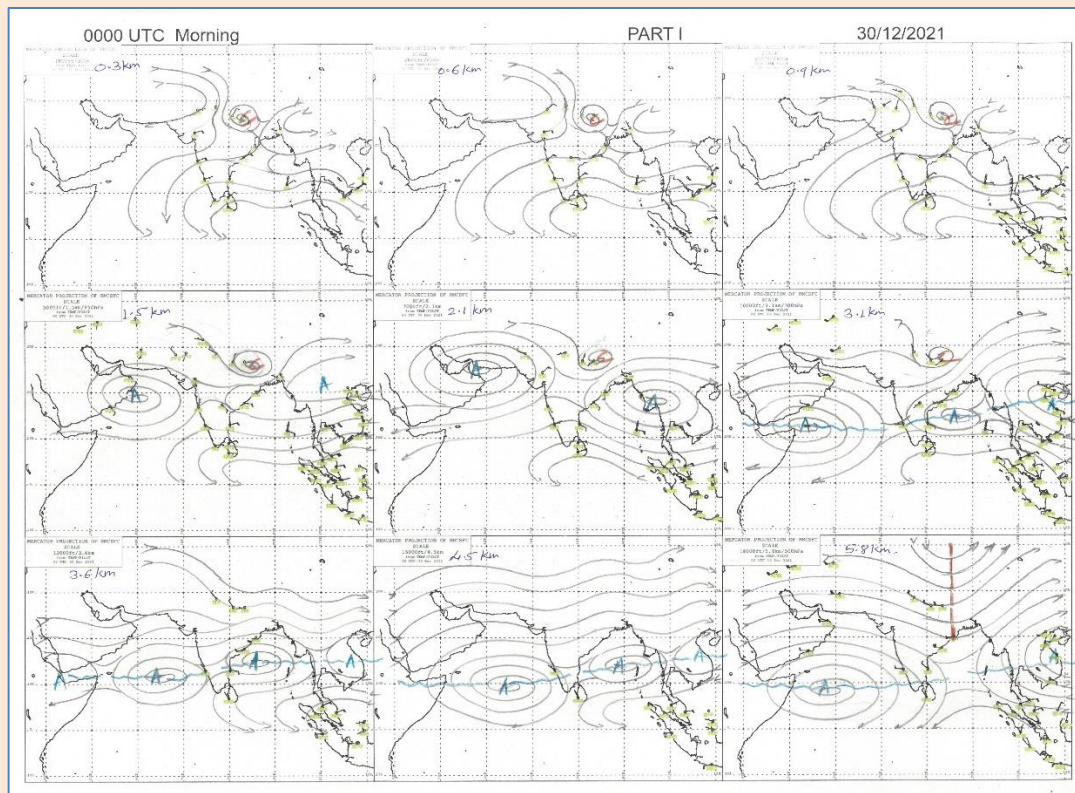
DGP Office (dist Chennai) -**24**, Avadi (dist Tiruvallur) - **23**, MRC Nagar (dist Chennai) - **21**,

Chennai(NBK) (dist Chennai), Poonamallee (dist Tiruvallur), MGR Nagar (dist Chennai), Ambathur (dist Tiruvallur) -**20** each, Anna University (dist Chennai), Chembarabakkam (dist Tiruvallur), Thondaiyarpuram (dist Chennai), ACS College (dist Chennai) - **19 each**, Ayyanavaram (dist Chennai), YMCA Nandhanam- **18 each**, Perambur (dist Chennai), Anna Uty ARG (dist Chennai), Chennai AP (dist Chennai) - **15 each**, Sholinganallur (dist Chennai), Koratur (dist Tiruvallur) -**12 each**,

Sirkali (dist Mayiladuthurai), Tirur KVK (dist Tiruvallur) - **11 each**, Kollidam (dist Mayiladuthurai), Red Hills (dist Tiruvallur), Poondi (dist Tiruvallur) - **10 each**, Kelambakkam (dist Chengalpattu), Cholavaram (dist Tiruvallur), Thamaraiyarpakkam (dist Tiruvallur), Sriperumbudur (dist Kancheepuram), Pallikarai (dist Chennai) -**9 each**, Chidambaram AWS (dist Cuddalore), Mayiladuthurai (dist Mayiladuthurai), Tambaram (dist Chengalpattu), Satyabama Uty ARG (dist Chengalpattu) - **7 each**.

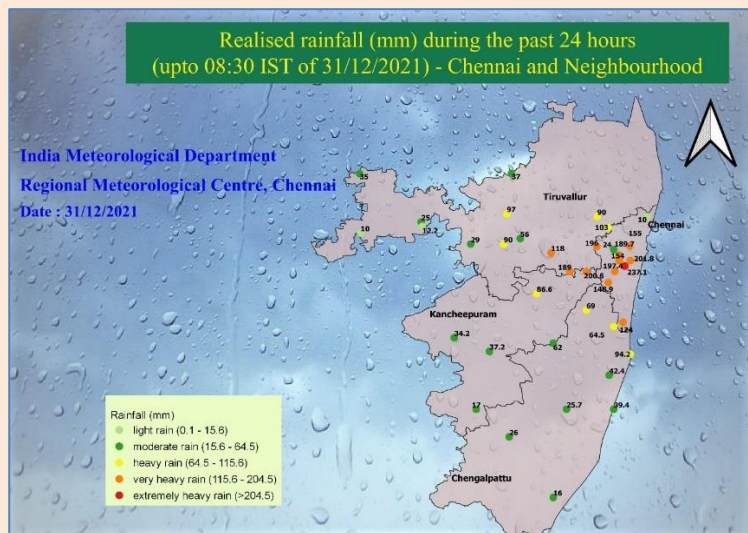
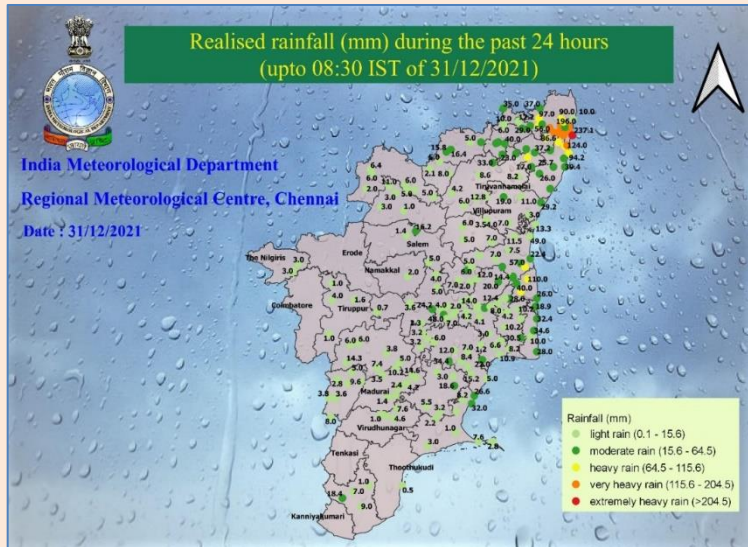
It is noted that *very -extremely heavy* rainfall reports were all from Chennai and adjoining Tiruvallur districts. Chennai (NBK) SRRG chart of 30.12.2022/0830 IST to 21.12.2022/0830 IST indicates that most of the rain occurred during an intense spell for about 3 hours from 1515 IST to 1800 IST and another for about 45 minutes during 2200 IST to 2245 IST (Fig.9c).

Satellite and radar imageries depicting the event are presented in Fig.9c&d. As seen, this extreme event was a meso scale event that affected the Chennai coast, Chennai and neighbourhood under the influence of westerly trough in the mid tropospheric levels. As per media reports, this extreme rainfall event caused extensive inland flooding and traffic blocks in most parts of Chennai and neighbourhood (Fig.9f).

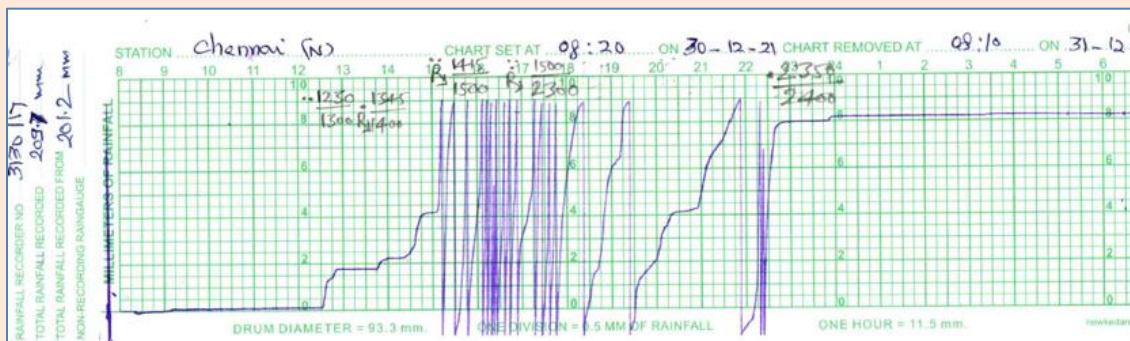


**Fig.9a: Upper air streamline analysis as on 0530 IST of 30 Dec 2021**



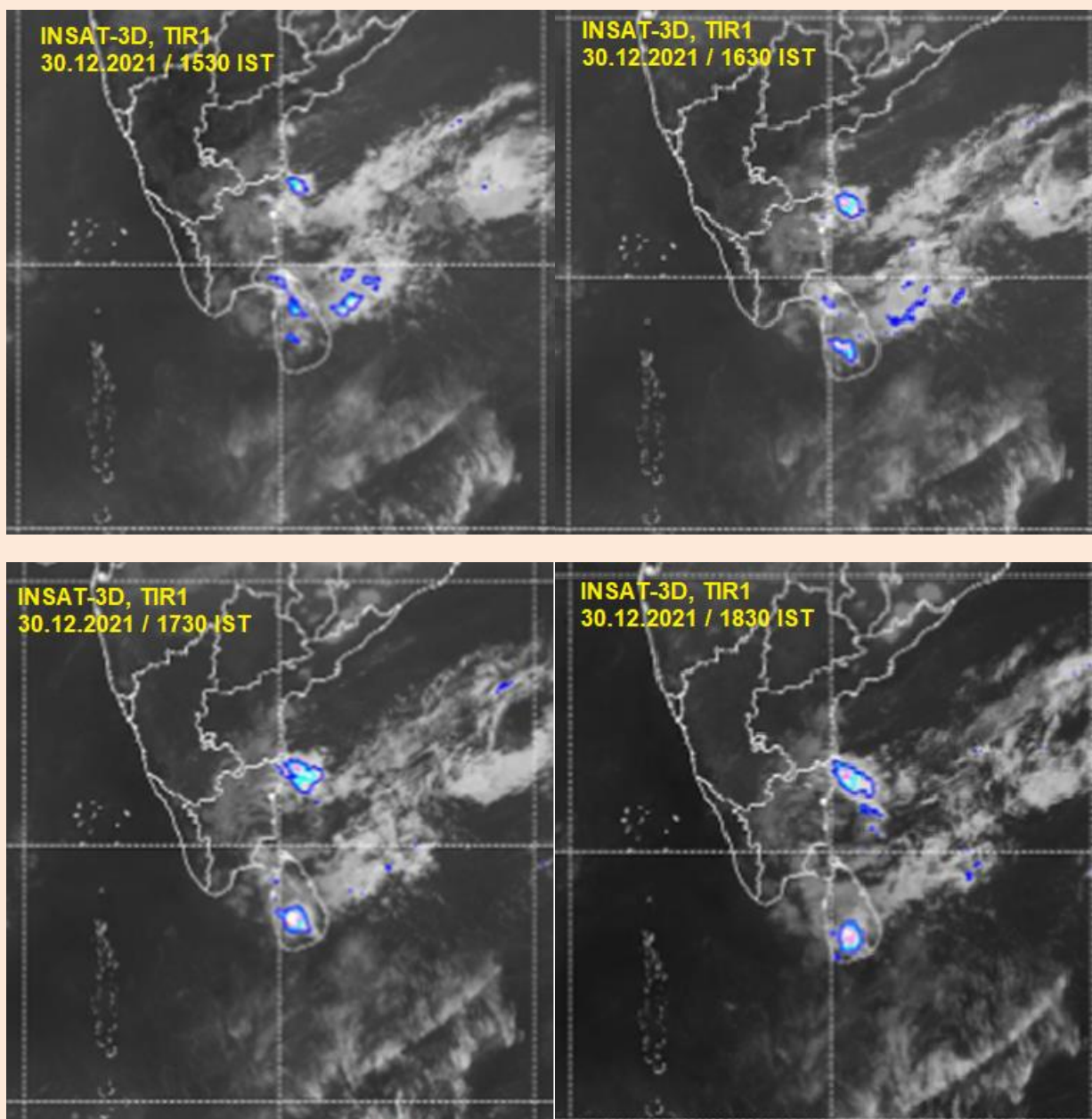


**Fig.9b: Past 24-hr accumulated rainfall over the TN subdivision and Chennai & neighbourhood as on 0830 IST of 31.12.2021**

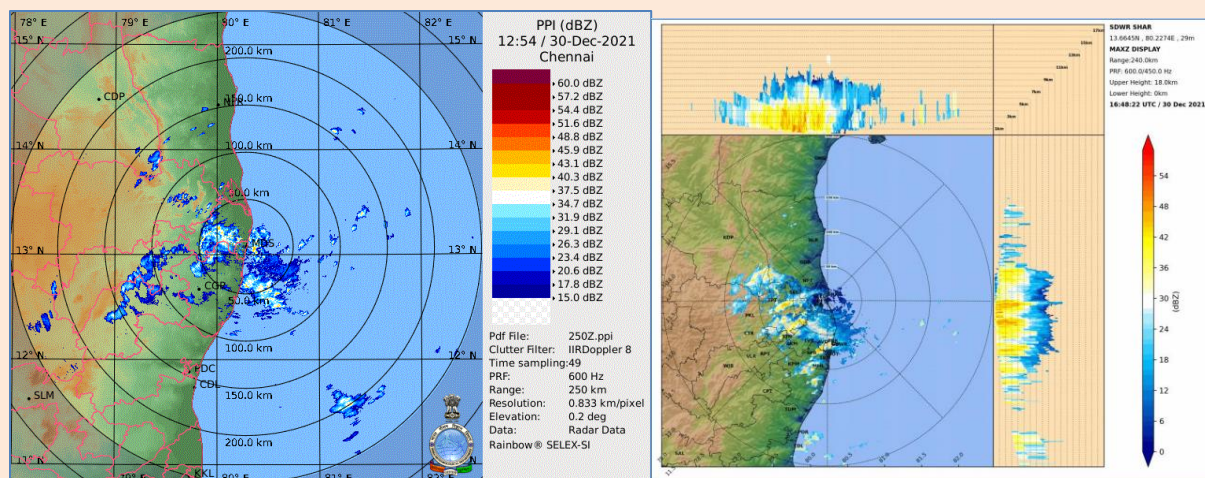


**Fig.9c: Chennai (NBK) SRRG chart for the period 30.12.2021/0830 IST to 31.12.2021/0830 IST**

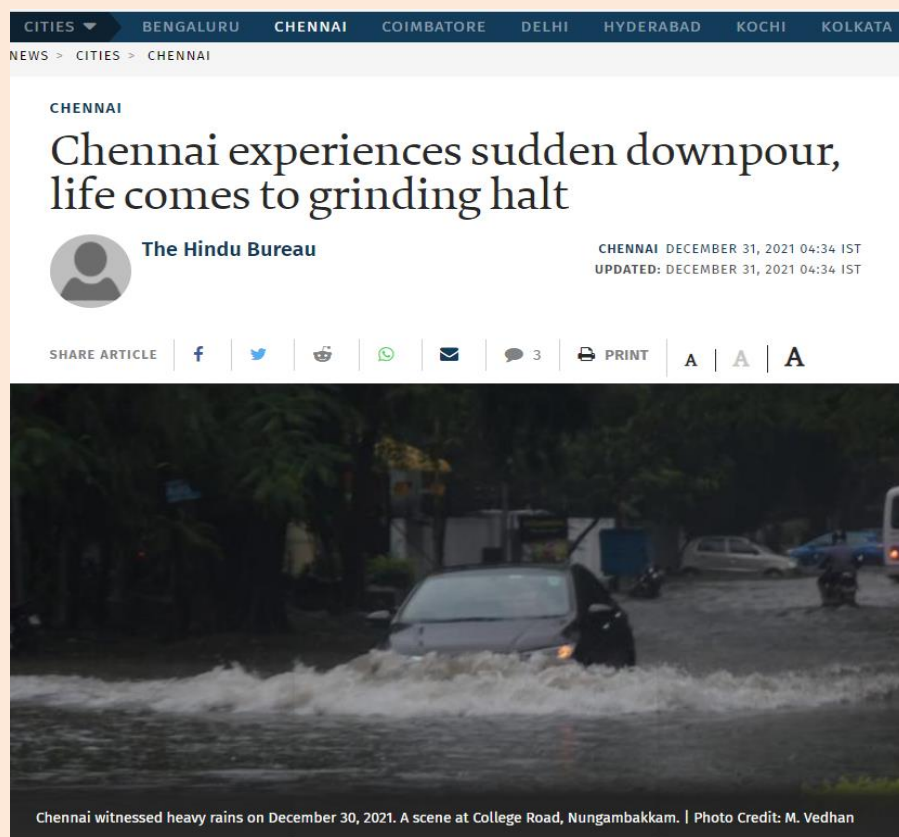




**Fig.9d:Satellite infra-red imageries as on 1530 IST, 1630 IST, 1730 IST & 1830 IST of 30.12.2021**



**Fig.9e: DWRs (S-band) Chennai & Sriharikota reflectivity &Max-Z products respectively as on 18:24 IST & 22:20 IST of 30.12.2021**

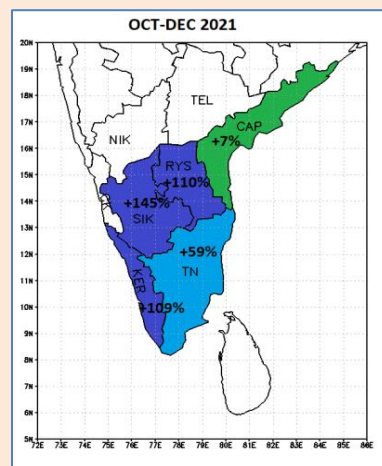


**Fig.9f: The Hindu report dated 31 December 2021**

#### 4. Sub divisional rainfall performance during NEM 2021

##### 4.1 Seasonal rainfall

During October-December 2021, the northeast monsoon seasonal rainfall was *normal* (-19% to +19%) to *large excess* ( $\geq 60\%$ ) over the 5 meteorological subdivisions benefitted by the NEM (TN, KER, CAP, RYS and SIK). It was *large excess* over SIK (+145%), RYS (+110%) and KER (+109%), *excess* (+20% to +59%) over TN (+59%) and *normal* over CAP (+7%). Fig.10 and Table-1 present the season ending (01<sup>st</sup> Oct-31<sup>st</sup> December 2021) rainfall figures over these subdivisions.



**Fig.10: Seasonal rainfall performance of NEM 2021 over the five meteorological subdivisions benefitted by the NEM**

**Table-1: Sub-divisional seasonal rainfall during October-December 2021**

Subdivision	01 <sup>st</sup> October – 31 <sup>st</sup> December 2021		
	Actual (mm)	Normal (mm)	PDN (%)
Tamilnadu, Puducherry & Karaikal (TN)	714.3	449.7	+59
Coastal Andhra Pradesh & Yanam (CAP)	360.6	338.1	+7
Rayalaseema (RYS)	469.7	223.3	+110
Kerala & Mahe(KER)	1026.3	491.6	+109
South Interior Karnataka (SIK)	500.8	204.1	+145

PDN: Percentage Departure from Normal

Legend:

<i>Largely Deficient</i>	<i>Deficient</i>	<i>Normal</i>	<i>Excess</i>	<i>Large Excess</i>
$\leq -60\%$	-20% to -59%	-19% to +19%	+20% to +59%	$\geq +60\%$

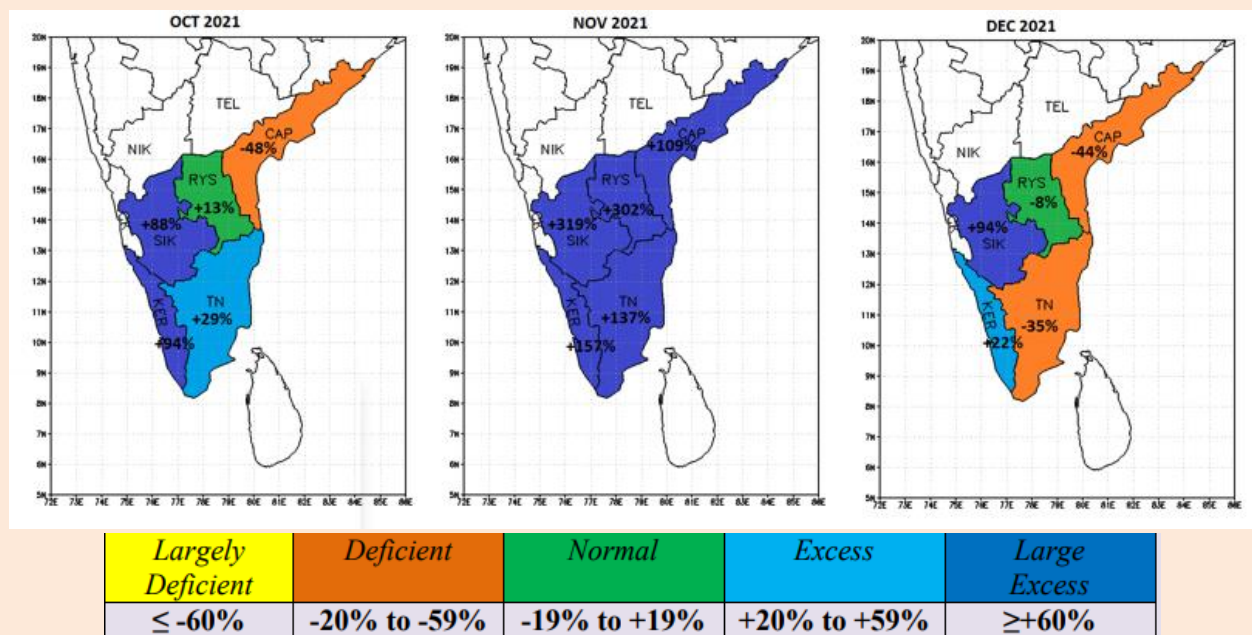


#### 4.2 Monthly & Daily rainfall scenario

The intra-seasonal rainfall distribution over various sub-divisions during Oct-Dec 2021 is presented in monthly and daily scales. Month-wise rainfall statistics are presented in Table-2 and Fig.11. Table-3a&b present the daily rainfall scenario in terms of spatial rainfall distribution (*Widespread:WS, Fairly widespread: FWS, Scattered:SCT, Isolated: ISOL and DRY*).

**Table-2: Sub-divisional monthly rainfall during NEM 2021**

SUB-DIVISION	OCT			NOV			DEC		
	ACL (mm)	NOR (mm)	PDN (%)	ACL (mm)	NOR (mm)	PDN (%)	ACL (mm)	NOR (mm)	PDN (%)
TAMIL NADU, PUDUCHERRY & KARAİKAL (TN)	228.6	177.6	29	425.3	179.5	137	60.4	92.6	-35
COASTAL ANDHRA PRADESH & YANAM (CAP)	98.9	191.3	-48	245.2	117.3	109	16.5	29.5	-44
RAYALASEEMA (RYS)	146.4	129.8	13	302	70.2	330	21.3	23.3	-8
KERALA & MAHE (KER)	589.5	303.4	94	394.5	153.4	157	42.3	34.8	22
SOUTH INTERIOR KARNATAKA (SIK)	266.6	141.6	88	212.1	50.6	319	23.1	11.9	94



**Fig.11: Subdivisional monthly rainfall performance during October-December 2021**

**Table-3a: Spatial rainfall distribution**

Date as on 0830 IST	TN	CAP	RYS	KER	SIK
01-Oct	FWS	SCT	ISOL	WS	SCT
02-Oct	FWS	ISOL	SCT	WS	WS
03-Oct	WS	ISOL	ISOL	WS	FWS
04-Oct	SCT	ISOL	ISOL	FWS	WS
05-Oct	SCT	SCT	ISOL	WS	FWS
06-Oct	WS	SCT	WS	WS	WS
07-Oct	SCT	FWS	FWS	WS	WS
08-Oct	ISOL	ISOL	FWS	FWS	SCT
09-Oct	FWS	ISOL	WS	WS	FWS
10-Oct	SCT	ISOL	SCT	WS	FWS
11-Oct	FWS	ISOL	ISOL	WS	FWS
12-Oct	FWS	ISOL	SCT	WS	WS
13-Oct	FWS	ISOL	SCT	WS	WS
14-Oct	SCT	ISOL	ISOL	WS	FWS
15-Oct	SCT	SCT	ISOL	WS	SCT
16-Oct	ISOL	FWS	SCT	FWS	ISOL
17-Oct	FWS	FWS	ISOL	WS	SCT
18-Oct	SCT	ISOL	ISOL	WS	SCT
19-Oct	ISOL	ISOL	DRY	WS	SCT
20-Oct	ISOL	ISOL	ISOL	ISOL	ISOL
21-Oct	FWS	ISOL	FWS	WS	FWS
22-Oct	FWS	ISOL	SCT	FWS	WS
23-Oct	SCT	ISOL	SCT	FWS	FWS
24-Oct	SCT	ISOL	FWS	WS	WS
25-Oct	FWS	ISOL	SCT	SCT	FWS
26-Oct	SCT	ISOL	DRY	WS	FWS
27-Oct	ISOL	ISOL	ISOL	FWS	SCT
28-Oct	FWS	ISOL	DRY	WS	ISOL
29-Oct	FWS	SCT	ISOL	FWS	ISOL
30-Oct	WS	WS	WS	FWS	FWS
31-Oct	FWS	FWS	FWS	WS	SCT
01-Nov	WS	SCT	SCT	WS	SCT
02-Nov	WS	FWS	SCT	WS	FWS
03-Nov	WS	FWS	FWS	WS	ISOL
04-Nov	FWS	FWS	SCT	WS	SCT
05-Nov	FWS	SCT	ISOL	WS	FWS
06-Nov	FWS	ISOL	SCT	SCT	WS
07-Nov	FWS	ISOL	ISOL	FWS	SCT
08-Nov	FWS	ISOL	ISOL	ISOL	SCT
09-Nov	WS	ISOL	ISOL	WS	SCT
10-Nov	WS	ISOL	ISOL	SCT	ISOL
11-Nov	FWS	SCT	SCT	SCT	SCT
12-Nov	FWS	WS	WS	WS	WS
13-Nov	SCT	WS	WS	WS	WS
14-Nov	SCT	WS	FWS	WS	WS
15-Nov	FWS	FWS	FWS	WS	WS

**Table-3a (contd.)**

<b>Date as on 0830 IST</b>	<b>TN</b>	<b>CAP</b>	<b>RYS</b>	<b>KER</b>	<b>SIK</b>
16-Nov	FWS	FWS	FWS	WS	WS
17-Nov	SCT	FWS	FWS	WS	WS
18-Nov	WS	SCT	WS	FWS	FWS
19-Nov	FWS	FWS	WS	WS	WS
20-Nov	FWS	WS	WS	WS	WS
21-Nov	SCT	FWS	FWS	SCT	FWS
22-Nov	ISOL	SCT	ISOL	SCT	SCT
23-Nov	FWS	FWS	SCT	FWS	FWS
24-Nov	SCT	SCT	ISOL	WS	SCT
25-Nov	SCT	ISOL	SCT	SCT	SCT
26-Nov	WS	ISOL	ISOL	WS	ISOL
27-Nov	WS	ISOL	ISOL	ISOL	ISOL
28-Nov	WS	ISOL	SCT	WS	ISOL
29-Nov	WS	SCT	FWS	FWS	ISOL
30-Nov	WS	ISOL	WS	FWS	SCT
01-Dec	FWS	ISOL	SCT	FWS	SCT
02-Dec	SCT	DRY	DRY	FWS	ISOL
03-Dec	ISOL	ISOL	DRY	ISOL	ISOL
04-Dec	ISOL	SCT	ISOL	SCT	FWS
05-Dec	SCT	ISOL	ISOL	SCT	SCT
06-Dec	SCT	ISOL	DRY	SCT	ISOL
07-Dec	SCT	ISOL	ISOL	SCT	ISOL
08-Dec	ISOL	ISOL	DRY	ISOL	DRY
09-Dec	ISOL	SCT	ISOL	ISOL	DRY
10-Dec	SCT	SCT	SCT	SCT	SCT
11-Dec	ISOL	ISOL	ISOL	ISOL	ISOL
12-Dec	SCT	ISOL	SCT	ISOL	ISOL
13-Dec	SCT	ISOL	ISOL	ISOL	ISOL
14-Dec	SCT	ISOL	SCT	ISOL	ISOL
15-Dec	SCT	ISOL	ISOL	ISOL	ISOL
16-Dec	ISOL	DRY	DRY	ISOL	DRY
17-Dec	ISOL	ISOL	DRY	ISOL	DRY
18-Dec	ISOL	DRY	DRY	DRY	DRY
19-Dec	DRY	DRY	DRY	DRY	DRY
20-Dec	DRY	DRY	DRY	ISOL	DRY
21-Dec	DRY	DRY	DRY	DRY	DRY
22-Dec	DRY	DRY	DRY	DRY	DRY
23-Dec	DRY	DRY	DRY	DRY	DRY
24-Dec	DRY	DRY	DRY	DRY	DRY
25-Dec	DRY	ISOL	DRY	DRY	DRY
26-Dec	DRY	DRY	DRY	DRY	DRY
27-Dec	DRY	DRY	DRY	DRY	DRY
28-Dec	DRY	DRY	DRY	DRY	DRY
29-Dec	ISOL	ISOL	ISOL	DRY	DRY
30-Dec	ISOL	ISOL	DRY	DRY	DRY
31-Dec	FWS	ISOL	ISOL	DRY	ISOL



**Table-3b: Frequency of various categories of spatial rainfall distribution**

Subdivision	No. of days				
	WS	FWS	SCT	ISOL	DRY
<b>TN</b>	14	27	25	16	10
<b>CAP</b>	5	13	15	47	12
<b>RYS</b>	9	12	20	30	21
<b>KER</b>	38	15	12	14	13
<b>SIK</b>	17	17	21	20	17

**WD: Widespread**

(76-100% of stations reporting rainfall)

**SCT: Scattered**

(26-50% of stations reporting rainfall)

**DRY:** No rain**FWD : Fairly widespread**

(51-75% of stations reporting rainfall)

**ISOL: Isolated**

(≤25% of stations reporting rainfall)

**4.3 Monsoon activity & heavy rainfall events**

Table-4 presents the frequency of active and vigorous monsoon days and frequency of heavy rainfall days (**Heavy** rainfall  $\geq 7$ cm/day; **Very Heavy** rainfall  $\geq 12$ cm/day; **Extremely Heavy** rainfall  $\geq 21$  cm/day).

**Table-4: Frequencies of active and vigorous monsoon days and heavy rainfall days**

Subdivision	No. of days				
	Activity		Heavy Rainfall		
	Vigorous	Active	Extremely Heavy	Very Heavy	Heavy
<b>TN</b>	8	22	9	33	65
<b>CAP</b>	2	7	0	8	28
<b>RYS</b>	8	12	1	4	22
<b>KER</b>	11	19	2	18	40
<b>SIK</b>	5	10	0	9	28

**Active:** Fairly widespread to widespread sub-divisional rainfall with rainfall more than 1½ to 4 times the normal with at least two stations reporting more than or equal to 5 cm in coastal Tamil Nadu, south coastal Andhra Pradesh and 3 cm elsewhere in the NEM region.

**Vigorous:** Fairly widespread to widespread sub-divisional rainfall with rainfall more than 4 times the normal with at least two stations reporting more than or equal to 5 cm in coastal Tamil Nadu, south coastal Andhra Pradesh and 3 cm elsewhere in the NEM region.

**Heavy:** rainfall  $\geq 7$ cm/day; **Very Heavy:** rainfall  $\geq 12$ cm/day; **Extremely Heavy:** rainfall  $\geq 21$  cm/day

During October, excepting CAP that became *deficient*, all the other four subdivisions received *normal* to *large excess* rainfall. In November, all the five subdivisions received *large excess* rainfall, more than 100% excess with SIK and RYS recording more than 300% excess. In December, SIK, KER & RYS received *normal* to *excess* rainfall and TN & CAP came under

deficient category. It may be noted that SIK came under *large excess* category during all the three months of the season; KER received *large excess* rainfall in October and November and *excess* rainfall in December.

In the daily scale, *FWS-WS* rainfall occurred over KER & TN on 58% & 45% respectively of the days during the season and over the other subdivisions, 20% to 40% (SIK:37%, CAP & RYS: 20%-23%) of the days during the season. *Isolated* rainfall or *dry* conditions prevailed over CAP & RYS on 55%-65% of the days; over SIK, on 40% of the days and over TN & KER, about 30% of the days.

*Active-vigorous* monsoon conditions prevailed over TN & KER on 33% of the days during the season; Over RYS, 22% of the days and over CAP & SIK, about 10-16% of the days during the season.

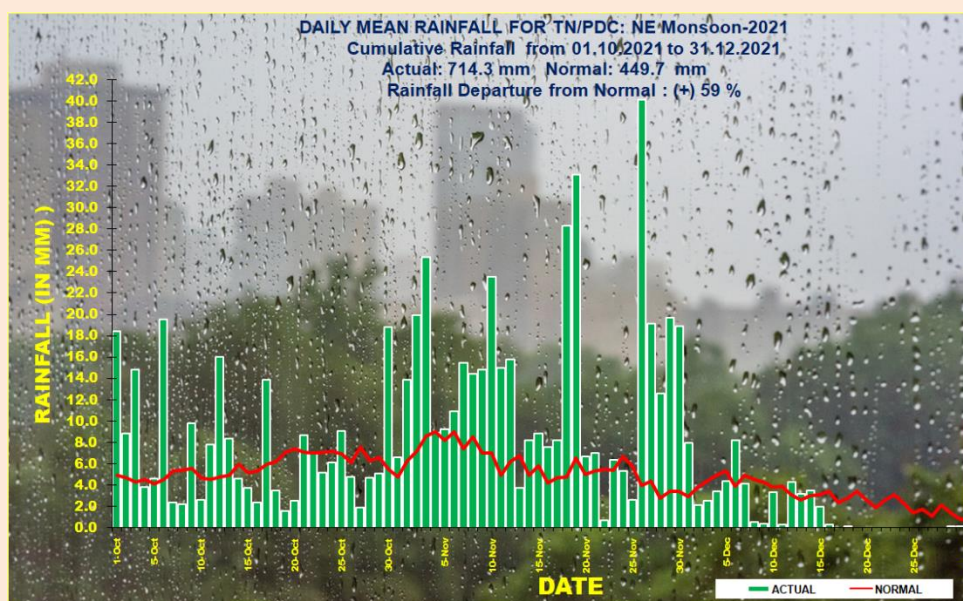
Regarding *heavy* rainfall occurrences ( $\geq 7$  cm/day), TN experienced 65 days of *isolated heavy* rainfall events during the season including 33 days of *isolated very heavy* rain with *isolated extremely heavy* falls on 9 days. Over Kerala, *isolated heavy* rain occurred on 40 days including 18 days of *isolated very heavy* rain with *extremely heavy* falls on 2 days. Over CAP & SIK, *isolated heavy* rain occurred on 28 days including 8-9 days of *isolated very heavy* rainfall. RYS experienced 22 days of *isolated heavy* rain including 4 days of *isolated very heavy* rain with *isolated extremely heavy* falls on 1 day. List of extremely heavy rainfall events is presented in Table-5.

**Table-5: List of extremely heavy rainfall events during October-December 2021**

Date	Subdivision	District	Station & rainfall amount (cm)
12OCT	KER	Malappuram	Karipur AP - <b>25</b>
		Palakkad	Mannarkkad - <b>24</b>
		Kozhikode	Kozhikode- <b>22</b>
17 OCT	TN	Tirunelveli	Papanasam - <b>27</b>
		Kanyakumari	Pechiparai- <b>22</b>
	KER	Idukki	Peermedu - <b>29</b>
		Kottayam	Kanjirappally - <b>27</b>
21 OCT	TN	Salem	Yethappur - <b>21</b>
07 NOV	TN	Chennai	Mylapore DGP office- <b>23</b> ; NBK- <b>21</b>
		Tiruvallur	Ambattur - <b>21</b>
10 NOV	TN	Nagapattinam	Nagapattinam, Thirupoondi – <b>31 each</b> ; Vedaranyam- <b>25</b> ; Thalaigayner - <b>24</b>
		Karaikal	Karaikal - <b>29</b>
		Thiruvarur	Thiruthuraiipoondi - <b>22</b>
11 NOV	TN	Chengalpattu	Tambaram - <b>23</b>
		Thiruvallur	Cholavaram – <b>22</b> ; Ennore AWS - <b>21</b>
14 NOV	TN	Kanyakumari	Perunchani Dam, Puthan Dam – <b>22 each</b>
19 NOV	TN	Villupuram	Tindivanam, Koliyanur, Vallam, Valavanur - <b>22 each</b> ; Manampoondi - <b>21</b>
	RYS	Anantapur	Nambulipilikonta - <b>24</b>
26 NOV	TN	Thootukudi	Kayalpattinam- <b>31</b> , Tuticorin- <b>27</b> , Tiruchendur- <b>25</b>
31 DEC	TN	Chennai	Mylapore DGP office – <b>24</b> ; MRC Nagar - <b>21</b>
		Tiruvallur	Avadi - <b>23</b>

## 5. Rainfall distribution over Tamil Nadu and Puducherry

Spatial and temporal distribution of rainfall over the TN subdivision during Oct-Dec 2021 are depicted by means of district-wise rainfall distribution and area averaged daily rainfall distribution over TN. Fig.12 presents the daily rainfall distribution over the TN subdivision (including Puducherry and Karaikal) during Oct-Dec 2021. During the period from 30<sup>th</sup> October to 01<sup>st</sup> December (33 days) the subdivisional rainfall was above normal on 30 out of 33 days.



**Fig.12: Area averaged daily rainfall over TN subdivision during Oct-Dec 2021**

State / UT & District-wise rainfall realized are presented in Tables-6a&b and Fig.13. As seen, Puducherry, Karaikal and all the districts in Tamilnadu excepting Madurai and Ramanathapuram districts received *excess to large excess* rainfall during the season (October-December 2021). Madurai and Ramanathapuram received *normal* rainfall during the period.

**Table-6a: State /UT wise rainfall figures of Tamil Nadu, Puducherry& Karaikal during Oct-Dec 2021**

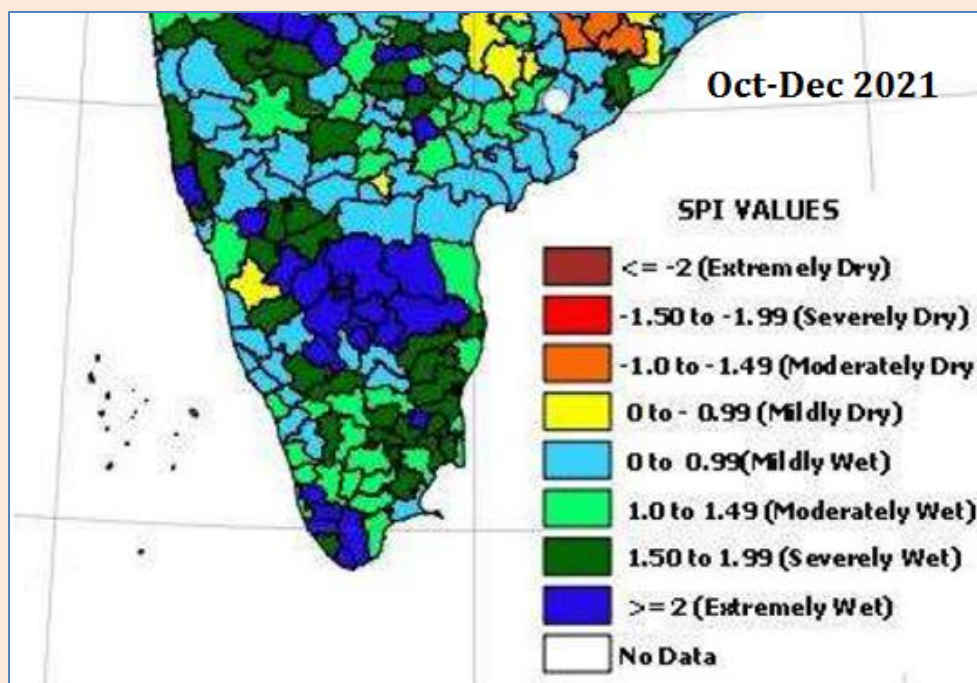
Subdivision / State / UT	Actual rainfall (mm)	Normal rainfall (mm)	Percentage departure from normal (%)
TN subdivision	714.3	449.7	59
Puducherry& Karaikal (UT)	1491.5	895.6	67
Tamil NaduState	711.6	448.0	59



**Table-6b: District-wise rainfall figures of Tamil Nadu, Puducherry& Karaikal during Oct-Dec 2021**

District	Actual rainfall (mm)	Normal rainfall (mm)	Percentage departure from normal (%)
ARIYALUR	933.0	578.3	61
CHENGALPATTU	1238.4	702.6	76
CHENNAI	1360.4	784.0	74
COIMBATORE	678.6	343.8	97
CUDDALORE	1184.7	704.6	68
DHARMAPURI	476.8	327.6	46
DINDIGUL	588.6	470.2	25
ERODE	521.9	308.4	69
KALLAKURICHI	818.2	471.4	74
KANCHEEPURAM	995.2	591.4	68
KANYAKUMARI	1076.8	523.9	106
KARAIKAL	1491.7	1032.5	44
KARUR	496.7	309.7	60
KRISHNAGIRI	442.0	289.8	53
MADURAI	484.6	418.8	16
MAYILADUTHURAI	1155.8	886.0	30
NAGAPATTINAM	1219.3	987.4	23
NAMAKKAL	531.6	293.2	81
NILGIRIS	635.0	477.2	33
PERAMBALUR	850.7	467.7	82
PUDUCHERRY	1491.4	882.0	69
PUDUKKOTTAI	629.3	410.5	53
RAMANATHAPURAM	593.2	523.1	13
RANIPET	788.2	423.4	86
SALEM	481.4	359.0	34
SIVAGANGA	661.1	423.7	56
TENKASI	717.9	448.6	60
THANJAVUR	867.3	593.7	46
THENI	596.1	363.9	64
TIRUNELVELI	841.2	491.4	71
TIRUPATTUR	576.2	268.5	115
TIRUPPUR	480.9	318.4	51
TIRUVALLUR	1058.2	639.1	66
TIRUVANNAMALAI	837.6	460.0	82
TIRUVARUR	1030.0	742.1	39
TOOTHUKUDI	592.4	427.7	39
TRICHY	668.0	394.2	69
VELLORE	626.2	389.8	61
VILLUPURAM	1211.4	554.3	119
VIRUDHUNAGAR	525.2	395.2	33





**Fig.14: Standardised Precipitation Index for October-December 2021 over the southern peninsular India.**

## 7. Large & Regional scale circulation features

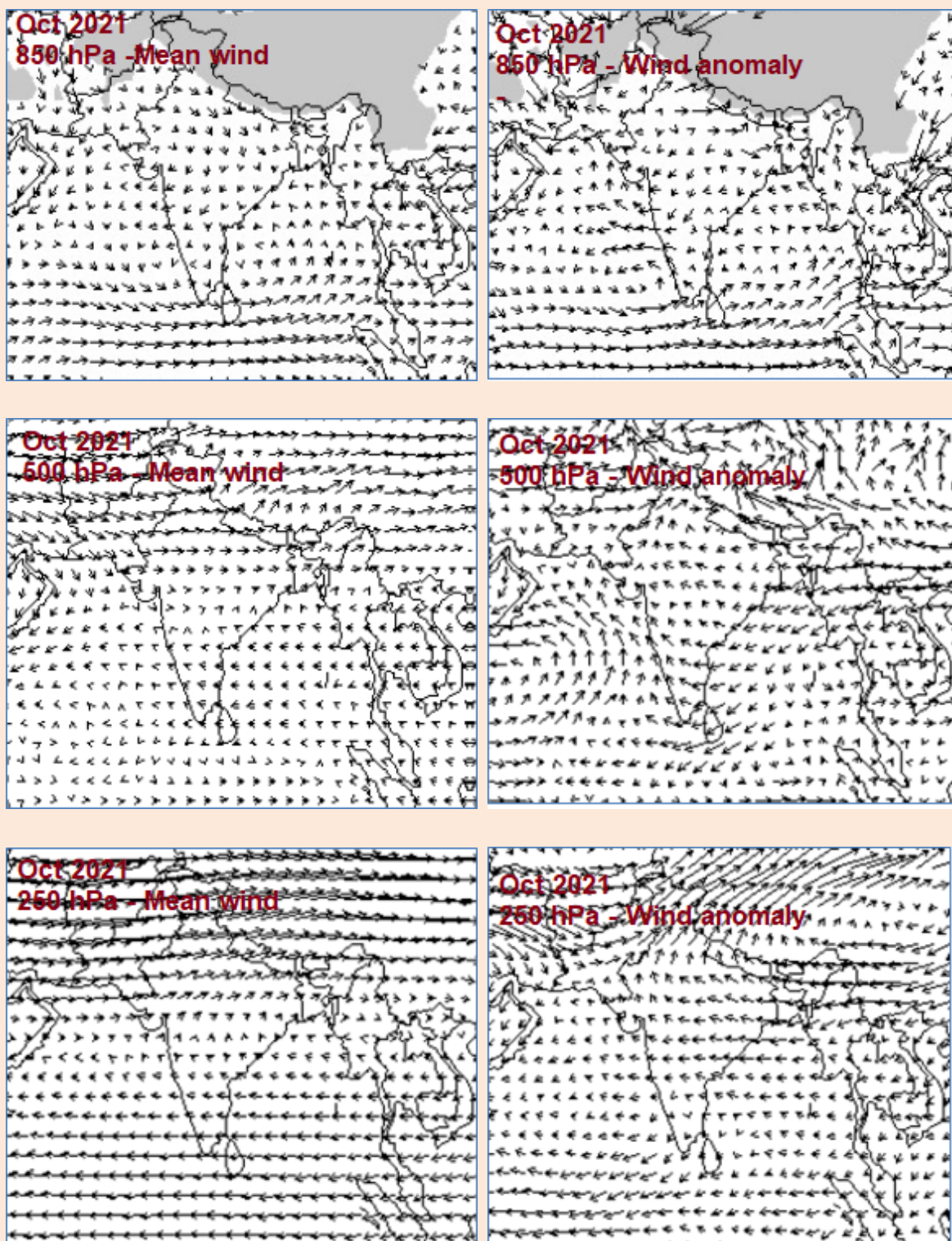
(a) **Flow pattern:** The mean and anomalous wind pattern over the Indian region at 850 hPa, 500 hPa and 250 hPa levels during October –December 2021 are presented in Fig.15(a-c).

In October 2021, cyclonic circulations were observed in the lower-mid tropospheric levels (850 hPa & 500 hPa) over the Arabian sea and anomalous easterlies were observed in the mid-tropospheric levels (500 hPa) over the southern peninsular India and adjoining Bay of Bengal.

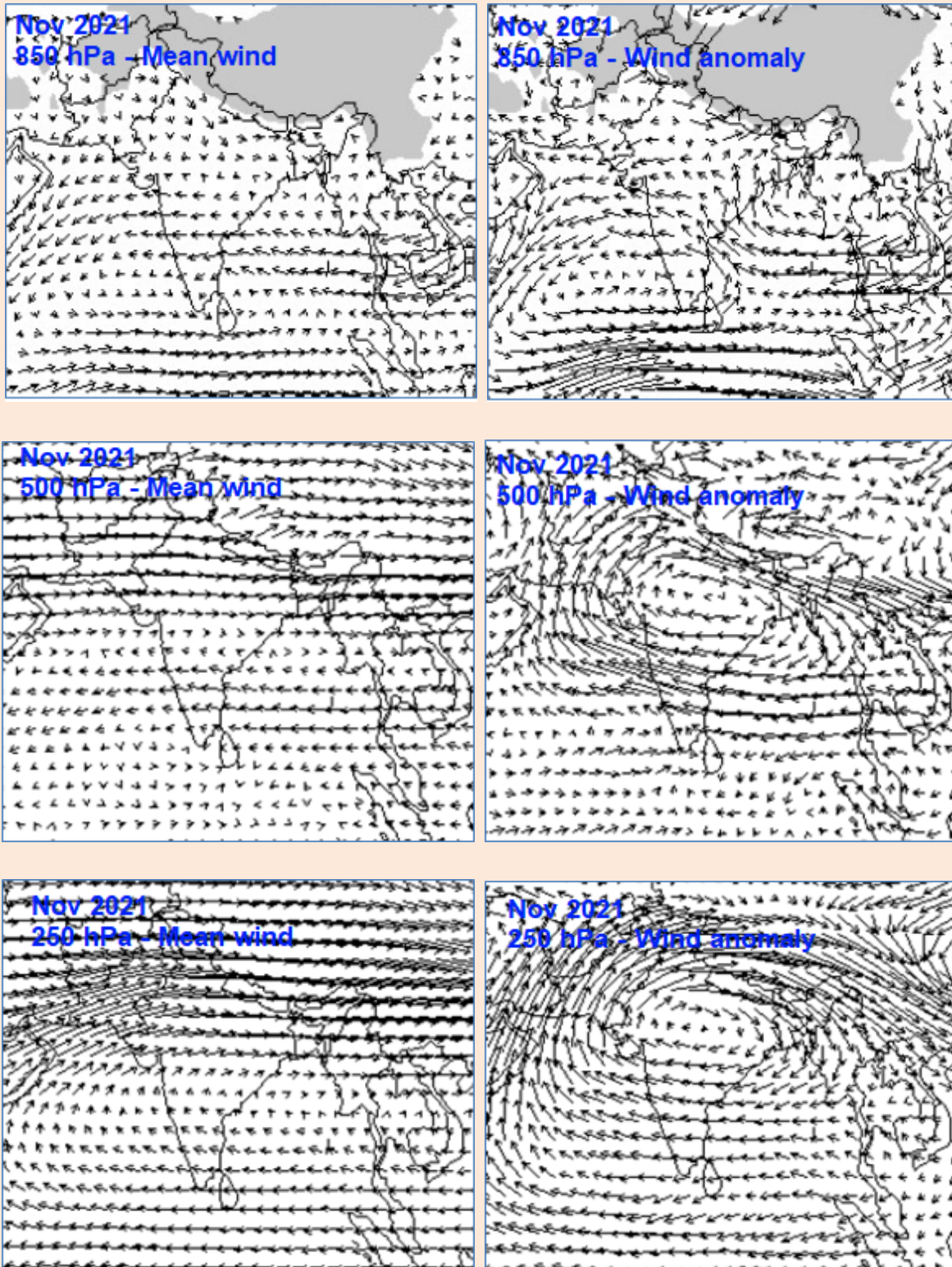
In November, anomalous easterlies were observed in the lower tropospheric levels (850 hPa) over the central parts of Bay of Bengal and Andhra Pradesh coast and anomalous cyclonic circulations were observed in the mid and upper tropospheric levels (500 hPa & 250 hPa) over the central India region.

In December, anomalous northerlies were observed in the southern parts of Bay of Bengal and adjoining equatorial Indian ocean in the lower tropospheric levels (850 hPa).



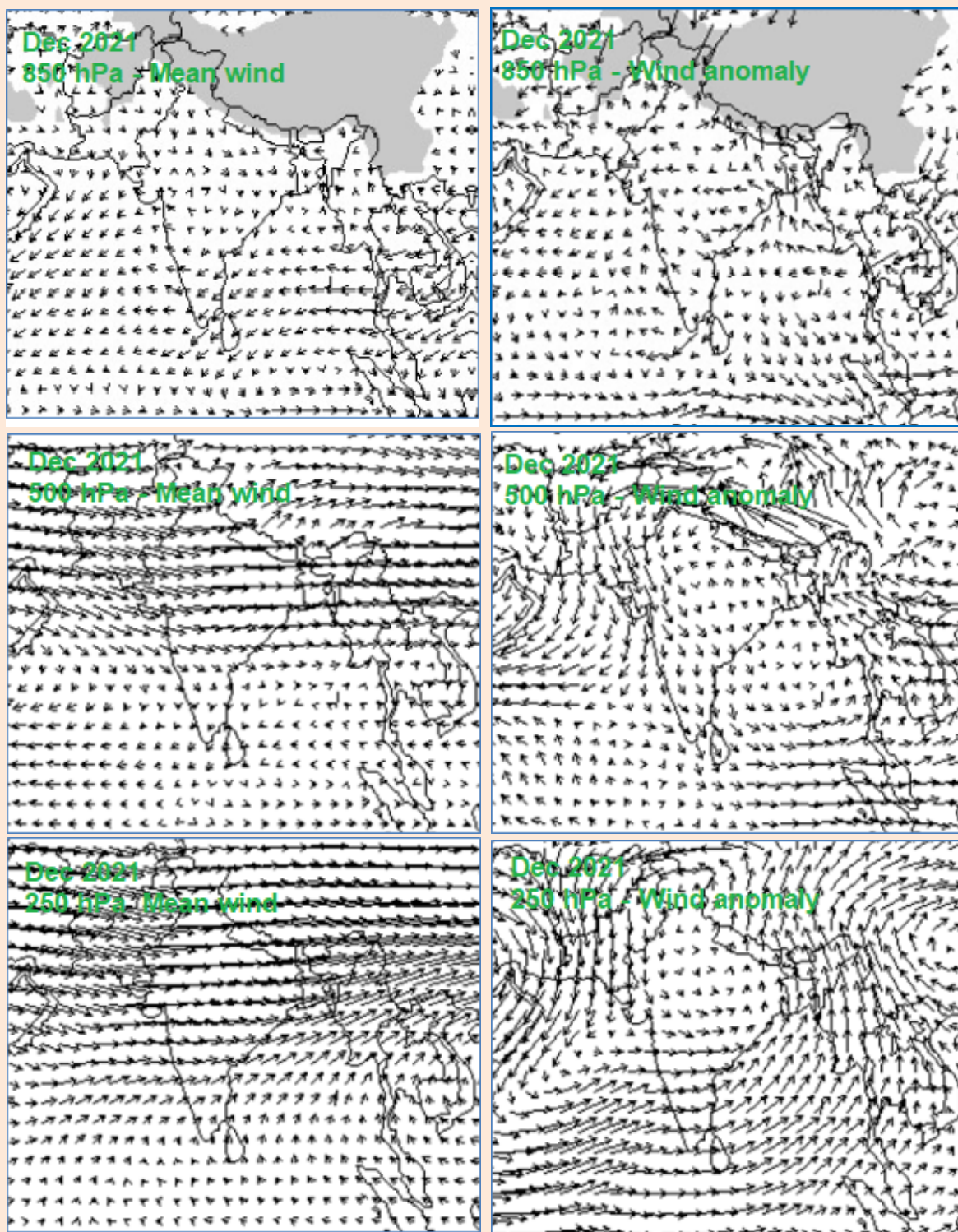


**Fig.15a: Mean and anomalous wind pattern over the Indian region at 850 hPa, 500 hPa and 250 hPa levels during October 2021** (Source: Climate Diagnostic Bulletin of India, IMD Pune)



**Fig.15b: Mean and anomalous wind pattern over the Indian region at 850 hPa, 500 hPa and 250 hPa levels during Nov 2021**(Source: Climate Diagnostic Bulletin of India, IMD Pune)

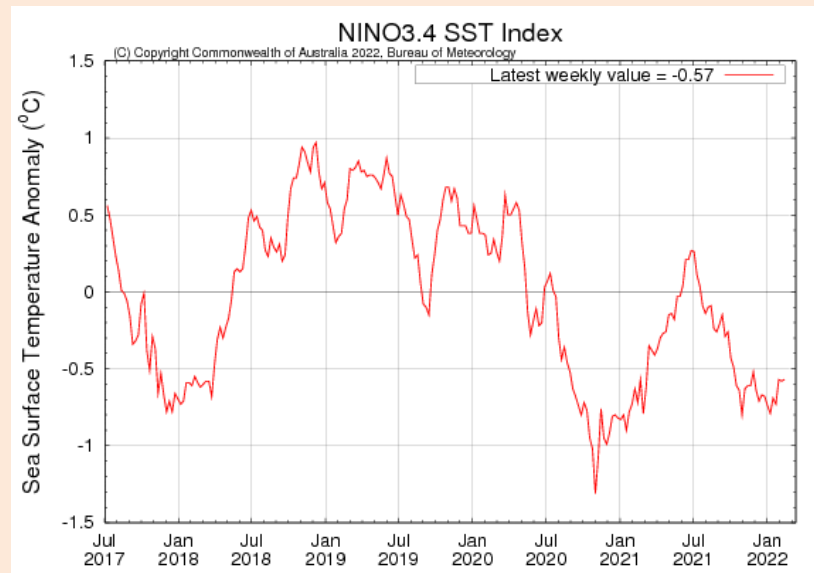




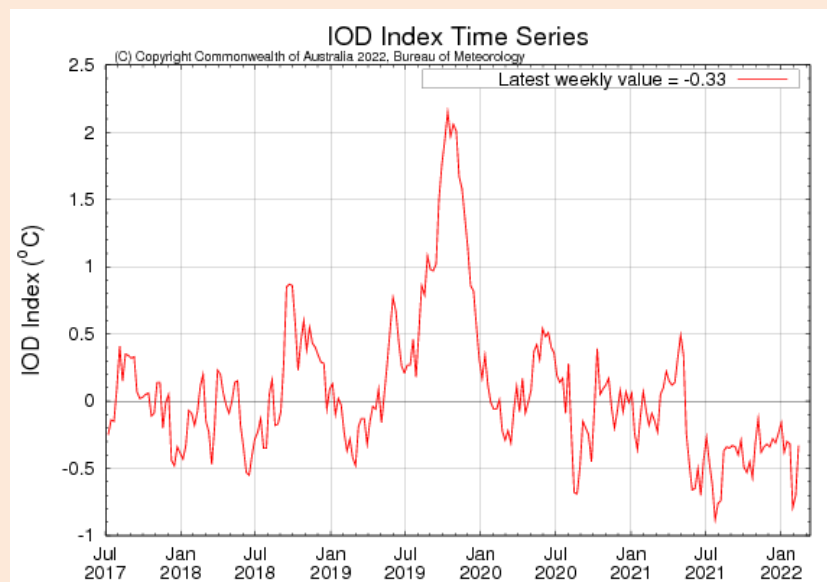
**Fig.15c: Mean and anomalous wind pattern over the Indian region at 850 hPa, 500 hPa and 250 hPa levels during December 2021** (Source: Climate Diagnostic Bulletin of India, IMD Pune)



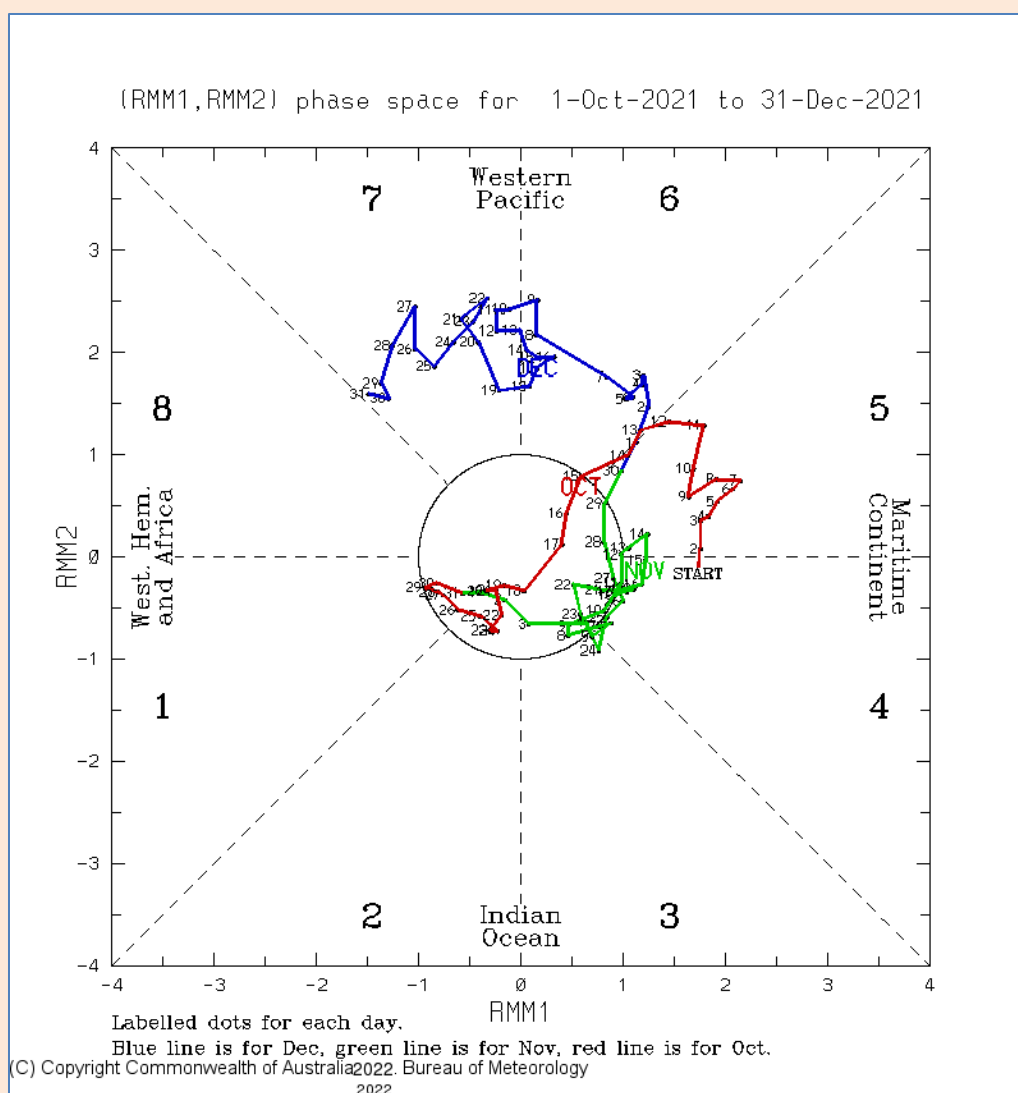
(b) **Large scale features:**Based on the reports of various global climate monitoring centres, it was noted that during October-December 2021, La Nina conditions (negative sea surface temperature anomalies) prevailed over the equatorial Pacific region. Indian Ocean Dipole was negative. Both these major climate indices were not favourable for NEM 2021. MJO was favourable for NEM activity during month of November 2021 (Fig.16a-c).



**Fig.16a: Sea surface temperature over the equatorial Pacific Ocean**(Source: Bureau of Meteorology, Australia)



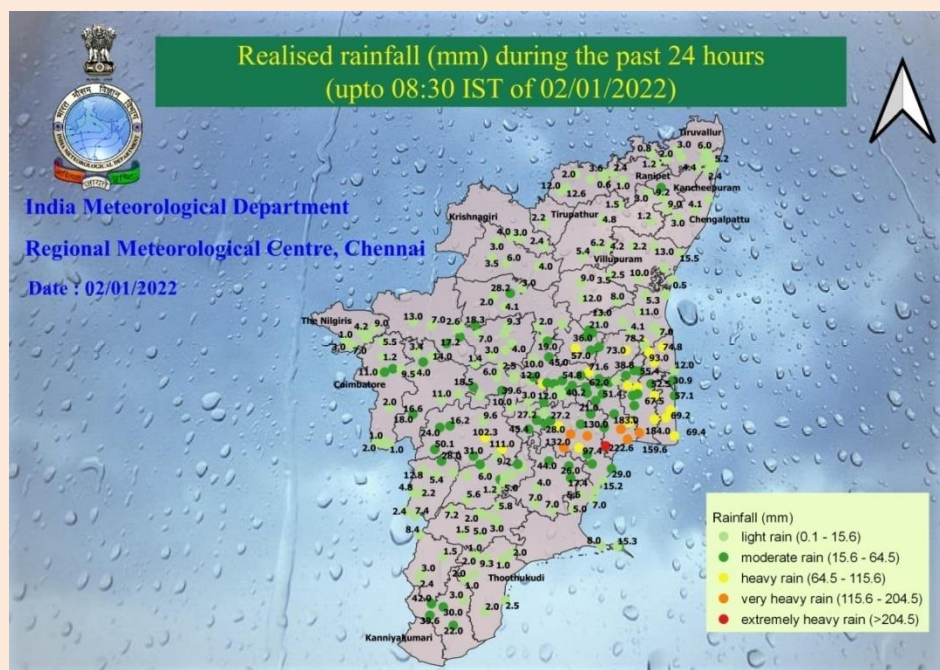
**Fig.16b: Indian Ocean Dipole mode index**(Source: Bureau of Meteorology, Australia)



**Fig.16c: MJO during Oct-Dec 2021**(Source: Bureau of Meteorology, Australia)

## 8. Cessation of NEM rains over peninsular India

The NEM monsoon extended into January 2021 with *FWS* rainfall over TN on 01<sup>st</sup> and 02<sup>nd</sup> January 2022 and three days of heavy rainfall activity during 01<sup>st</sup>-03<sup>rd</sup> January 2022. On 02<sup>nd</sup> January, *heavy to very heavy* rain with *isolated extremely heavy* falls occurred over the Delta districts (Peravuruni, Thanjavur district – **22cm** & Echanviduthi, Thnajakavur district – **21 cm**) (Fig.17). Subsequently after a spell of light to moderate rainfall during 15<sup>th</sup>-17<sup>th</sup> January, cessation of NEM rains over southern peninsular India was declared on 22<sup>nd</sup> January 2022.



**Fig.17: Past 24-hr accumulated rainfall over the TN subdivision as on 0830 IST of 02.01.2022**

## 9. Summary

During the year 2021, the southwest monsoon withdrew from the Indian region on 25<sup>th</sup> October and simultaneously, the Northeast monsoon of 2021 commenced over the southeastern parts of peninsular India on 25<sup>th</sup> October against the normal date of 20<sup>th</sup> October. Excepting Coastal Andhra Pradesh (CAP) that received *normal* rainfall during the season, the other four sub divisions benefitted by the NEM [Tamil Nadu (TN (including Puducherry & Karaikal), Kerala (KER), Rayalaseema (RYS) and South Interior Karnataka (SIK)] received *excess* to *large excess* rainfall during the NEM season (October-December) with KER, SIK, RYS recording more than 100% excess (*large excess*) rainfall. There were 30 days of *active* to *vigorous* monsoon conditions over TN & KER during the season. There were 65 days of *isolated heavy* rainfall activity with 33 days of *isolated very heavy* rain including 09 days of *isolated extremely heavy rainfall* activity over TN. Two **Depressions** that formed over the North Indian Ocean during November contributed significantly to NEM rainfall over the peninsular India. Cyclonic Storm **Jawad** over Bay of Bengal during 02<sup>nd</sup> - 06<sup>th</sup> December tracked northwards towards West Bengal-Bangladesh coasts and did not contribute towards NEM rainfall. There were two days of *extremely heavy rainfall* activity over Chennai (i) 06<sup>th</sup> November night & (ii) 30<sup>th</sup> December 2021. Recurrent heavy rainfall over the coastal and adjoining districts from last week of October to November, led to filling up of water bodies and inland and riverine flooding occurred over several areas of TN and RYS. NEM 2021 extended into January 2022 and cessation of NEM 2021 rainfall over peninsular India was declared on 22.01.2022.



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#### APPENDIX-(i): Terminologies for Spatial rainfall distribution

**WS - Widespread (Most places):** 75 % or more number of stations of a region (sub-division) reporting at least 2.5 mm rainfall.

**FWS- Fairly widespread (Many places):** 51% to 74 % number of stations of a region (sub-division) reporting at least 2.5 mm rainfall.

**SCT- Scattered (at a few places):** 26 % to 50% number of stations of a region (sub-division) reporting at least 2.5 mm rainfall.

**ISOL- Isolated (At isolated places):** 25% or less number of stations of a region (sub-division) reporting at least 2.5 mm rainfall.

**DRY:** No station of a region reported rainfall

#### APPENDIX-(ii): Terminologies for description of intensity of rainfall

S No.	Terminology	Rainfall range In mm	Rainfall range In cm	Percentile
1	Very light rainfall	Trace -2.4		
2	Light rainfall	2.5-15.5	Upto 1	Upto 65
3	Moderate rainfall	15.6-64.4	02-06	65-95
4	Heavy Rainfall	64.5- 115.5	07-11	95-99
5	Very Heavy Rainfall	115.6-204.4	12-20	99.0-99.9
6	Extremely heavy rainfall	Greater or equal to 204.5 mm	21 cm or more	>99.9
7	Exceptionally Heavy Rainfall	When the amount is a value near about the highest recorded rainfall at or near the station for the month or season. However, this term will be used only when the actual rainfall amount exceeds 12 cm.		

#### APPENDIX-(iii): Description of NEM rainfall activity

**Active:** Fairly widespread to widespread sub-divisional rainfall with rainfall more than 1½ to 4 times the normal with at least two stations reporting more than or equal to 5 cm in coastal Tamil Nadu, south coastal Andhra Pradesh and 3 cm elsewhere in the NEM region.

**Vigorous:** Fairly widespread to widespread sub-divisional rainfall with rainfall more than 4 times the normal with at least two stations reporting more than or equal to 5 cm in coastal Tamil Nadu, south coastal Andhra Pradesh and 3 cm elsewhere in the NEM region.