



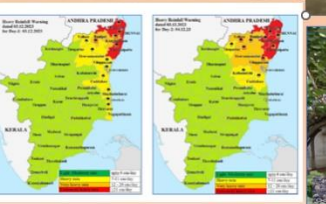
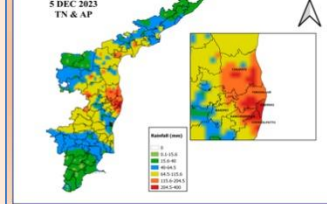
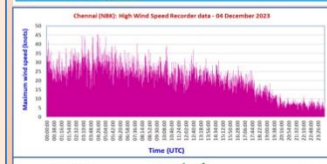
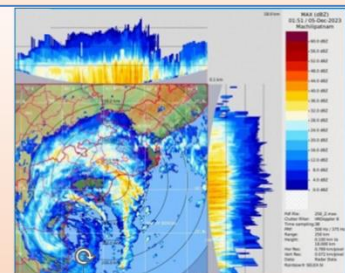
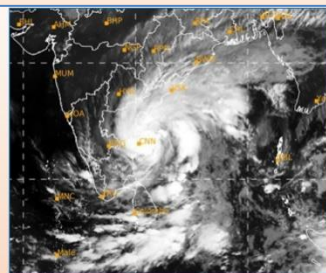
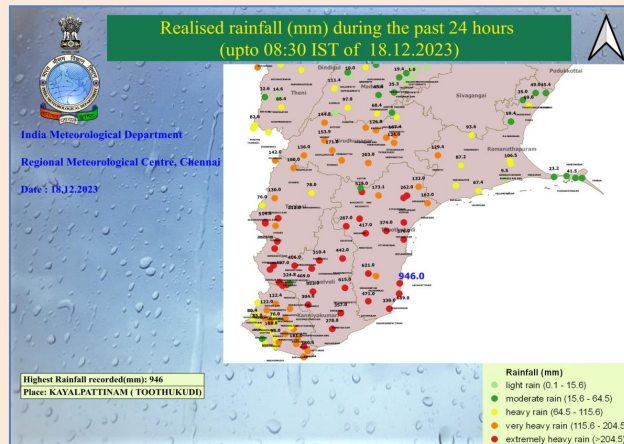
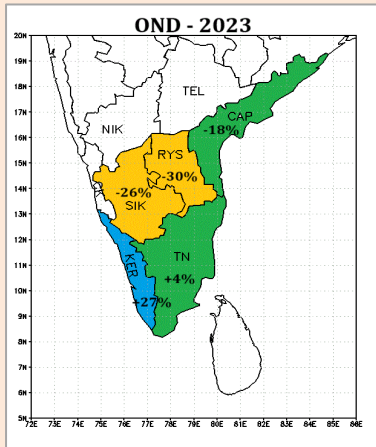
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IMD Chennai Scientific Report No. IMDC-SR/16

REPORT ON NORTHEAST MONSOON – 2023



Regional Meteorological Centre, Chennai
 March 2024

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Executive Summary

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Abstract

During the year 2023, the southwest monsoon withdrew from the Indian region on 16th October and the Northeast monsoon (NEM) of 2023 commenced simultaneously over the southeastern parts of peninsular India on **16th October 2023** against the normal date of 20th October. Of the five meteorological sub divisions benefitted by the NEM, three subdivisions - Tamil Nadu (including Puducherry & Karaikal) (TN), Coastal Andhra Pradesh (CAP) & Kerala (KER) received **normal to excess** rainfall and the other two subdivisions - Rayalaseema (RYS), and South Interior Karnataka (SIK)] received **deficient** rainfall during the NEM season (October-December) 2023. *Active to vigorous* monsoon conditions prevailed over TN on 20 days, over KER on 12 days and over RYS, CAP & SIK – 3-5 days during the season. There were **57** days of *isolated heavy* rainfall activity with 24 days of *isolated very heavy* rain including 07 days of *isolated extremely heavy* rainfall activity over TN. **Four cyclones** affected the Indian seas during the season – ***Extremely Severe Cyclonic Storm (ESCS) TEJ*** over the **Arabian Sea (AS)** and ***Very Severe Cyclonic Storm (VSCS) HAMOON, Cyclonic Storm (CS) MIDHILI and Severe Cyclonic Storm (SCS) MICHAUNG*** over the Bay of Bengal (BOB). The **SCS MICHAUNG** over the BOB during 01st-06th December **crossed south Andhra Pradesh coast**, south of **Bapatla** on 05th afternoon as SCS with maximum sustained surface wind speed of **90-100 kmph gusting to 110 kmph**. Associated with the passage of this system, ***very heavy to extremely heavy*** rainfall occurred over **Chennai** and neighbouring districts of extreme north Tamilnadu, Rayalaseema & Coastal Andhra Pradesh during 04th-06th December. The other three cyclones ESCS TEJ that affected AS during 20th-24th Oct 2023 moved westwards and crossed Yemen coast, VSCS HAMOON that affected BOB during 21st-25th Oct 2023 tracked northeastwards and crossed Bangladesh coast and CS MIDHILI that affected BOB during 15th-18th Nov 2023 also tracked northeastwards and crossed Bangladesh coast leading to weak NEM rainfall activity over the peninsular India during the respective periods. However, associated with an upper air cyclonic circulation over the Comorin area and neighbourhood, historical *extremely heavy* rainfall occurred over south Tamilnadu during 17th-19th December, with **Kayalpattinam** in Thoothukudi district recording **95 cm/day** and 30 other stations over Thoothukudi, Tirunelveli, Kanyakumari and Tenkasi districts recording over 30 cm/day on 18th December leading to devastating floods over extreme south Tamilnadu. Thereafter, with the gradual decrease in rainfall activity, the cessation of NEM 2023 rainfall over the southern peninsular India was declared on **14th January 2024**.

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% (328.5 mm) of its annual rainfall (921.4 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% (442.8 mm) of its annual rainfall realised during this season and hence its performance is a key factor for this regional agricultural activity.

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 14th October. The normal date of onset of NEM over Coastal TN (CTN) and south CAP is 20th October. The normal rainfall received over the five NEM sub-divisions during OND is TN-442.8 mm, KER-492.0 mm, CAP-322.9 mm, RYS-236.4 mm and SIK-199.0 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. Onset phase

During October 2023, El Nino conditions prevailed over the equatorial Pacific Ocean, IOD was positive which were favourable for good NEM activity. However, MJO was in the western hemisphere and Africa (phase 7,8 &1) throughout the month which was not favourable for good NEM rainfall activity.

Under favourable large scale climate settings (El Nino & positive IOD), atmospheric flow pattern over the Indian region gradually changed from the SWM to NEM conditions during the second week of October 2023 with the establishment of low level anticyclone over the central India and reversal of low level winds over the southern peninsular India from westerly to easterly flow pattern around 12th October and gradually, the **SWM withdrew from the entire country on 16th October**. Pentad mean wind flow pattern depicting the reversal of wind from westerlies to easterlies during the second week of October 2023 are presented in Fig.1a.

Simultaneously, under the influence of an upper air cyclonic circulation over TN and neighbourhood during 13th-16th October and another cyclonic circulation over LAK and neighbourhood during 15th & 16th October, generally *scattered to fairly widespread* rainfall occurred over TN during 13th-18th October and *fairly widespread to widespread* rainfall occurred on most days over KER during the same period. With *isolated* rainfall activity over CAP, RYS & SIK on 16th, **commencement of NEM rains over TN, KER, CAP, RYS & SIK occurred on 16th October 2023**. Upper air streamline analysis as on 0530 IST of 13th-16th October depicting the two cyclonic circulations in the lower levels, one over TN & neighbourhood during 13th-16th and another over LAK area during 15th & 16th October are presented in Fig.1b. INSAT-3D, infra-red imageries during 13th-16th October depicting the associated cloudiness are shown in Fig.1c.

Scattered to fairly widespread rainfall occurred over TN during 15th-18th with *isolated heavy to very heavy* rain as on 24-hr ending 0830 IST of 15th & 16th & *isolated heavy* rain on 17th & 18th October. Thereafter, with the formation of a low pressure system over the BOB, moisture incursion over TN decreased considerably and rainfall activity over TN became weak till the end of October 2023. However, significant rainfall activity continued over KER till 25th October. *Scattered to widespread* rainfall occurred over KER on all days during 13th-25th October with *isolated heavy to extremely heavy* rainfall reports on 15th; *isolated heavy to very heavy* rainfall on 24th; and *isolated heavy* rain on 13th,14th, 16th-18th, 21st, 23rd & 25th October 2023. Thiruvananthapuram airport (KER) recorded 21 cm and Chertala (Alapuzha district, KER) recorded 20 cm on 15th October. In TN, Mambazhathuraiyaru & Anaikedanku in Kanniyakumari district reported 17 cm on the same day.

Active NEM conditions prevailed over TN on 17th and over KER on 24th & 25th October 2023.

GPM satellite-gauge merged rainfall depicting the rainfall over the southern peninsula as on 24-hr ending 0830 IST of 15th & 17th October is presented in Fig.1d. Maps of spatial rainfall distribution and rainfall intensity over TN during the 24-hr ending 0830 IST of 14th-17th October 2023 are presented in Fig.1e.

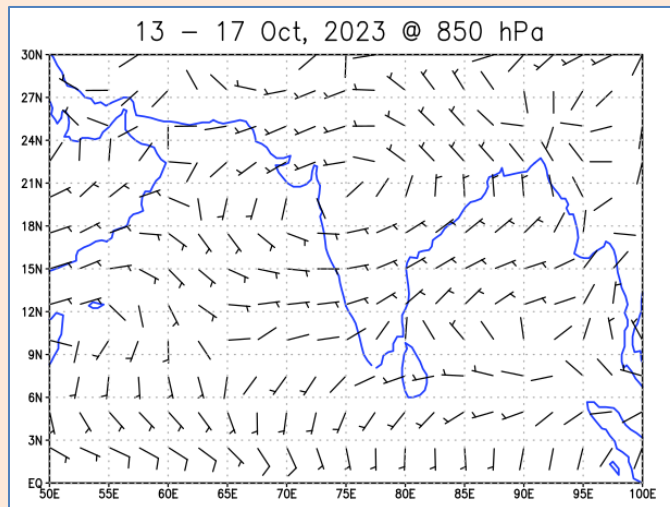
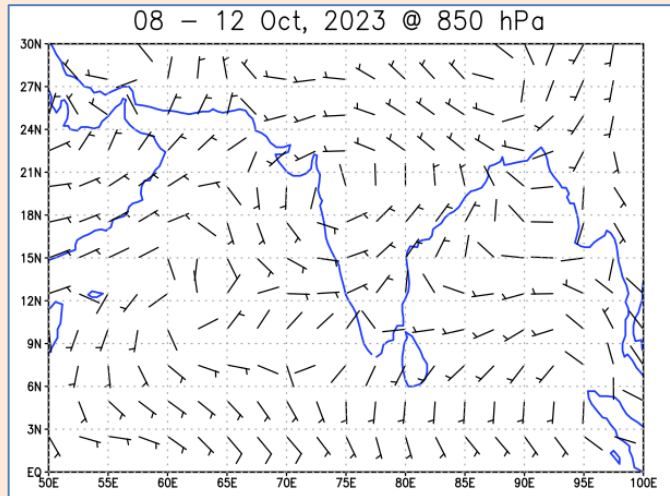
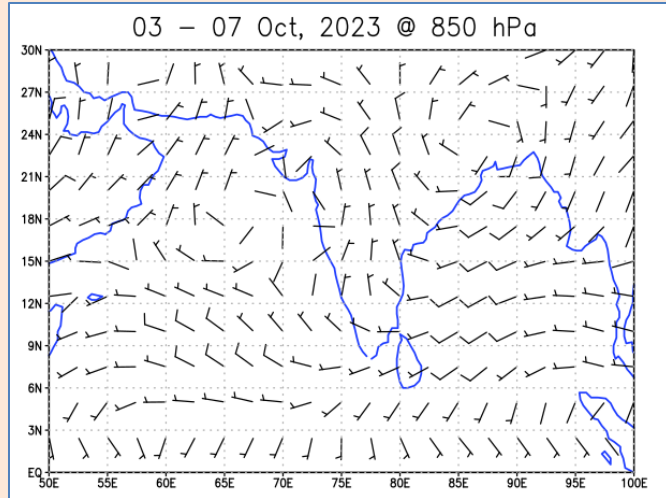


Fig.1a: NCEP reanalysis 850 hPa streamline pattern indicating reversal wind from westerly to easterly over peninsular India during the second week of October 2023.

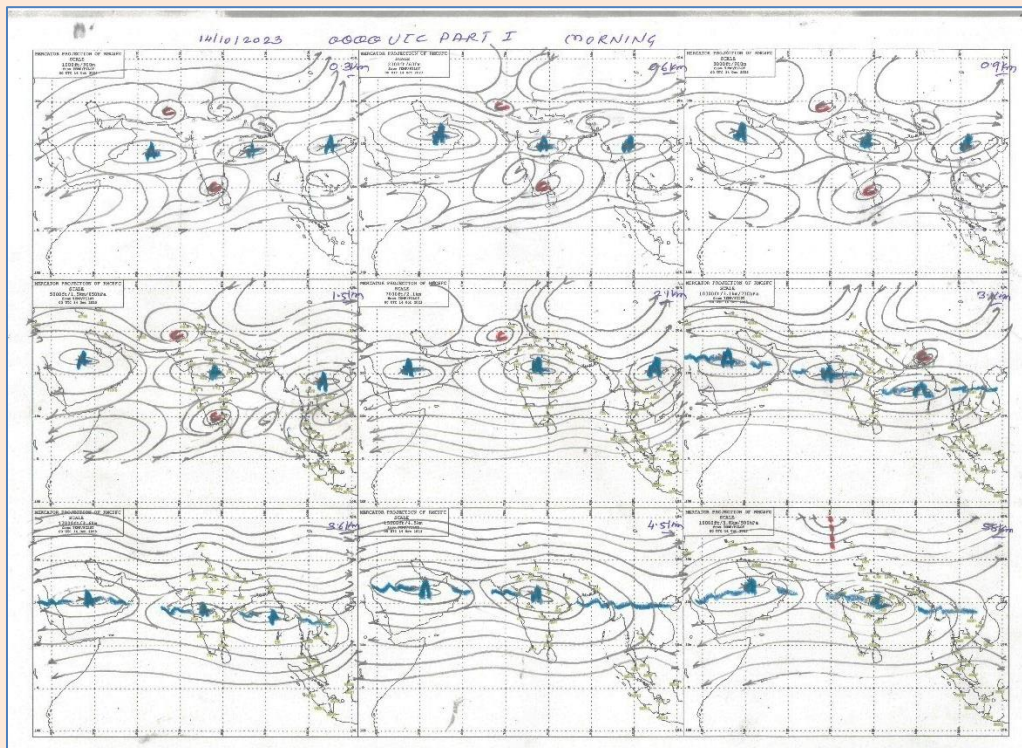
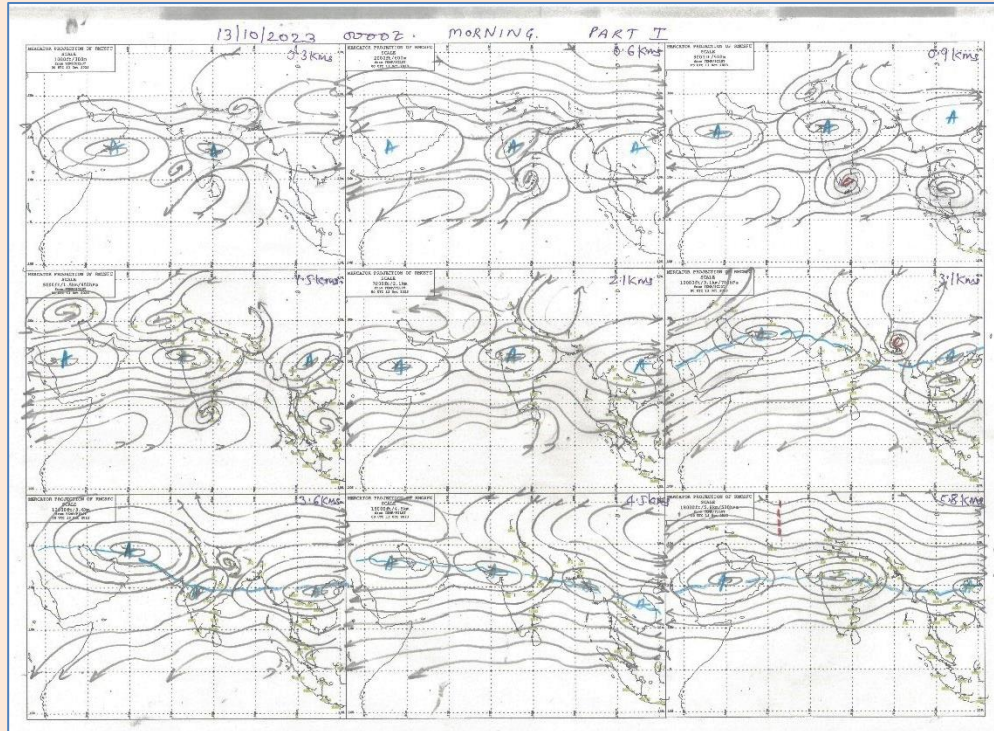


Fig.1b: Lower-mid level upper air streamline analysis as on 0530 IST of 13-16 Oct 2023

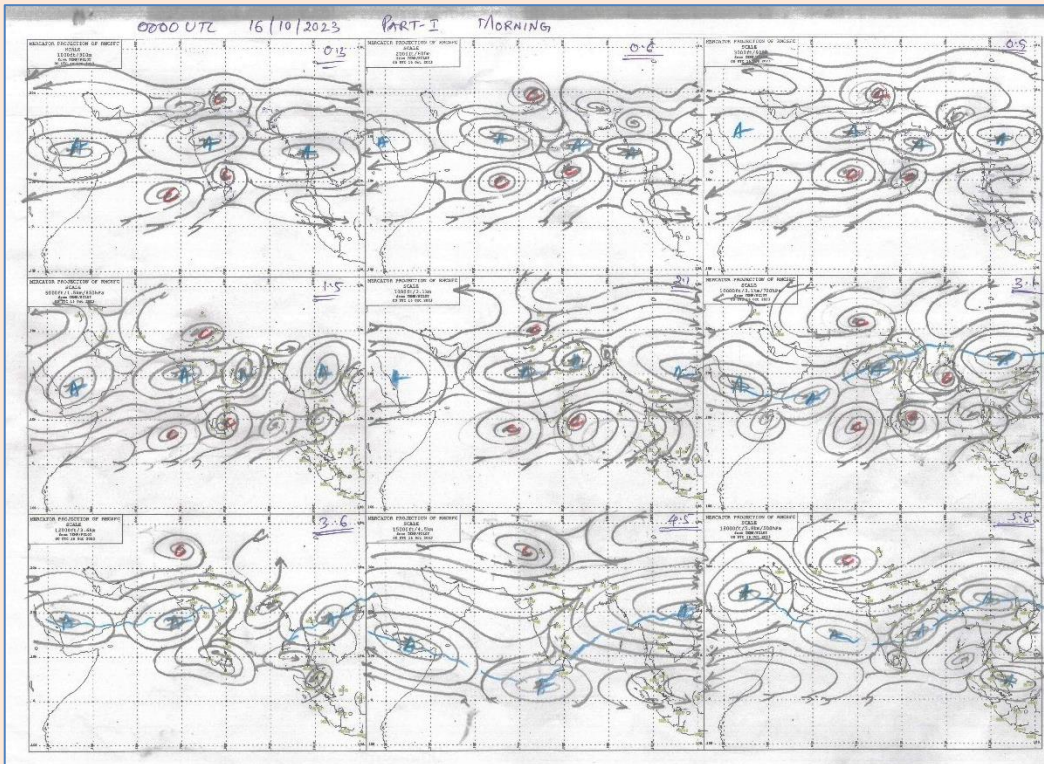
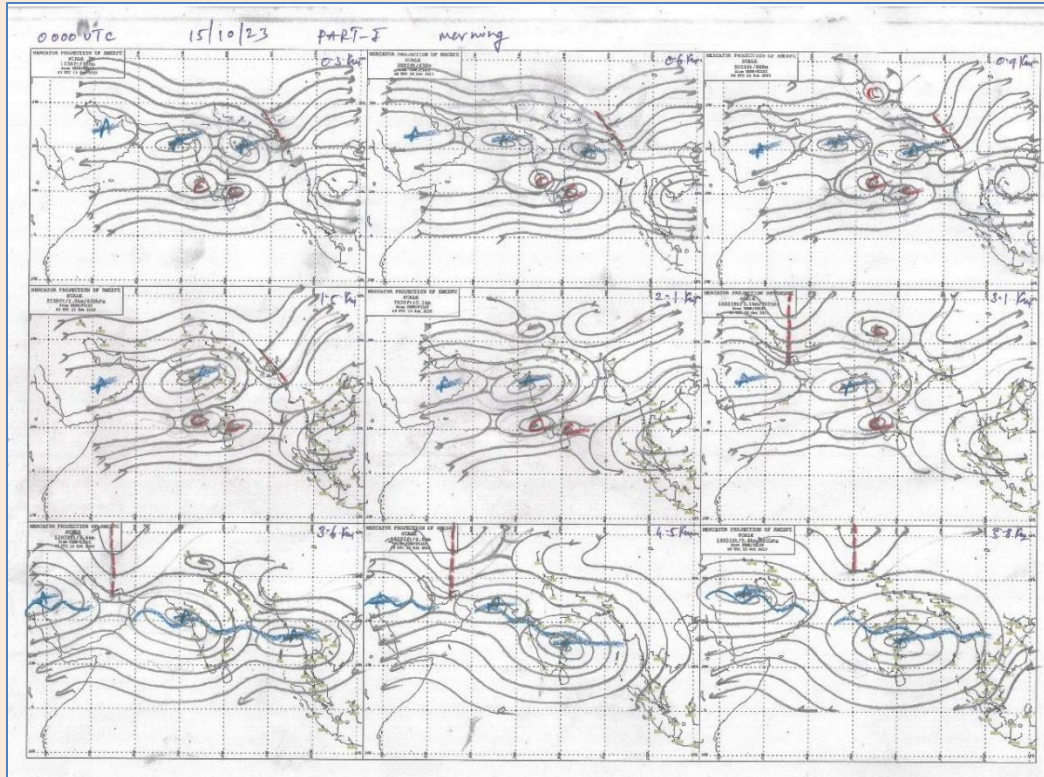


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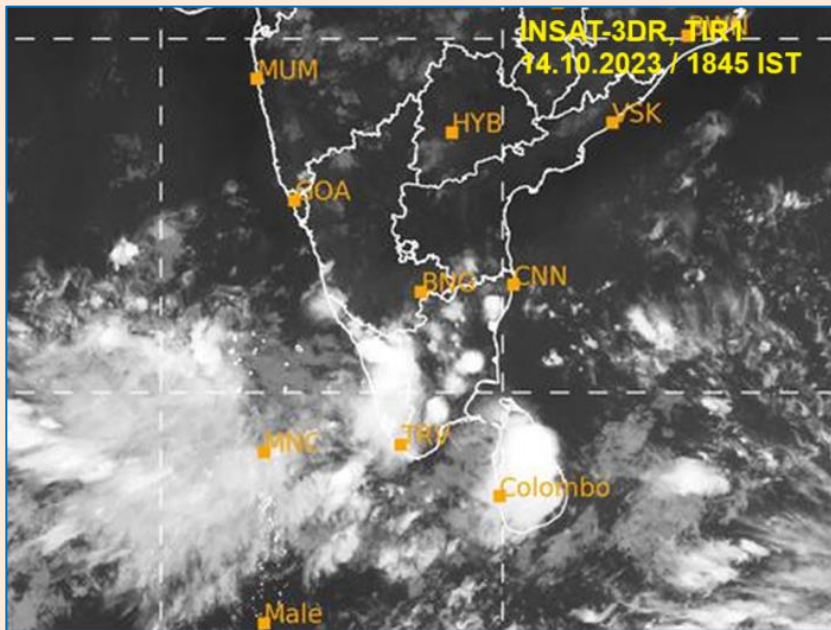
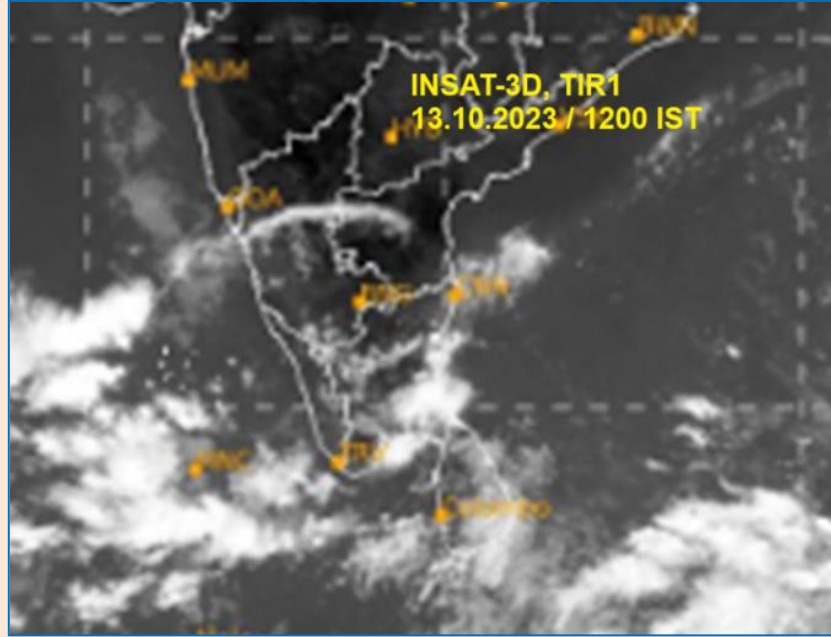


Fig.1c: INSAT-3D / 3DR infra-red imageries as on 13/1200 IST, 14/1845 IST & 16/0530 IST of Oct 2023

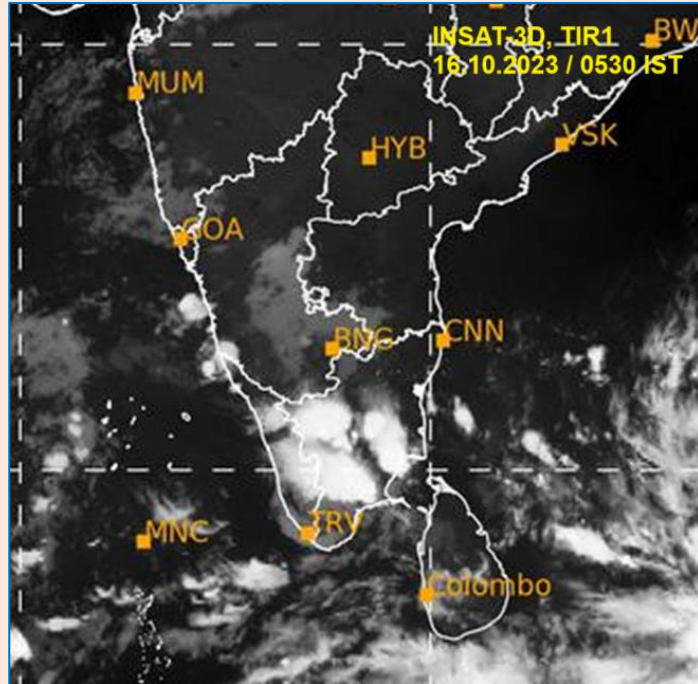


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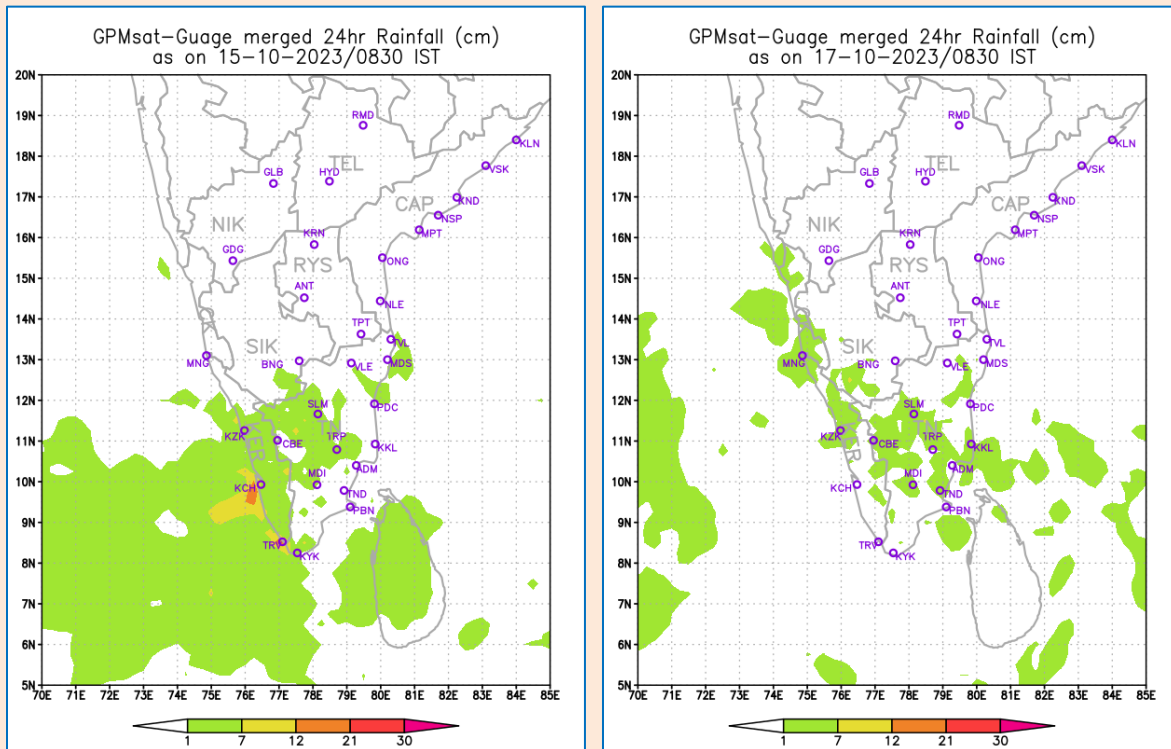


Fig.1d: GPM satellite -gauge merged rainfall as on 24 hr ending 0830 IST of 15 & 17 Oct 2023

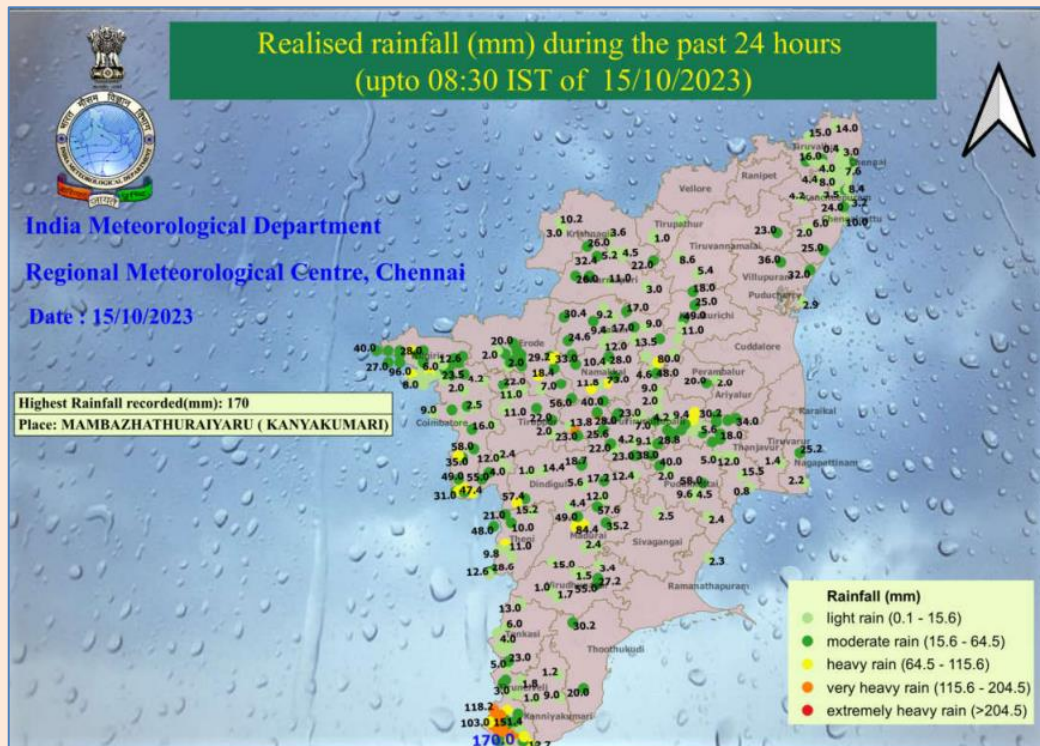
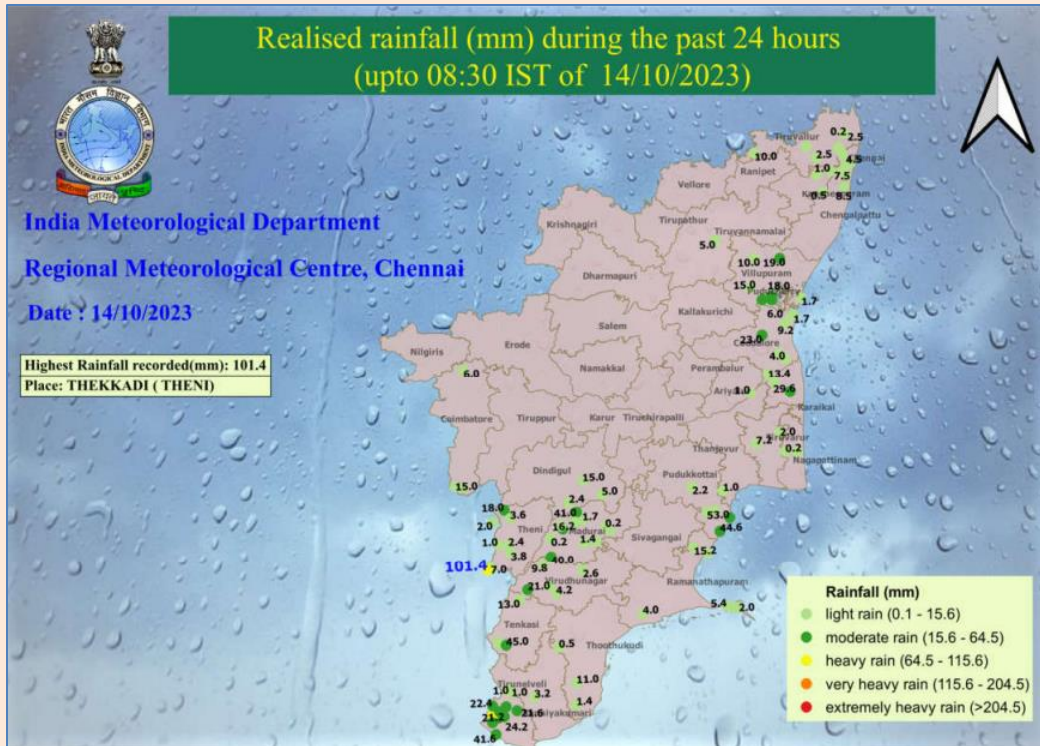


Fig.1e: Maps of spatial rainfall distribution and intensity over TN during 14-17 Oct 2023

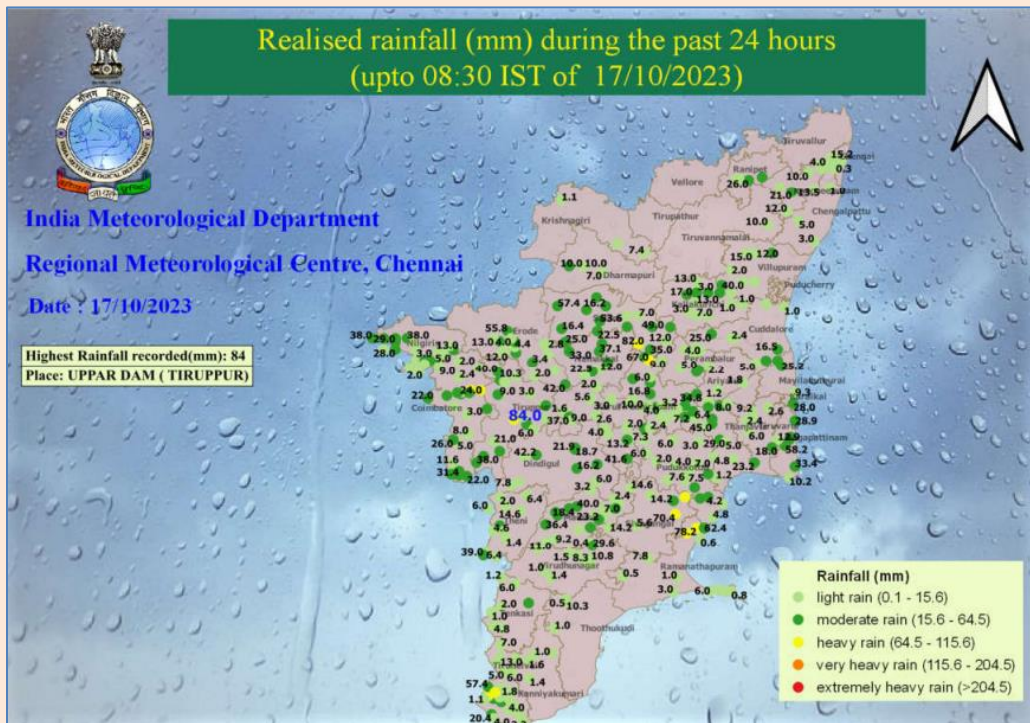
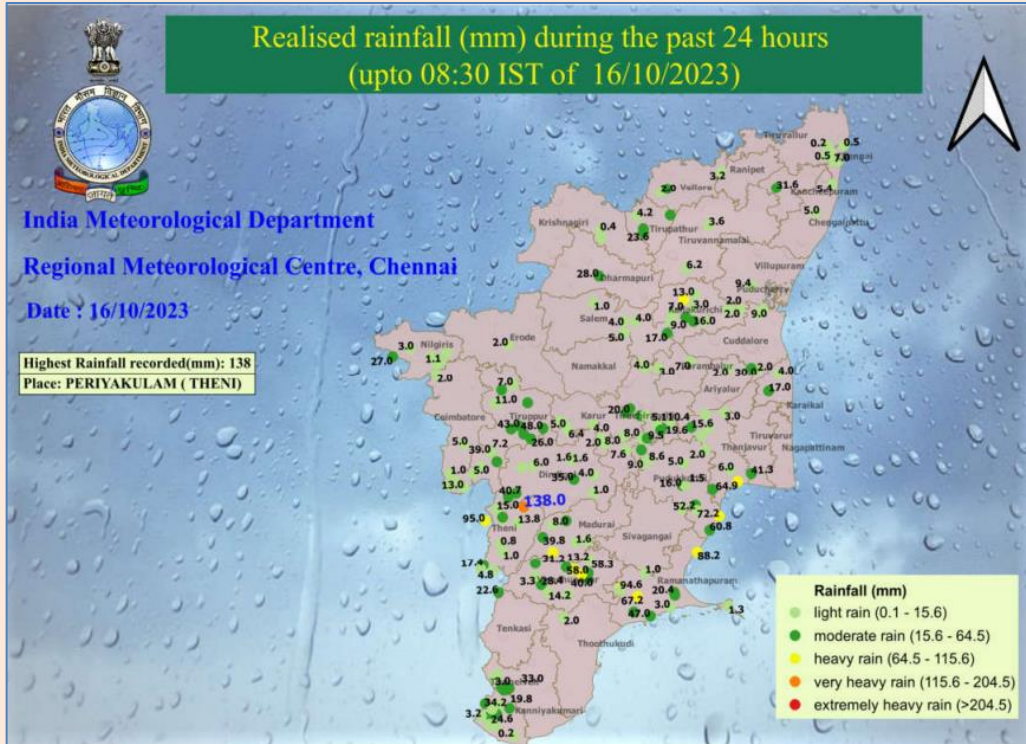


Fig.1e: contd.

3a. Major synoptic scale systems during the NEM 2023 season

During the period October-December 2023, four tropical cyclones formed over the Indian seas – (i) *Extremely Severely Cyclonic Storm (ESCS)* ‘TEJ’ over the Arabian sea during 20th-24th October, (ii) *Very Severe Cyclonic Storm (VSCS)* ‘HAMOON’ over the Bay of Bengal during 21st-25th October, (iii) *Severe Cyclonic Storm (SCS)* ‘MIDHILI’ over the Bay of Bengal during 15th-18th November and (iv) *Severe Cyclonic Storm* ‘MICHAUNG’ over the Bay of Bengal during 01st-06th December 2023.

(B) *Extremely Severely Cyclonic Storm* ‘TEJ’ over the Arabian sea during 20th-24th October & (ii) *Very Severe Cyclonic Storm (VSCS)* ‘HAMOON’ over the Bay of Bengal during 21st-25th October 2023

Under the influence of an upper air cyclonic circulation that formed over the Lakshadweep and adjoining southeast AS on 15th October 2023 which gradually moved west-northwestwards and lay over southeast AS and adjoining Lakshadweep on 17th, a *Low Pressure Area (LOPAR)* formed over southeast and adjoining eastcentral AS in the early morning (0530 IST) of 18th. It lay as a *Well Marked Low pressure Area (WML)* over southwest AS in the midnight (2330 IST) of 19th over the same region and concentrated into a *Depression (D)* over southwest AS in the early morning (0530 IST) of 20th and lay centered about 1280 km east-southeast of Al Ghaidah. It moved west-northwestwards and intensified into a *Deep Depression (DD)* in the evening 1730 IST of 20th over southwest AS and lay centered about 1240 km east-southeast of Al Ghaidah. Continuing to move further west-northwestwards, it intensified into the *Cyclonic Storm (CS)* “TEJ” pronounced as “TEJ” in the early morning (0530 IST) of 21st over southwest AS and further into a *Severe Cyclonic Storm (SCS)* around mid-day (1130 IST) over the same region. From 21st afternoon (1430 IST), it started moving northwestwards and intensified into a *Very Severe Cyclonic Storm (VSCS)* in the night (2030 IST) of 21st over the same region. Moving further northwestwards, it intensified rapidly into an *Extremely Severe Cyclonic Storm (ESCS)* in the morning (0830 IST) of 22nd over westcentral and adjoining southwest AS. “TEJ” exhibited rapid intensification during midnight (2330 IST) of 21st to noon (1130 IST) of 22nd reaching its peak intensity of 95 knots in the morning (0830 IST) of 22nd. It then maintained its intensity till early hours (0230 IST) of 23rd. Thereafter, it entered into an area with less ocean thermal energy and high vertical wind shear. It also experienced cold/dry air incursion from Arabian Peninsula. Under these unfavourable conditions, it gradually started weakening. Continuing to move northwestwards, it weakened into a *VSCS* in the morning (0830 IST) of 23rd over westcentral AS. Weakening trend further continued with land interactions and “TEJ” crossed Yemen coast close to South of Al Ghaidah in the early hours (between 0230 and 0330 IST) of 24th October as a *VSCS* with intensity of 65 knots gusting to 75 knots (120-130 kmph gusting to 140 kmph). Thereafter, it moved nearly westwards and weakened rapidly and lay as a *WML* over Yemen in the night (2030 IST) of 24th October 2023. The observed track of the system is presented in Fig. 2a(i).

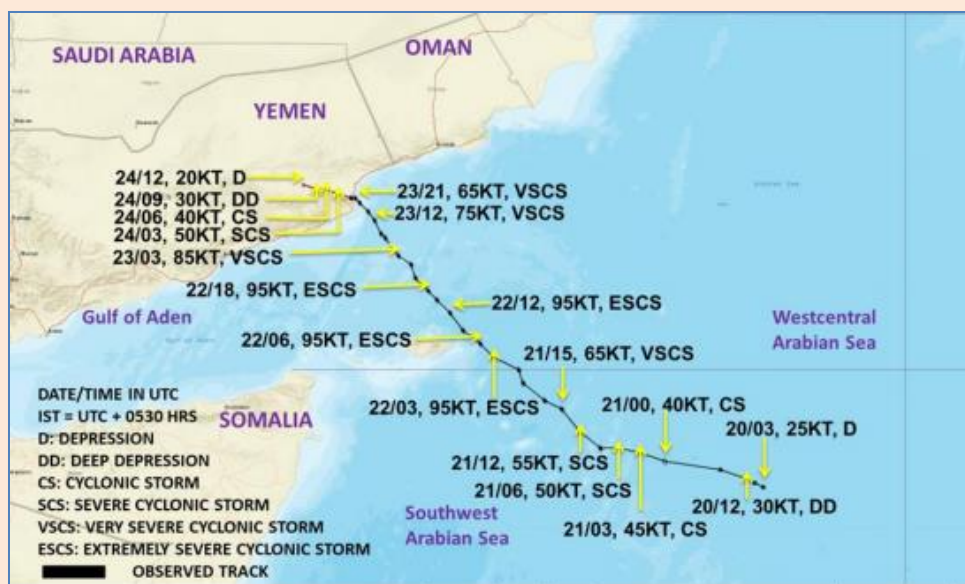


Fig.2a(i): Observed track of ESCS TEJ over the Arabian Sea during 20-24 Oct 2023

Under the influence of an upper air cyclonic circulation over southeast BOB during 17th-19th October 2023, a **Low Pressure Area** formed over southwest and adjoining southeast BOB in the early morning (0530 IST) of 20th. It lay as a **Well Marked Low pressure Area** over southwest and adjoining central BOB in the morning (0830 IST) of 21st and concentrated into a **Depression** over westcentral BOB in the midnight (2330 IST) of 21st. It moved initially northwestwards for some time, then recurved gradually north-northeastwards and intensified into a **Deep Depression** in the evening (1730 IST) of 22nd over westcentral BOB. Continuing to move further north-northeastwards, it intensified into a **Cyclonic Storm “HAMOON”** pronounced as “HAMOON” in the evening (1730 IST) of 23rd over westcentral & adjoining southwest BOB. Thereafter, it moved northeastwards and intensified into a **Severe Cyclonic Storm** in the early morning (0530 IST) of 24th October over westcentral BOB. Continuing to move further northeastwards, it rapidly intensified into a **Very Severe Cyclonic Storm** over the same region in the same morning (0830 IST) of 24th. Thereafter, it entered into an area with high vertical wind shear and weakened into an SCS in the evening (1730 IST) of 24th. Continuing with the weakening trend “HAMOON” crossed Bangladesh Coast to the south of Chittagong near (21.90 N/91.90 E) between 2330 IST of 24th – 0030 hours IST of 25th October as a Severe Cyclonic Storm with maximum sustained wind speed of 90-100 kmph gusting to 110 kmph. Thereafter, continuing to move north-eastwards, it weakened rapidly into a DD over coastal Bangladesh in the morning (0830 IST) of 25th, into a D over southwest Mizoram & adjoining Bangladesh & Myanmar in the noon (1130 IST) and into a WML over Mizoram and adjoining areas of Manipur and Myanmar the evening (1730 IST) of 25th October 2023. The observed track of the system is presented in Fig.2a(ii).

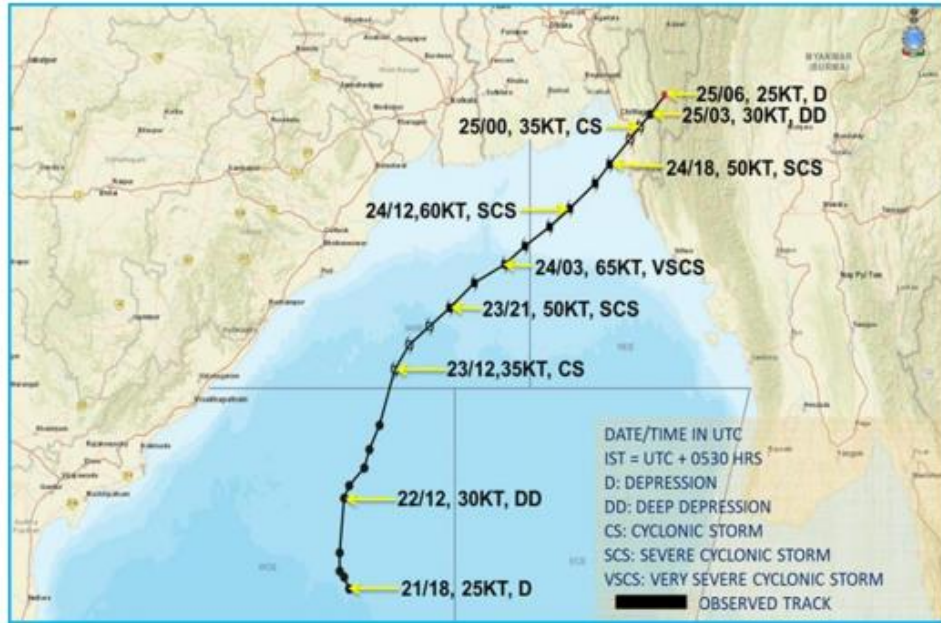


Fig.2a(ii): Observed track of VSCS HAMOON over the Bay of Bengal during 21-25 Oct 2023

As such, there was simultaneous occurrence of two cyclones – TEJ over AS & HAMOON over BOB during 21st to 24th October 2023. INSAT-3D infra-red imagery depicting the cloudiness associated with TEJ & HAMOON as on 21st / 1300 IST & 23rd / 1000 IST is shown in Fig.2b (i&ii).

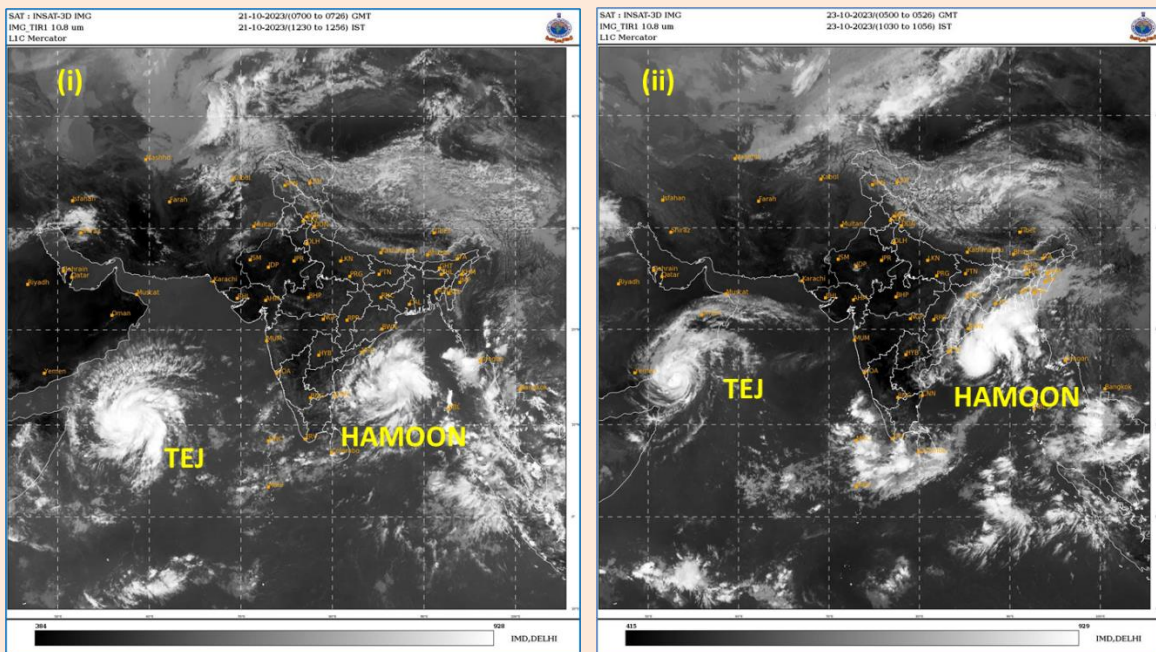


Fig.2b (i&ii): INSAT-3D, infra-red imagery as on (i) 21/1300 IST & (ii) 23/1000 IST of October 2023

IMD-GFS 850 hPa wind analysis as on 17th/0530 IST & 22nd/0530 IST of Oct 2023 depicting the low level circulation associated with cyclones **TEJ & HAMOON** is presented in Fig.2c.

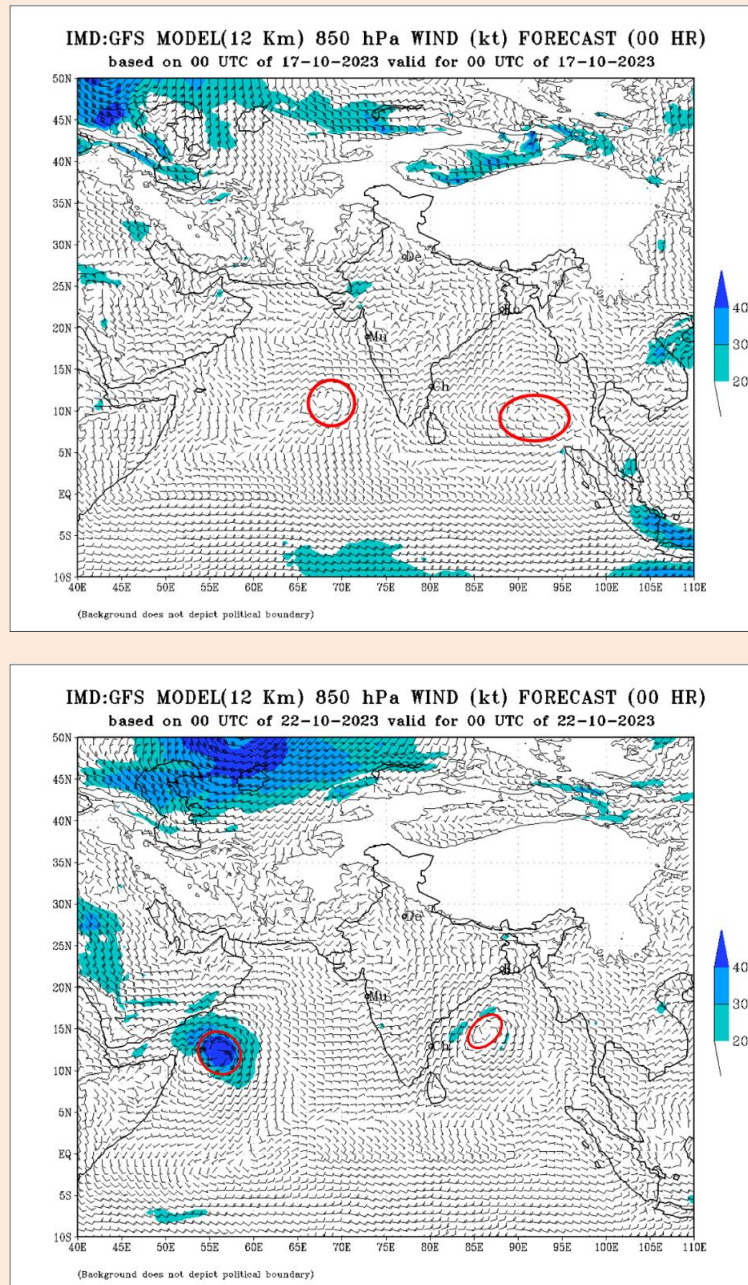


Fig.2c: IMD-GFS, 850 hPa wind analysis as on 17/0530 IST & 22/0530 IST of Oct 2023

Due to sweeping away of moisture by cyclone HAMOON over BOB, NEM rainfall activity decreased drastically over TN. Generally, isolated light to moderate rainfall activity prevailed over TN during 19th-26th with sporadic heavy rainfall reports at one or two places on 21st & 24th October 2023. Subsequently, with the flow pattern gradually returning to the normal seasonal pattern and gradual building up of moisture over the southeastern peninsula, rainfall

activity over TN picked up gradually. *Fairly widespread to widespread* rainfall occurred at *many* places over TN and at most places over KER during 30th October – 11th November 2023.

(iii) Severe Cyclonic Storm “MIDHILI” over Bay of Bengal during 15th-18th Nov 2023

Under the influence of an upper air Cyclonic Circulation lay over Gulf of Thailand on 12th November 2023 which emerged into South Andaman Sea on 13th, a **Low Pressure Area** formed over southeast BOB and adjoining Andaman & Nicobar Islands in the early morning (0530 IST) of 14th. It lay as a **Well Marked Low Pressure Area** over southeast & adjoining central BOB in the evening (1730 IST) of 14th and concentrated into a **Depression** over westcentral BOB in the morning (0830 IST) of 15th. It moved nearly northwards till the midnight (2330 IST) of 15th & thereafter gradually recurved north-northeastwards and intensified into a **Deep Depression** in the early morning (0530 IST) of 16th and further into **Cyclonic Storm “MIDHILI”** (pronounced as “MIDHILI”) over Northwest Bay of Bengal in the early morning (0530 IST) of 17th. It intensified further into **Severe Cyclonic Storm** over the same region off Bangladesh coast in the afternoon (1430 IST) of 17th and **crossed Bangladesh coast close to east of Patuakhali** near 22.3N/90.5E during 1430-1530 IST of 17th November as a Severe Cyclonic Storm with the maximum sustained wind speed of 85-95 kmph gusting to 105 kmph. Thereafter, it moved northeastwards and weakened gradually into a D over Tripura and adjoining Bangladesh & Mizoram in the early morning (0530 IST) of 18th and further into a low pressure area over North Tripura and neighbourhood in the forenoon (0830 IST) of 18th November 2023. The observed track of the system is presented in Fig. 2d.

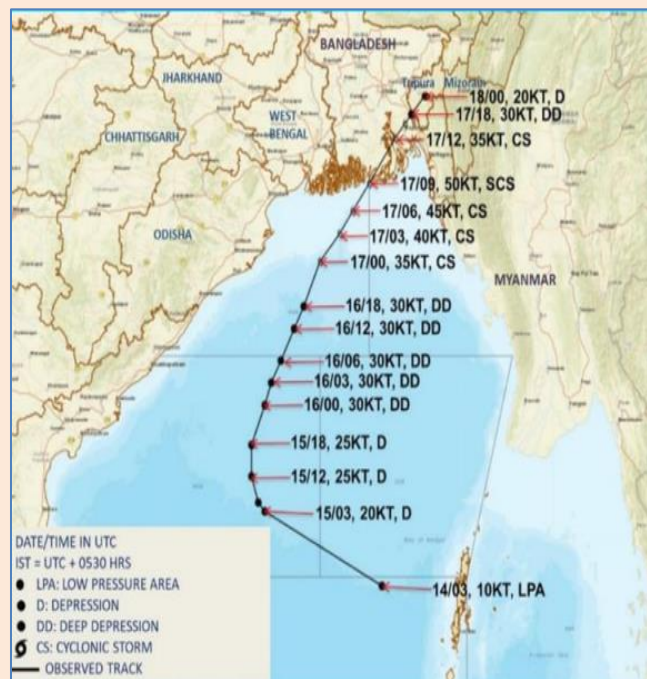


Fig.2d: Observed track of SCS MIDHILI over the Bay of Bengal during 15-18 Nov 2023

(iv) Severe Cyclonic storm “MICHAUNG” over Bay of Bengal during 01st-06th Dec 2023

Under the influence of a cyclonic circulation that entered Andaman sea and neighbourhood from the east a **Low Pressure Area** formed over south Andaman sea and neighbourhood on 27th November 2023. It became **Well Marked Low Pressure Area** over Southeast Bay of Bengal & adjoining South Andaman Sea on 29th. Moving west-northwestwards it concentrated into a **Depression** over Southeast and adjoining Southwest Bay of Bengal on 01st December / 0530 IST and lay centered at 0830 IST over the same region near Latitude 9.3°N and Longitude 86.2°E, about 760km east-southeast of Puducherry & 780 km east-southeast of Chennai. Moving further west-northwestwards it intensified into a **Deep Depression** on 02nd /0530 IST and lay centered at 0830 IST over the same region near Latitude 10.6°N and Longitude 83.6°E, about 440 km east-southeast of Puducherry & 450 km east-southeast of Chennai.

It intensified in to **Cyclonic Storm “MICHAUNG” (pronounced as MIGJAUM)** over Southwest Bay of Bengal on 03rd /0530 IST, moved northwestwards and lay centered on 03rd/0830 IST over the same region near Latitude 11.5°N and Longitude 82.4°E, about 290 km east-southeast of Puducherry, 290 km southeast of Chennai. Moving northwestwards, it was centered at about 145 km ESE of Chennai on 03rd midnight (2330 IST); at **about 97 km ENE of Chennai on 04th early morning (0530 IST)**.

Moving further northwestwards, it intensified into **Severe Cyclonic Storm** over the Westcentral & adjoining Southwest Bay of Bengal off south Andhra Pradesh and adjoining north Tamilnadu coasts in the forenoon (0830 IST) of 4th. Thereafter, it moved nearly northwards and **crossed south Andhra Pradesh coast between Nellore and Machilipatnam, close to south of Bapatla during 1230 to 1430 hours IST of 5th December 2023 as a Severe Cyclonic Storm with maximum sustained wind speed of 90-100 kmph gusting to 110 kmph.**

The system moved almost parallel to the south Andhra Pradesh coast and was centered within 150 km from the coast from 03rd midnight (2330 IST) (off Chennai coast) till the time of crossing the coast at Bapatla on 05th /1430 IST.

After the landfall, it continued to moved nearly northward and weakened into a Cyclonic Storm and lay centered at 1530 IST of 5th over south coastal Andhra Pradesh. It then moved north-northeastwards and weakened into a **Deep Depression** around midnight (2330 IST) of 5th over coastal Andhra Pradesh and further into a **Depression** over northeast Telangana and adjoining areas of south Chhattisgarh, south Odisha and coastal Andhra Pradesh in the early morning (0530 IST) of 6th and weakened further gradually. The observed track of the system is presented in Fig. 2e(i). CAP, RYS, extreme northeastern districts of TN & southeastern districts of TEL experienced severe weather associated with the system.

Surface isobaric analysis and upper air streamline analysis as on 03rd/1730 IST & surface isobaric analysis as on 04th /0830 IST and upper air streamline analysis as on 04th/0530 IST are presented in Fig.2e(ii & iii). Plots of hourly special observations along the Andhra Pradesh coast from 04th/1830 IST to 05th/1630 IST are shown in Fig.2e(iv).

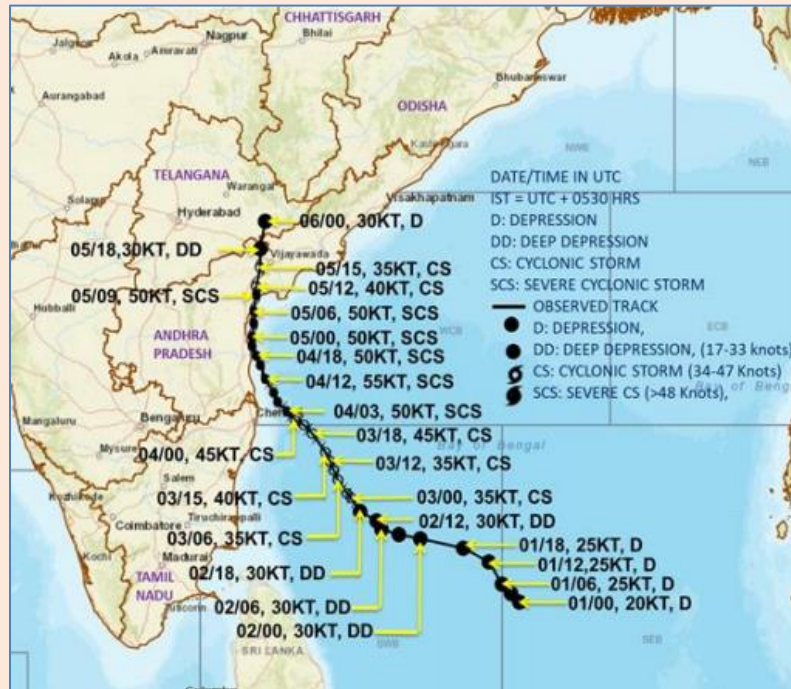


Fig.2e(i): Observed track of SCS MICHAUNG over the Bay of Bengal during 01-06 Dec 2023

As per the hourly coastal special observations, Nellore reported the lowest Mean Sea Level Pressure (MSLP) of 987.9 hPa with a 24-hr pressure change of -17.2 hPa on 05th/0230 IST; Kavali reported MSLP of 989.6 hPa with 24-hr pressure change of -16.6 hPa on 05th/0630 IST; and Ongole reported MSLP of 992.3 hPa with 24-hr pressure change of -14.7 hPa on 05th/1330 IST. Bapatla reported maximum sustained surface wind of 40 knots (74 kmph) on 05th/1430 IST and lowest MSLP of 997.4 hPa with 24-hr pressure change of -8.0 hPa on 05th/1630 IST. Chennai – Nungambakkam (NBK) & Meenambakkam (MBK) reported lowest MSLP of 997.0 hPa with 24-hr pressure change of -8.6 hPa & 998.3 hPa with 24-hr pressure change of -6.9 hPa respectively on 04th/1530 IST.

Plots of Mean Sea Level Pressure and Maximum wind speed in gusts recorded by AWS stations at Chennai (NBK), Ennore Port & VIT Chennai and High Wind Speed Recorder data of Chennai (NBK) as on 03rd & 04th December 2023 are shown in Fig.2e(v). It may be noted that maximum wind speed in gust reaching 55 kmph (30 kt), 80 kmph (44 kt) & 65 kmph (35 kt) and lowest MSLP of 996.7 hPa at 14:00 IST, 995.2 hPa at 14:30 IST and 997.4 hPa at 14:15 IST were recorded at Chennai (NBK), Ennore port & VIT Chennai respectively on 04th December 2023.

High Wind Speed Recorder at Chennai (NBK) recorded wind speed of about 75-80 kmph (40-45 knots) in gusts during early hours to noon of 04th December 2023.

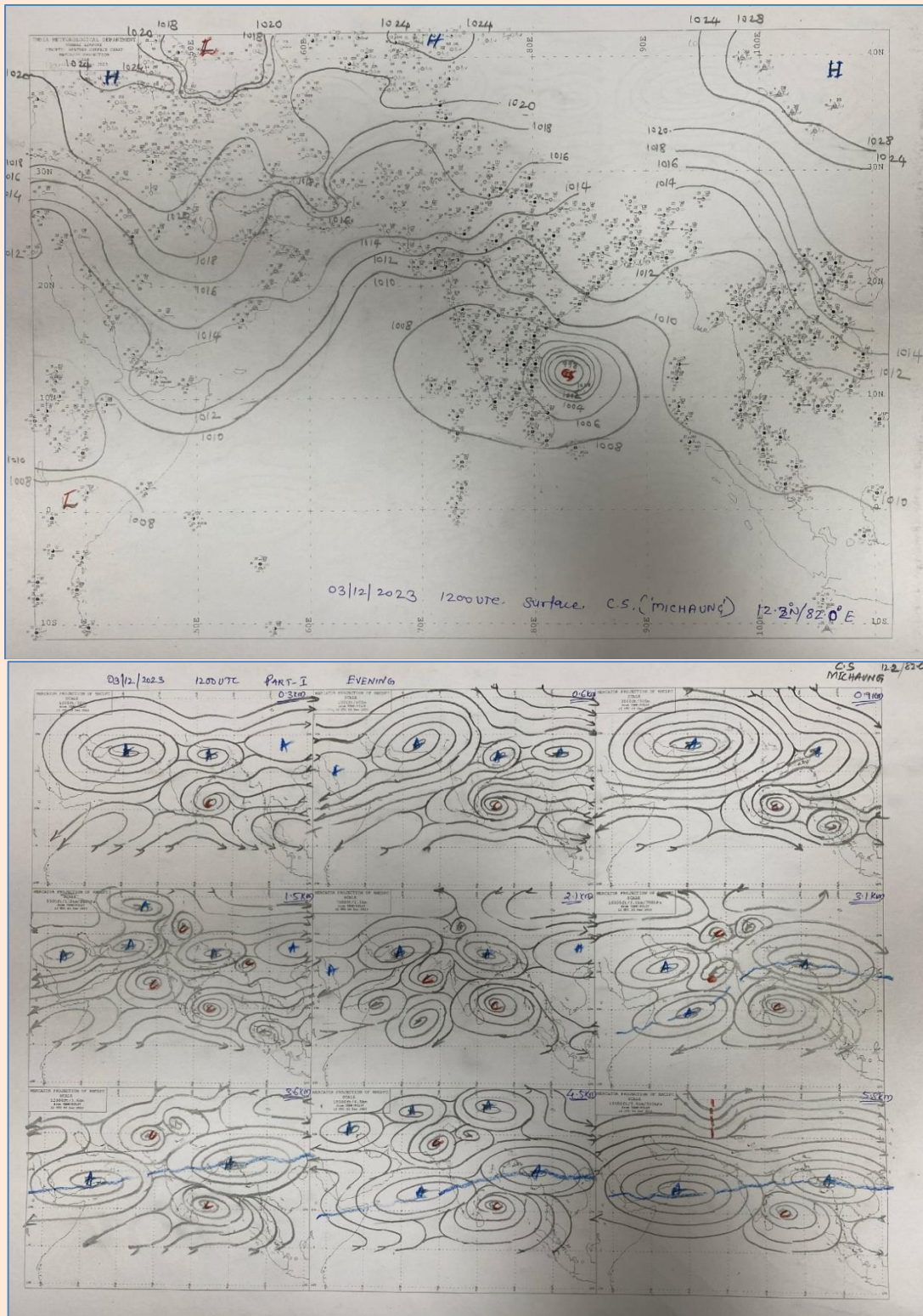


Fig. 2e(ii) Surface isobaric analysis and upper air streamline analysis as on 03rd/1730 IST

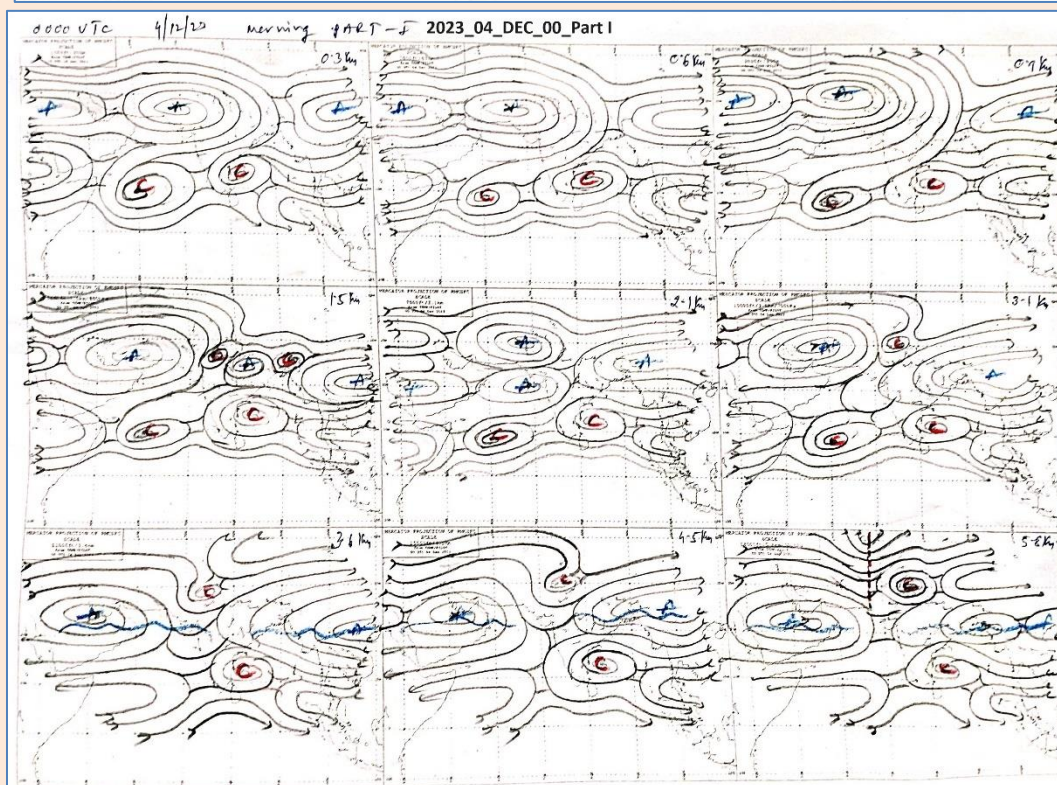
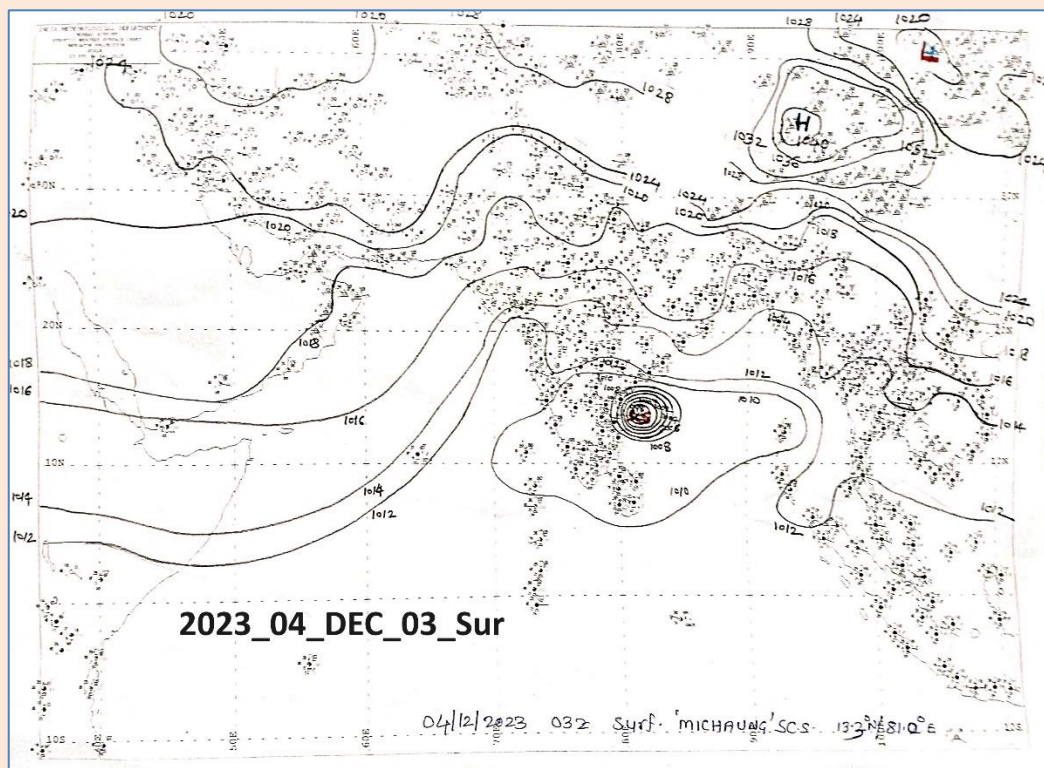


Fig. 2e(iii) Surface isobaric analysis as on 0830 IST and upper air streamline analysis as on 0530 IST of 04 Dec 2023

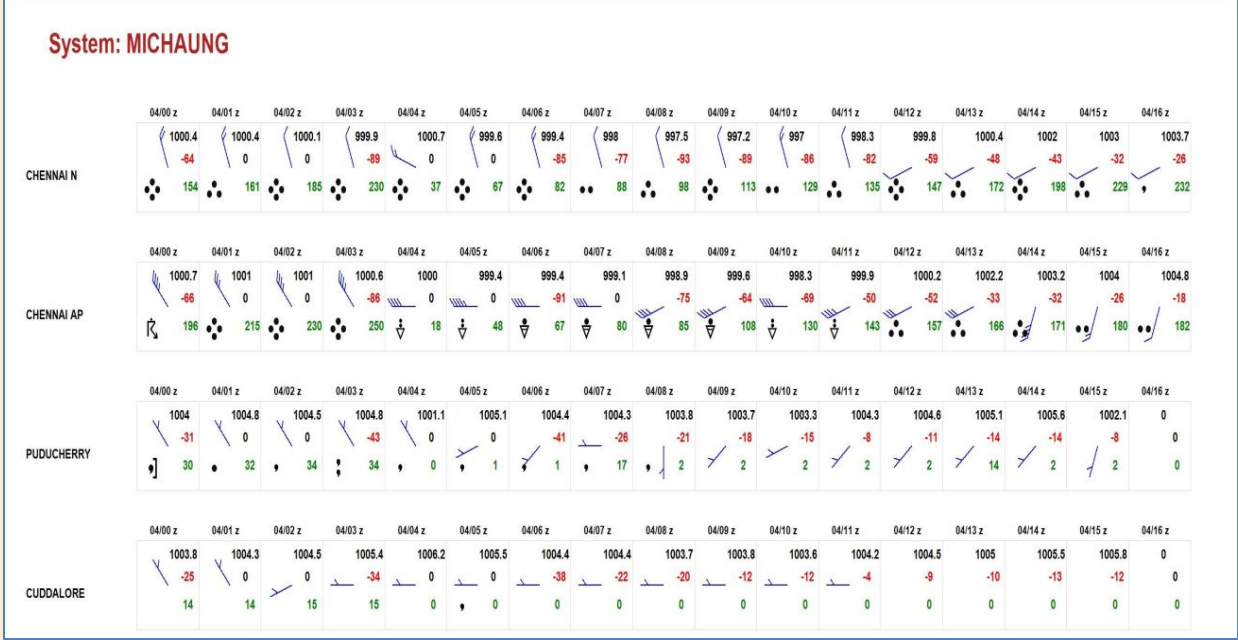


Fig.2e(iv): Plots of hourly observations at IMD stations along (a) coastal Andhra Pradesh from Nellore to Kakinada and (b) adjoining north Tamilnadu (Cuddalore to Chennai).

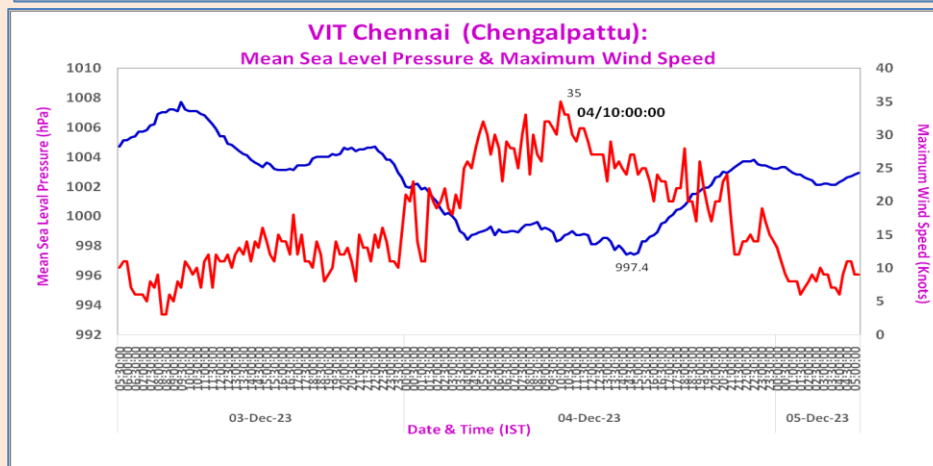
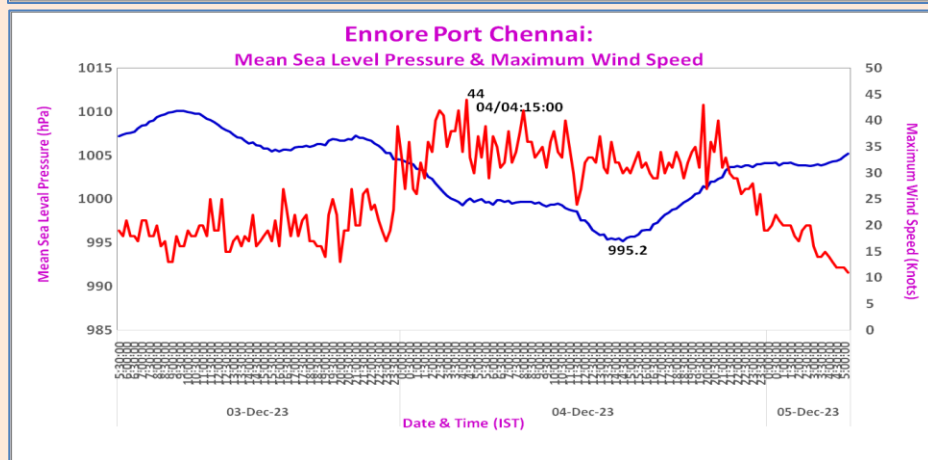
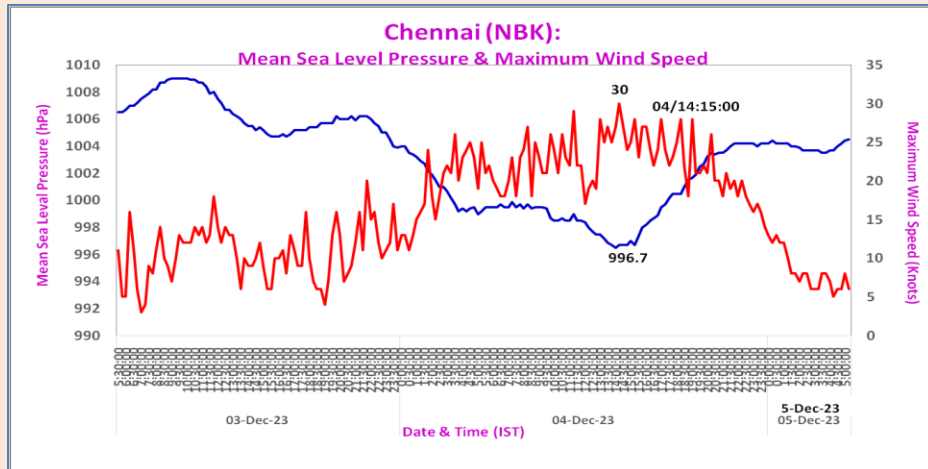


Fig.2e(v): Plots of Mean Sea Level Pressure and Maximum wind speed in gusts recorded by AWS stations at Chennai (Nungambakkam), Ennore Port & VIT Chennai on 03rd & 04th December 2023

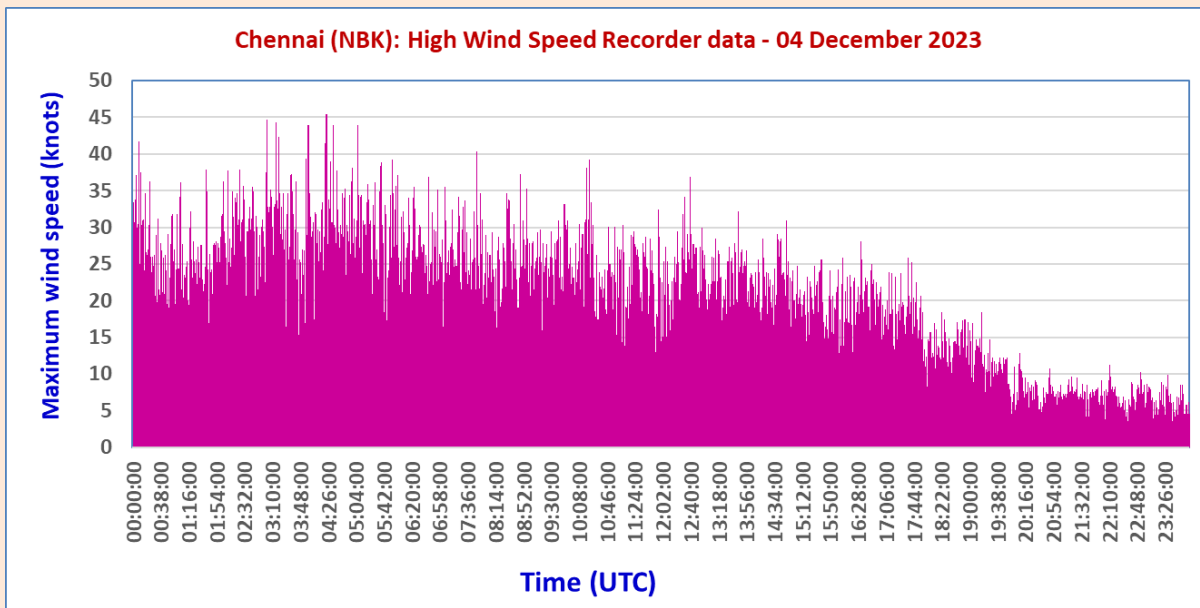
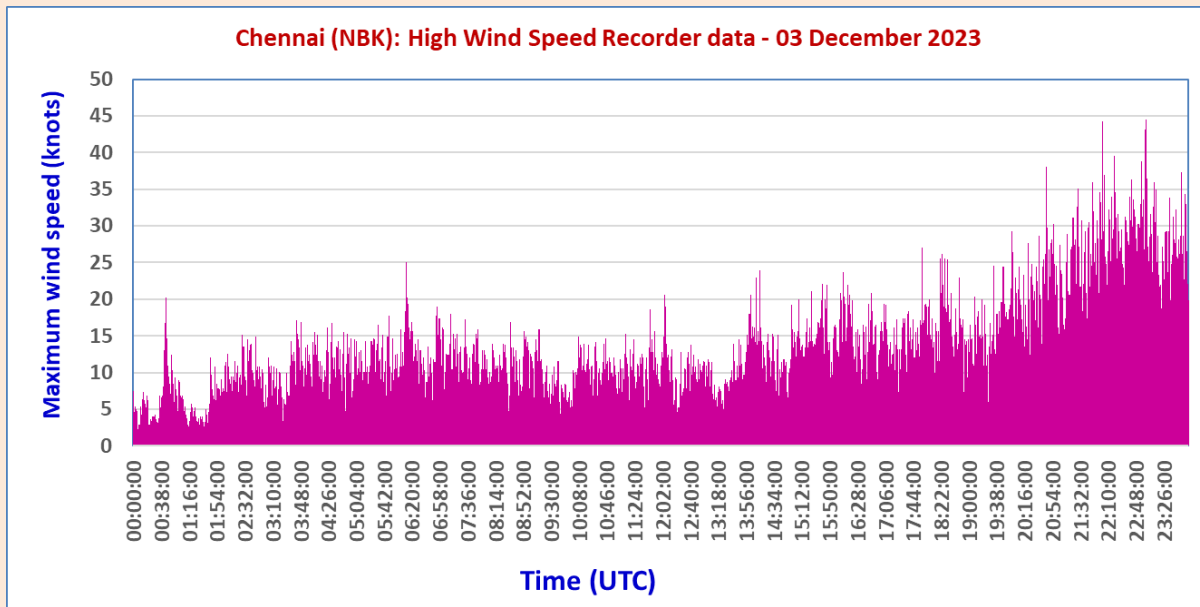


Fig.2e(v): contd.

INSAT-3D, enhanced infra-red imagery as on 03rd/2330 IST & 04th / 1730 IST indicating the cloudiness over extreme northeastern TN, CAP & RYS are presented in Fig.2e(vi). Maximum Reflectivity product of Doppler Weather Radar (DWR) Chennai as on 04th/1840 IST and that of DWR Machilipatnam as on 05th/ 0720 IST depicting the eye and the inner spiral bands are shown in Fig.2e(vii).

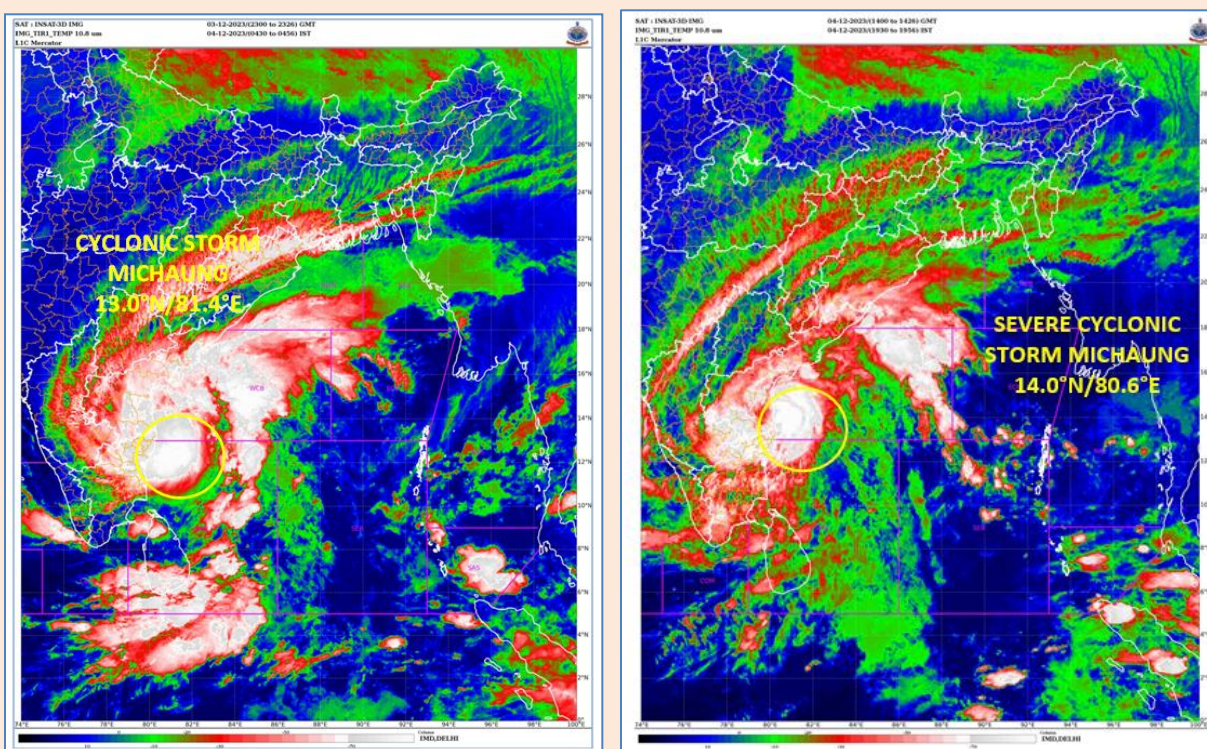


Fig.2e(vi): INSAT-3D enhanced infra-red imagery as on 03/2330 IST & 04/1730 IST of Dec 2023

Associated with the passage of the system, *widespread to fairly widespread* rainfall with *active to vigorous* monsoon conditions prevailed over CAP during the 24-hr ending 0830 IST of 05th, 06th & 07th December 2023, *scattered to fairly widespread* rainfall occurred over RYS during 03rd-06th with *vigorous* monsoon conditions on 05th and *scattered* rainfall occurred over TN on 03rd & 04th December 2023 with *active* monsoon conditions over north coastal TN on 03rd December 2023. Isolated heavy to extremely heavy rain occurred over TN during the 24-hr ending 0830 IST of 04th & 05th, over RYS on 05th, over CAP on 05th & 06th and over TEL on 06th December 2023.

Heavy to extremely heavy rainfall reports from IMD observatories, automatic weather stations (AWS), automatic rain gauge stations (ARG) and state district rainfall monitoring stations over CAP, RYS, TN & TEL during 03rd-06th December 2023 are listed in the Table-1.

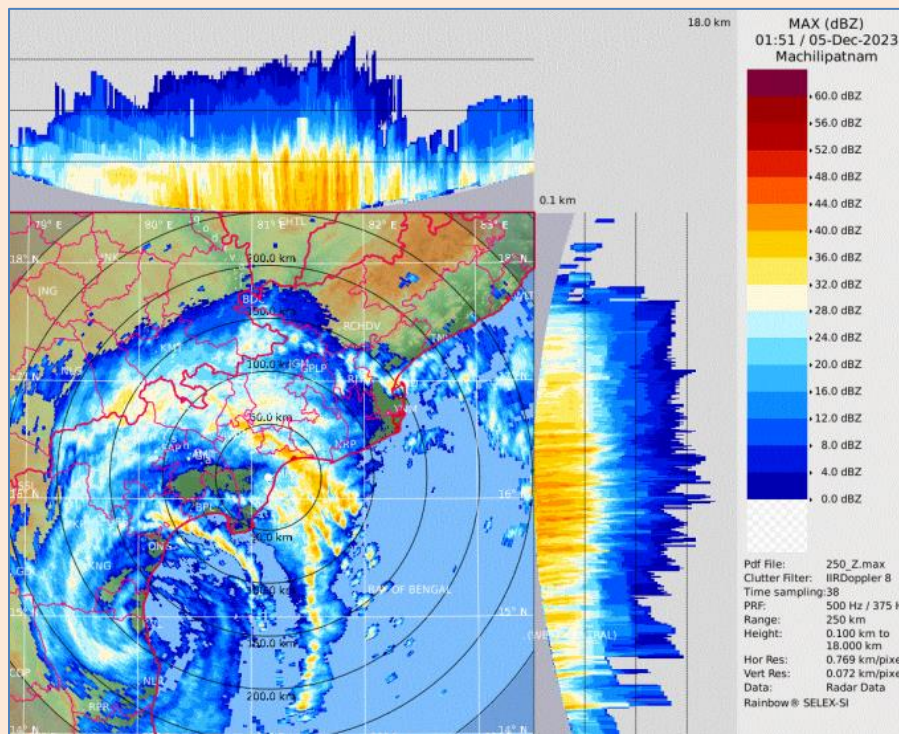
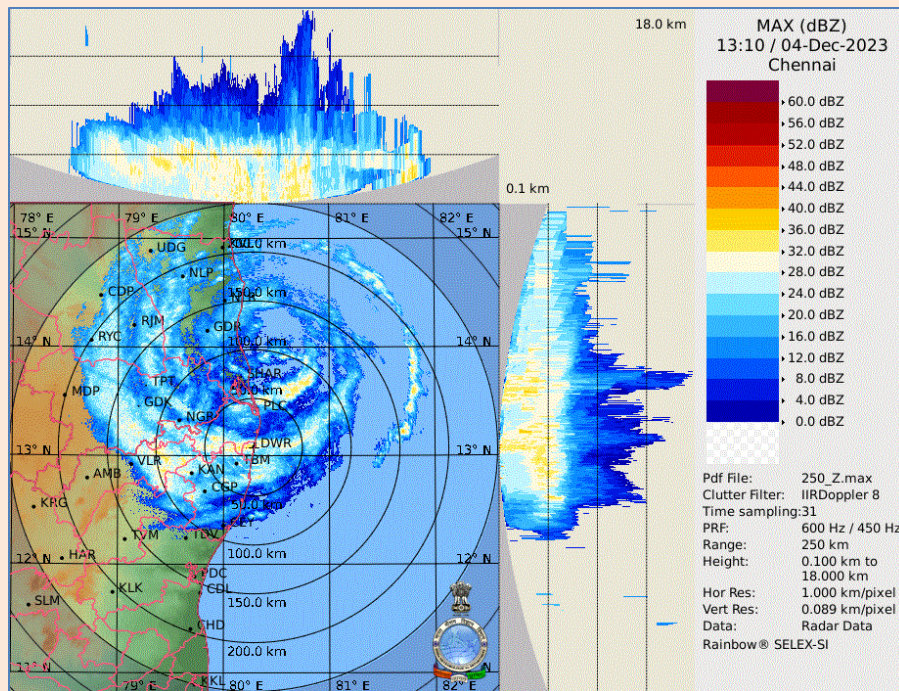


Fig.2e(vii): Maximum Reflectivity product of Doppler Weather Radars at (i) Chennai as on 04/18:40 IST & (ii) Machilipatnam as on 05 / 07:20 IST

Table-1: List of stations reporting heavy to extremely heavy rainfall and rainfall amounts reported during 03rd-06th December 2023 over TN, CAP, RYS & TEL

TAMILNADU	
District	Station & 24-hr accumulated rainfall (cm) ending 08:30 IST of date mentioned against each
Chennai	<p>03rd: Alandur, Anna University, Anna University ARG, Chennai (MBK): 8 each, MGR Nagar: 7;</p> <p>04th: Zone 14 Perungudi-29, Alandur & Chennai (MBK)-25 each, Zone 13 Adyar, Meenambakkam AWS, Zone 12 Meenambakkam, Chennai (NBK)-23 each, MGR Nagar, Zone 10 Kodambakkam, CD Hospital Tondiarpet -22 each, Zone 11 Valasaravakkam, Zone 15 Sholinganallur, DGP Office Mylapore, NIOT_Pallikaranai ARG, Chennai (N) AWS, Anna University -21 each, Zone 03 Puzhal, Perambur, Zone 09 Ice House -20 each, Ayanavaram Taluk Office, Taramani ARG, Anna Nagar – 19 each, Chennai Collector Office, Sholinganallur, Zone 09 Teynampet, Zone 08 Malar Colony, Anna University ARG, Valasaravakkam, YMCA Nandnam ARG, Kodambakkam – 18 each, Ambathur-2 – 17, Zone 06 T.V.K Nagar, Zone 04 Tondiarpet, Teynampet, Zone 01 Kathivakkam, Thiru-Vi-Ka Nagar, Zone 03 Madhavaram -16 each, Zone 08 Anna Nagar, Sholinganallur, Zone 06 D65 Kolathur, Tondairpet, Zone 14 U41 Perungudi , Ennore AWS-15 each , Zone 07 Ambattur -14, Zone 13 Adyar Eco Park., Zone 05 GCC, Zone 12 Alandur-14 each, Zone 02 Manali, Zone U39 Adyar-13 each, Zone D156 Mugalivakkam, Zone 15 Uthandi, Royapuram , Zone 07 U18 D81 Vanagaram-12 each ;</p> <p>05th: Chennai (NBK), Chennai(NBK) AWS – 24 each, Zone 09 Ice House-22, Royapuram, Zone 13 Adya, Thiru-Vi-Ka Nagar-21, Zone 05 GCC, Zone 10 Kodambakkam-21 each, Zone 15 Sholinganallur.,Taramani ARG, Meenambakkam AWS, Chennai (MBK), Kodambakkam-19 each, Teynampet,Valasaravakkam, Anna University ARG.,Zone 11 Valasaravakkam -18 each, NIOT_Pallikaranai ARG-17, Zone Alandhur-12</p>
Chengalpattu	<p>03rd: Tambaram: 7;</p> <p>04th: Mahabalipuram-22, VIT_Chennai AWS-19, Tambaram, Kelambakkam – 17 each, Thirukalukundram-14, Thirupporur-13, Chengalpattu-12 ; Madurantakam: 9, Cheyyur: 8;</p> <p>05th: Tambaram-24, Mahabalipuram-22, Kelambakkam-16, Alandur, Thirupporur-14 each, Thirukalukundram: 11, Chengalpattu: 9</p>
Kancheepuram	<p>04th: Satyabama Uty ARG- 19, KVK Kattukuppam AWS -18, Chembarapakkam_Rev-16, Sriperumbudur, Chembarabakkam_CMWSSB-13 each, Kundrathur-12; Kancheepuram, Uthiramerur: 9 each, Walajabad:</p>

	8; 05 th : KVK Kattukuppam AWS-27, Chembarapakkam_Rev-21, Kundrathur-19, Sriperumbudur-17, Chembarabakkam_CMWSSB-12, Walajabad: 7
Tiruvallur	03 rd : Pallipattu-15, Uthukottai-13; Ponneri:10, Tiruttani, Avadi: 9 each, Tiruvallur, Thamaraiykkam: 8 each; 04 th : Avadi-28, Puzhal ARG, Cholavaram-23 each, Ponneri-21, Red Hills-20, Good Will School Villivakkam ARG, Thamaraiykkam -18 each, Gummidipoondi-17, Tiruvallur-16, Uthukottai, Tirur KVK AWS -15 each, Poonamallee, Koratur-14 each ; Tiruttani: 10, Thiruvalangadu: 9; 05 th : Poonamallee-34, Avadi-28, Thamaraiykkam, Tirur KVK AWS-19 each, Tiruvallur-18, Uthukottai, Koratur, Ponneri – 17 each, Cholavaram-15, Thiruvalangadu, Poondi – 14 each, Red Hills-13, Tiruttani, Gummidipoondi -12 each, Tiruttani PTO: 8, R.K.pet, Pallipattu: 7 each
COASTAL ANDHRA PRADESH & YANAM	
District	Station & 24-hr accumulated rainfall (cm) ending 08:30 IST of date mentioned against each
Bapatla	05 th : Bapatla: 22; Addanki & Karamchedu: 17; Repalle: 11, Santhamaguluru: 9, 06 th : Santhamaguluru: 16, Addanki: 9
SPSR Nellore	04 th : Nellore:19, 05 th : Nellore: 22, Rapur: 21, Atmakur:19, Kavali: 15, Vinjamur: 14, Udayagiri:13, Kandukur: 11, Seetharamapuram: 7
Dr.B.R.Ambedkar Konaseema	05 th : Amalapuram: 17, 06 th : Amalapuram: 19
Krishna	05 th : Machilipatnam: 16, Avanigadda: 14, Gudivada: 9, 06 th : Gudivada: 7
Prakasam	05 th : Ongole: 12, Konakanamitla: 9, Marripudi, Veligandla, Mundlamuru: 7 each, 06 th : Darsi: 14, Mundlamuru: 9, Podili: 8
Guntur	05 th : Tenali: 8, Guntur:7, 06 th : Guntur: 11, Amaravati:11, Mangalagiri: 10, Lam (A): 9,
Kakinada	05 th : Kakinada:8, Peddapuram: 7 06 th : Prathipadu: 16, Kakinada: 14, Tuni: 12, Peddapuram: 9
Yanam	05 th : Yanam: 8
West Gadavari	05 th : Tanuku: 7, 06 th : Narsapuram, Chintalapudi: 21 each, Bheemavaram: 20, Palakoderu: 18, Tanuku: 17, Tadepalligudem: 14
NTR	05 th : Vijayawada airport: 7, 06 th : Tiruvuru: 13, Nandigama:11, Vijyawada AP: 8
Eluru	06 th : Bhimadole: 24, Kukunoor: 22, Koyyalagudem: 20, Kaikalur, Polavaram: 16 each, Velairpad: 13, Nuzvid: 12, Eluru: 11
Anakapalle	06 th : Narsipatnam: 20, Anakapalle: 19, Yelaamanchili: 19, Chodavaram: 15, Anakapalle (A): 13
Alluri	06 th : Kunavaram: 19, Chintur: 15, Chintapalle, Paderu: 12 each

Sitaramaraju	Vararamachandrapur: 11 , Araku valley: 10
Palnadu	06th : Sattenapalle: 18 , Piduguralla: 10 , Atchampet: 8 , Jangamaeswarapuram: 7
Visakhapatnam	06th : Visakhapatnam: 15 , Bheemunipatnam: 10 , Visakhapatnam AP: 7
Vizianagaram	06th : Denkada: 15 , Srungavarapukota: 13 , Mentada: 12 , Bondapalle, Gajapathinagaram, Vepada: 11 each , Vizianagaram: 10 , Pusapatirega, Gandyada: 9 each , Garividi: 8 , Nellimarla, Cheepurupalle: 7 each
Srikakulam	06th : Ranastahalam: 8
Yanam (Puducherry)	06th : Yanam: 10
RAYALASEEMA	
District	Station & 24-hr accumulated rainfall (cm) ending 08:30 IST of date mentioned below
Tirupati	04th : Sullurpeta: 20 , Tada: 19 , Gudur: 14 , Srikalahasti, Thottambedu, Satyavedu: 13 each , Tirupati Aero: 7 , 05th : Gudur: 28 , Srikalahasti: 24 , Thottambedu, Sullurpeta: 23 each , Tada: 20 , Venkatagiri: 18 , Satyavedu: 14 , Tirupati Aero: 13
YSR	05th : Kodur: 24 , Atlur: 9 , Badvel: 8 , Cuddapah: 7
Annamayya	05th : Penagaluru: 23 , Rajampet: 12 , Gurrarakonda, Kalakada, Sambepalle, Royachoti: 7 each
Chittoor	04th : Nagari: 12 , 05th : Nagari: 13
TELANGANA	
District	Station & 24-hr accumulated rainfall (cm) ending 08:30 IST of date mentioned below
B.Kothagudem	06th : Aswaraopeta: 34 , Palawancha: 25 , Chandrugonda: 23 , Kothagudem: 22 , Julurpad, Mulakalapalle: 20 each , Aswapuram: 19 , Burgampadu: 18 , Bhadrachalam: 18 , Tekulapalle: 15 , Manuguru: 12 , Pinapaka: 10 , Gundala: 8 , Yellandu: 7
Khammam	06th : Sathupalle: 16 , Madhira, Enkuru: 14 each , Bonakal: 13 , Wyra KVK: 12 , Thollada: 10 , Konijerla: 9 , Chinthakam: 7
Mulugu	06th : Venkatapur: 7

It may be noted that *isolated extremely heavy* rainfall occurred over Nellore, Bapatla, West Godavari & Eluru districts of CAP on 05th/06th; over Tirupati, YSR & Annamayya districts of RYS on 05th; over B.Kothagudem district of TEL on 06th December 2023. Highest rainfall of **34 cm** was reported at **Poonamallee in Tiruvallur** district of TN on 05th and over **Aswaraopeta in B.Kothagudem** district of TEL on 06th December 2023.

Spatial rainfall maps of TN, CAP & RYS for 24-hr ending 0830 IST of 03rd, 04th & 05th and that for TN, CAP, RYS & TEL for 06th December 2023 are presented in Fig. 2e(viii).

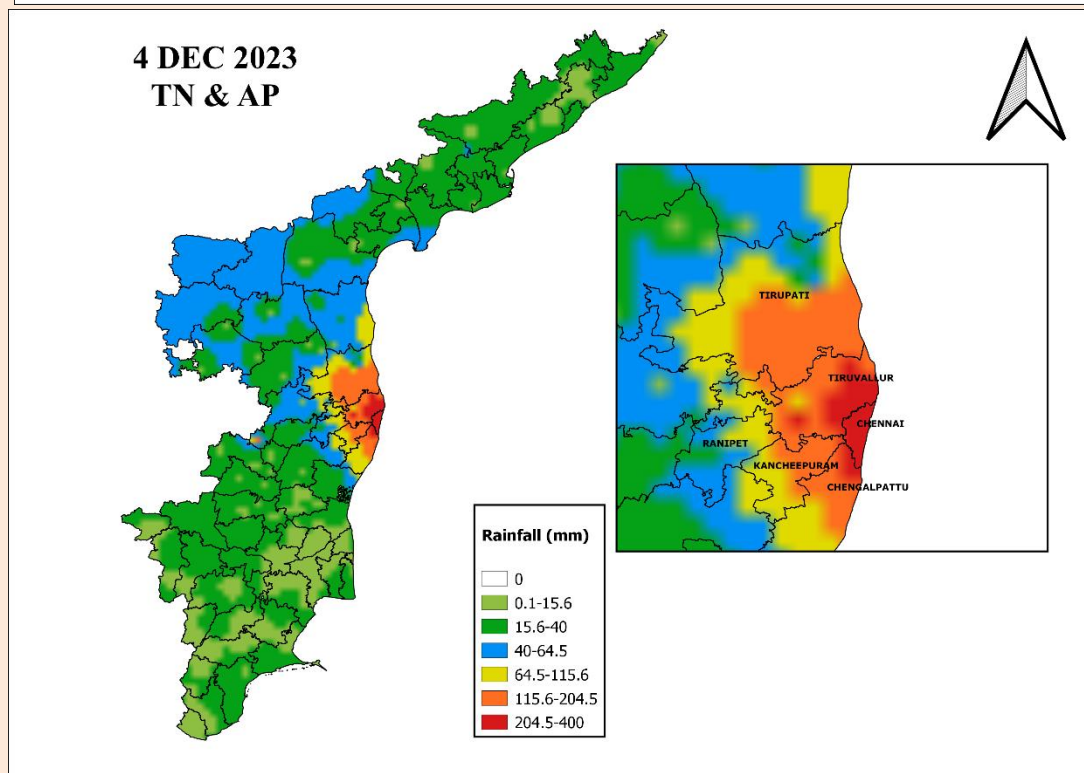
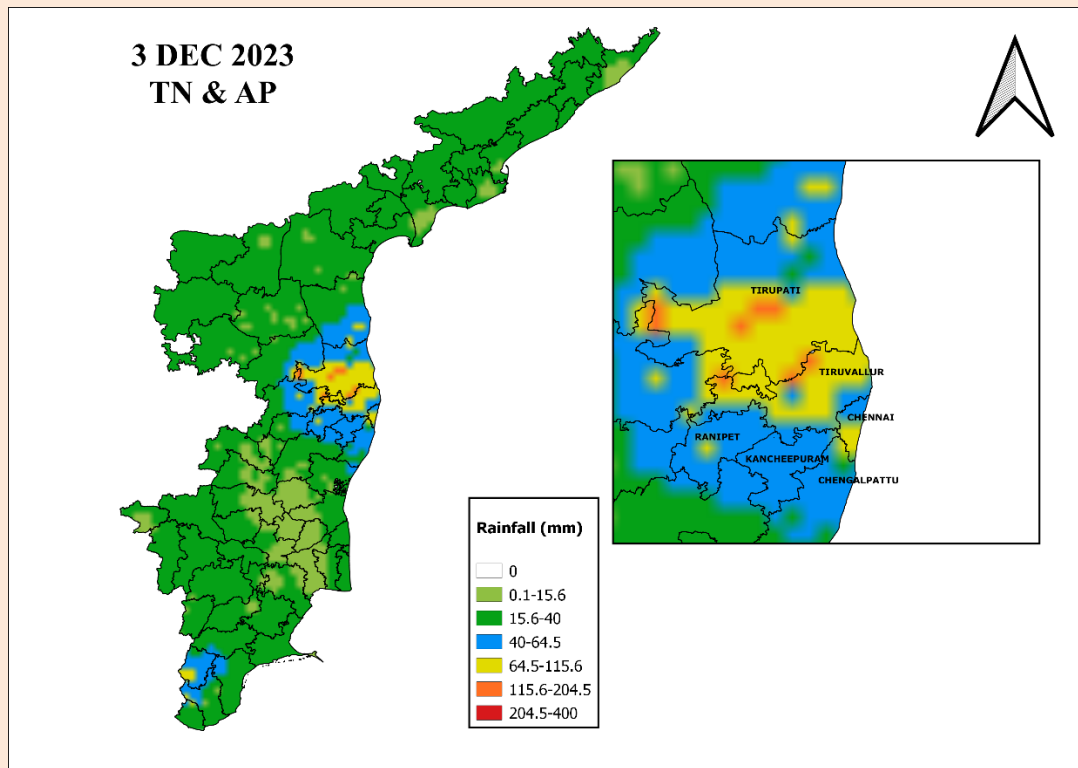


Fig.2e(viii): Spatial rainfall maps of TN, AP (CAP & RYS) for 24-hr ending 0830 IST of 03rd, 04th & 05th & that for TN, AP & TEL for 06th December 2023

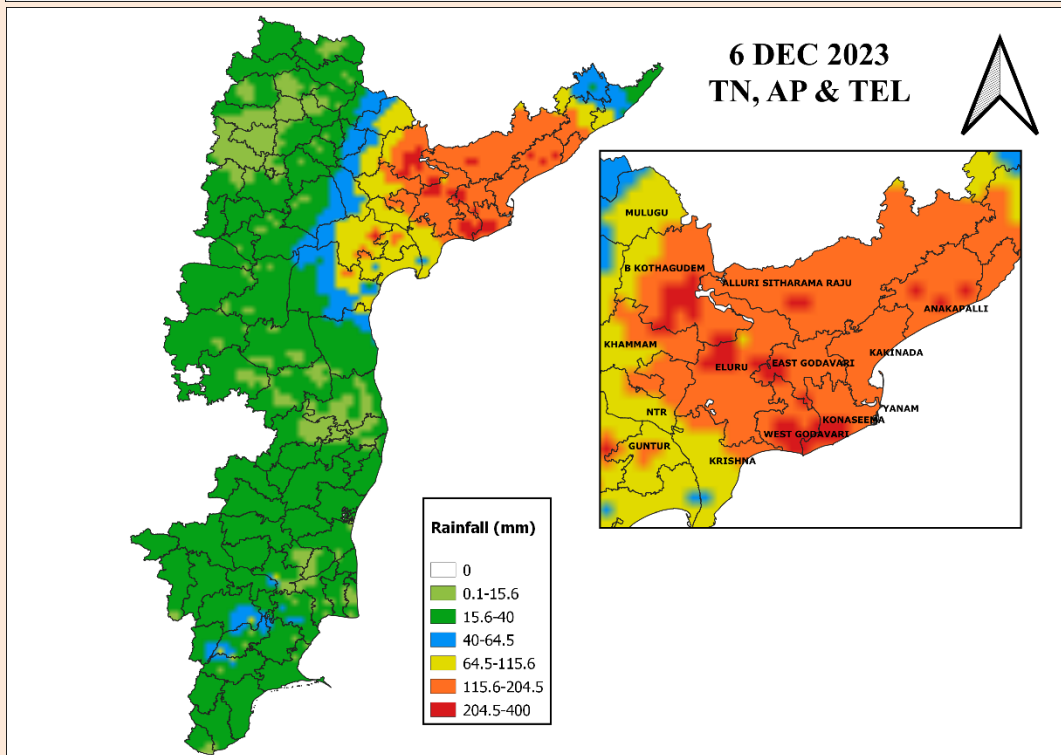
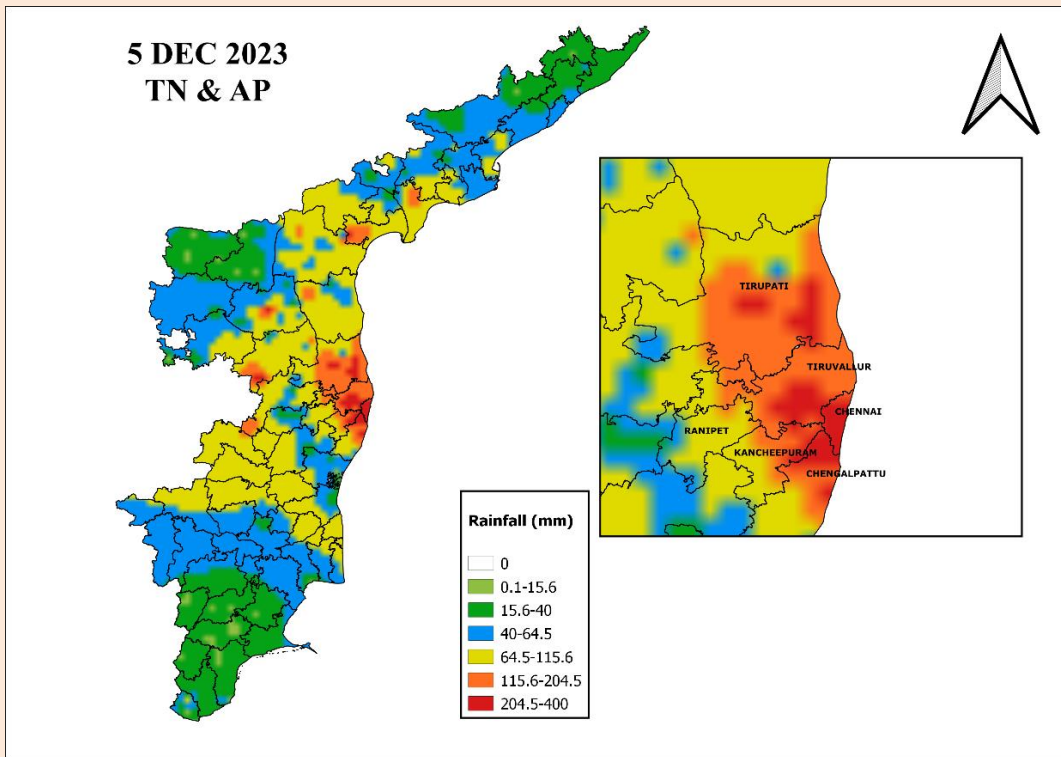


Fig.2e(viii): contd.

Very heavy to extremely heavy rainfall occurred at *many* places over Chennai, Chengalpattu, Kancheepuram & Tiruvallur districts of TN on 04th & 05th December 2023. Maps depicting very

heavy to extremely heavy rainfall reports over Chennai & neighbourhood as on 24-hr ending 0830 IST of 04th & 05th December 2023 are presented in Fgi.2e(ix).

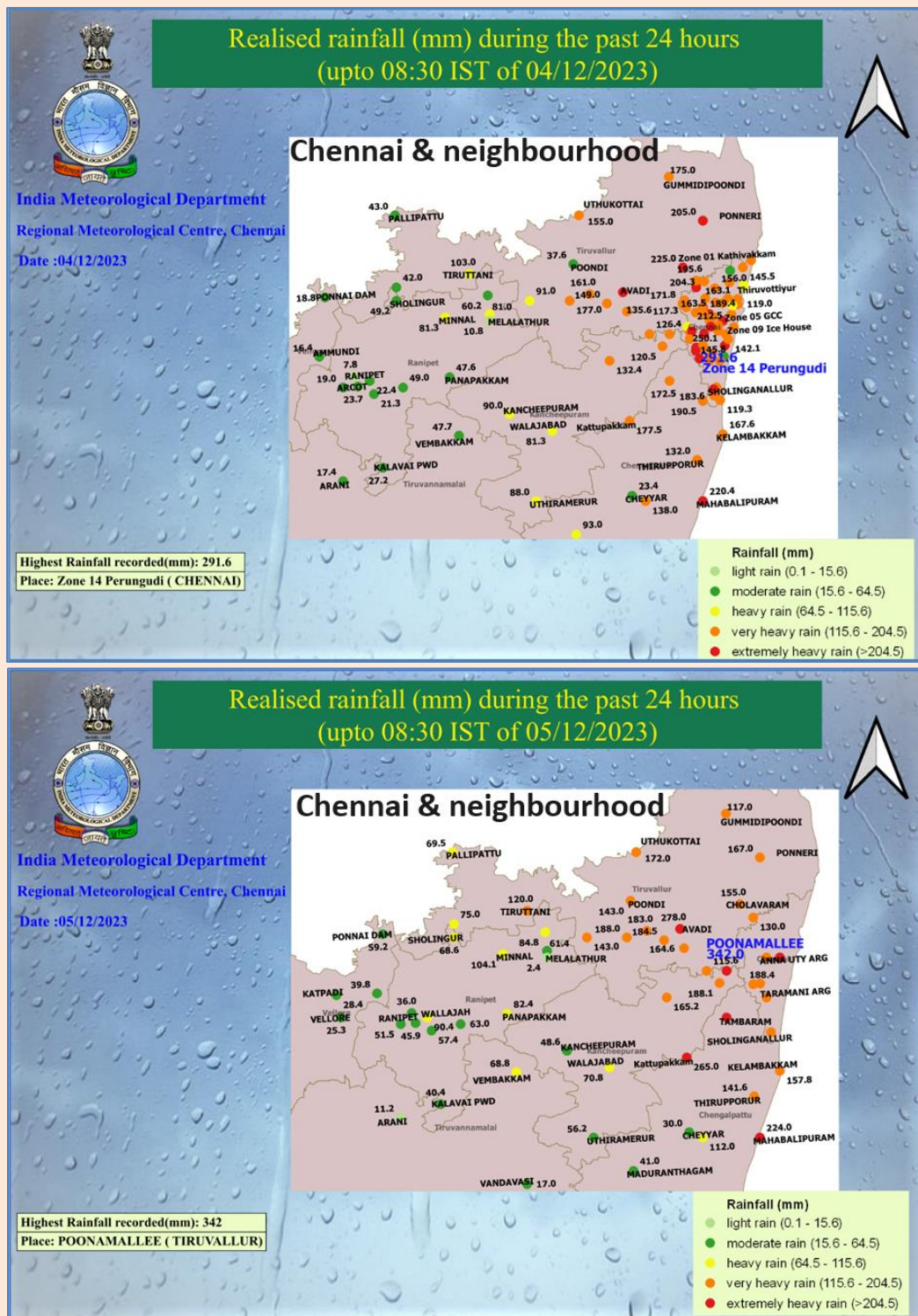


Fig.2e(ix): 24-hr rainfall over Chennai and adjoining districts as on 0830 IST of 04 & 05 Dec 2023

Catastrophic urban flooding occurred over the mega city of Chennai and its suburbs leading to loss of lives and property. As per media reports, 17 deaths were reported due to rain related incidents in Chennai and neighbourhood and properties worth hundreds of crores of rupees were damaged.

Charts of self-recording raingauge (SRRG) at Chennai (NBK) for the 24-hr period ending 08:30 IST of 04th & 05th December indicating intense rain spells from 03rd late night to 04th night leading 230.2 mm (23 cm) & 238.3 mm (24 cm) of rainfall on 04th & 05th December respectively are shown in Fig.2e(x).

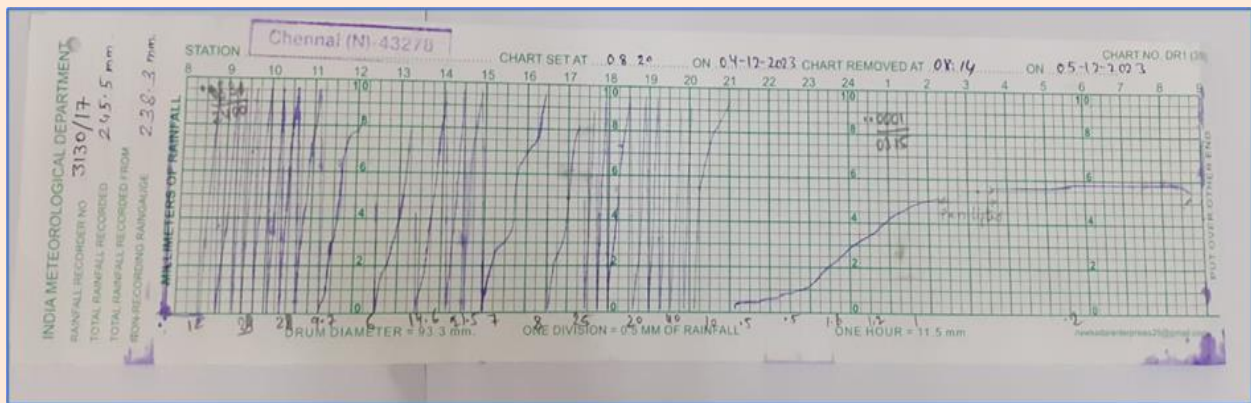


Fig.2e(x): Charts of self recording raingauge at Chennai (NBK) as on 24-hr ending 0830 IST of 04 & 05 Dec 2023

Plots of hourly rainfall recorded by AWS & ARG stations at Chennai & neighbourhood are depicted in Fig.2e(xi).

As seen, rainfall of 01-03 cm/hr were recorded in AWS /ARG stations from 03rd evening/night to 04th evening/night (20:30 IST) with occasional spells of 3-5 cm/hr in some areas.

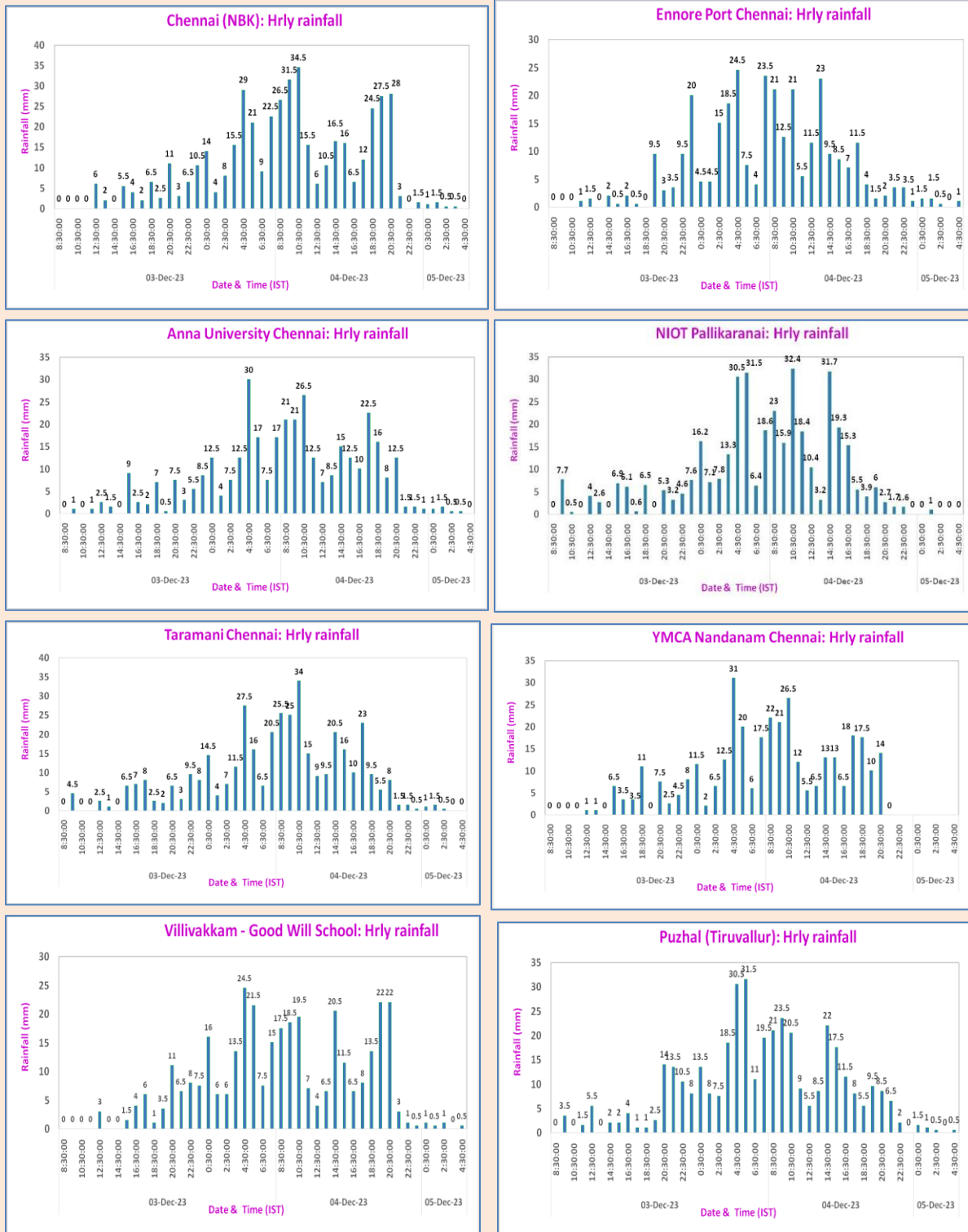


Fig.2e(xi): AWS/ARG rainfall data plotted at hourly intervals on 03rd & 04th Dec 2023

Early warnings for *very heavy to extremely heavy* rainfall and gale force winds during the landfall with frequent updates were issued to the state administrative & disaster management authorities, agriculture and fisheries departments of Andhra Pradesh & Tamilnadu and to the port authorities along Andhra Pradesh & Tamilnadu coasts. Warnings and frequent updates were also disseminated to the Press and media (in English & Regional language) and to the general public through social media and website updates. Sample heavy rainfall & strong wind warnings issued for Chennai & neighbourhood on 03rd December 2023 & posted in the social media and website is shown in Fig.2e(xii).

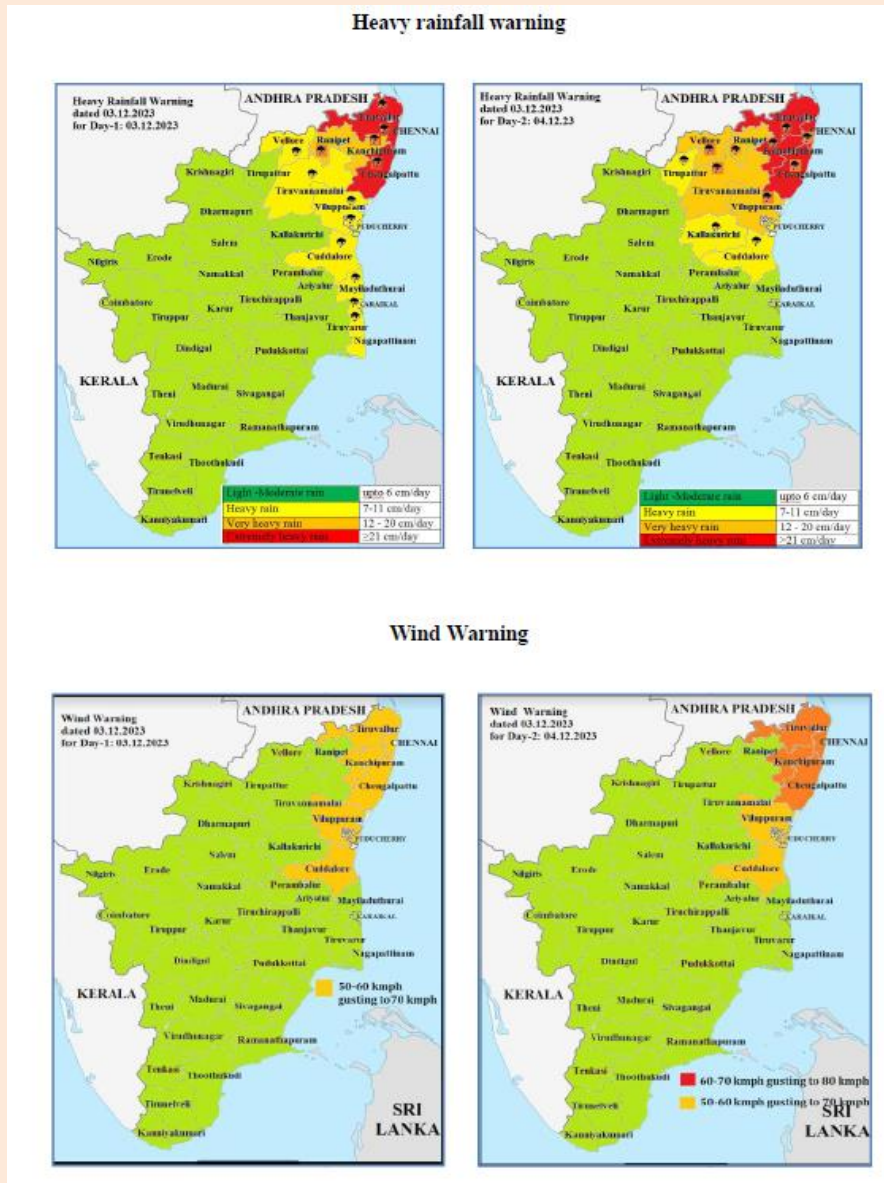


Fig.2e(xii): Heavy rainfall & gale wind warnings issued for Chennai & neighbourhood on 03rd Dec 2023

The following videos posted by the media depict the gravity of the flood situation in Chennai & neighbourhood and the extent of damages caused by the cyclone ‘Michaung’.

<https://www.youtube.com/watch?v=o-DIQeNccz4>

<https://www.youtube.com/watch?v=GybOaa63Lv4>

<https://www.youtube.com/watch?v=07GsfzTsngs>

<https://www.youtube.com/watch?v=YgjtuljMO5A>

A few media reports and photographs depicting the damages caused by the cyclone Michaung including the gravity of the flood situation in Chennai & neighbourhood are presented in Fig.2e(xiii).

Printed from
THE TIMES OF INDIA

Cyclone Michaung landfall between Andhra Pradesh's Nellore and Machilipatnam

TNN | Dec 5, 2023, 10:24 AM IST



VISAKHAPATNAM: Heavy rains along with strong winds lashed Nellore and Tirupati districts on Monday under the impact of cyclone Michaung, which is expected to make landfall between Nellore and Machilipatnam around noon on Tuesday. Most low-lying areas in Tirupati and Nellore were flooded, and people were evacuated from the water-logged areas. Authorities have also declared a holiday for schools in many parts of the state. The wind, which was gaining in speed with each passing hour, uprooted trees and caused damage to standing crops in the south coastal districts.

While operations at Renigunta (Tirupati) airport were closed till further orders, nearly 150 trains have been cancelled. Many parts of Chittoor, Annamayya, YSR Kadapa, Prakasam, Bapatla, Krishna, West Godavari and Konaseema districts also received heavy rains. The rains are expected to continue on Tuesday as well. The rains disrupted daily life in Tirupati and Nellore districts, with heavy traffic jams reported at some places due to waterlogging on the roads. The winds uprooted electric poles, leading to power outage at many places.

Renigunta airport remained shut on Monday. A total of 15 flights scheduled from the airport, and four flights from Visakhapatnam, were cancelled. Airlines have advised passengers to check the flight status before reaching airports in Tamil Nadu and Andhra Pradesh. Transport services took a hit too as several trains and buses were cancelled.

Fig.2e(xiii): Media reports dated 04th/05th December 2023 on damages due to the cyclone Michaung



The Indian Express

+ Follow

Cyclone Michaung wreaks havoc: Flights cancelled, roads submerged

Story by Express Web Desk • 1d

04/12/2023-07:41:30 pm



The Indian Express

+ Follow

Cyclone Michaung claims 17 lives in Tamil Nadu, leaves trail of deluge, disruption

Story by Express Web Desk • 7h

05/12/2023-10:59:26 pm



The New Indian Express

+ Follow

1,000 cusecs of water from Chembarambakkam Lake let out every half hour

22h

05.12.2023-09:29:00 a.m.

The WRD increased the release of surplus water from 6,000 cusecs to 8,000 cusecs at 5 pm, and later resorted to the phased discharge as inflow was 1,20,000 cusecs.

CHENNAI: Amidst heavy downpour, the Water Resources Department discharged 1,000 cusecs of surplus water from Chembarambakkam Lake every half hour, as the lake reached maximum storage level on Monday. Residents in low-lying areas were alerted and rescue teams were taking steps to rescue them.

Fig.2e(xiii) contd.

Cyclone Michaung plays havoc in Nellore; officials on alert as landfall projected near Andhra Pradesh's Bapatla

Normal life was paralyzed in Nellore city and Kavali town as the rainwaters entered the households in several low-lying areas

Updated - December 05, 2023 11:09 am IST Published - December 05, 2023 11:06 am IST - NELLORE



K. UMASHANKER

The Hindu



Streets in Nellore flooded by the impact of cyclone Michaung. | Photo Credit: Kommuri Srinivas



Fig.2e(xiii) contd.

Damages over Chennai & neighbourhood

Scenes from Ambattur Industrial Estate (Source: Polimer News dated 05.12.2023)



1500 factories completely flooded and machinery worth several hundred crores damaged



Fig.2e(xiii) contd.

Scenes from West Tambaram – Source: Polimer News dated 05.012.2023



Scenes from Pallikaranai –Source: Thanthi TV report dated 04.12.2023



Fig.2e(xiii) contd.

Scenes from OMR IT parks – Tidel Park, Ascendas

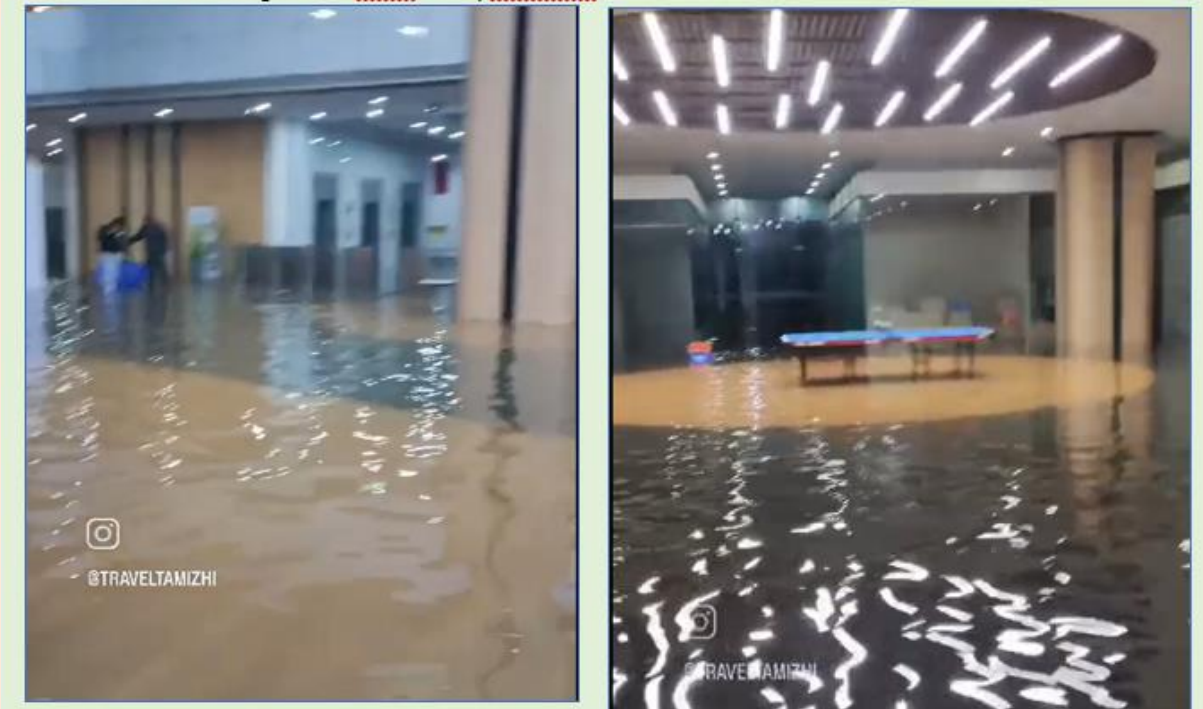


Fig.2e(xiii) contd.

3b. Historical rainfall event over South Tamilnadu during 17th-19th December 2023

An upper air circulation was observed over southwest Bay of Bengal and adjoining equatorial Indian ocean in the lower tropospheric levels on 15th December 2023. It was seen over equatorial Indian Ocean and adjoining southwest Bay of Bengal off south Sri Lanka coast on 16th morning and over Comorin area and neighbourhood extending up to mid tropospheric levels on 17th and 18th December 2023.

IMD-GFS 850 hPa wind analysis depicting the cyclonic circulation during 15th-18th December are presented in Fig.3a(i) and NCMRWF-NCUM 850 hPa analysis as on 16th/0530 IST is shown in Fig.3a(ii). ASCAT (METOP-C) scatterometer data depicting the cyclonic circulation off south Sri Lanka coast on 15th night is shown in Fig.3b. INSAT-3D, TIR1 product depicting the cloudiness as on 17th/2130 IST and Doppler Weather Radar, Kochi, Maximum Reflectivity product as on 17th/2112 IST depicting the rainfall activity over extreme south Tamilnadu are presented in Fig.3c.

Associated with this circulation, moderate to strong easterlies / southeasterlies prevailed over extreme south Tamilnadu and Gulf of Mannar area [Fig.3a(ii)]. CIMSS dynamical products indicated (i) cyclonic vorticity of about $50-100 \times 10^{-5}$ per sec in the lower to mid tropospheric levels over the Comorin area (Fig.3d). Low Level convergence over the Comorin and adjoining areas increased from 20 to 40×10^{-5} per sec and Upper level Divergence increased from was 20 to 30×10^{-5} per sec during 17th night [Fig.3e(i&ii)]. Thiruchendur AWS (Thoothukudi district in south coastal Tamilnadu) indicated 15-20 knots (25-30 kmph) winds gusting to 30 knots (50 kmph) on 17th morning (Fig.3f). Under the influence of strong maritime winds and moisture convergence, very high precipitable water of more than 70 mm prevailed over the Gulf of Mannar area and adjoining south Tamilnadu (Fig.3g).

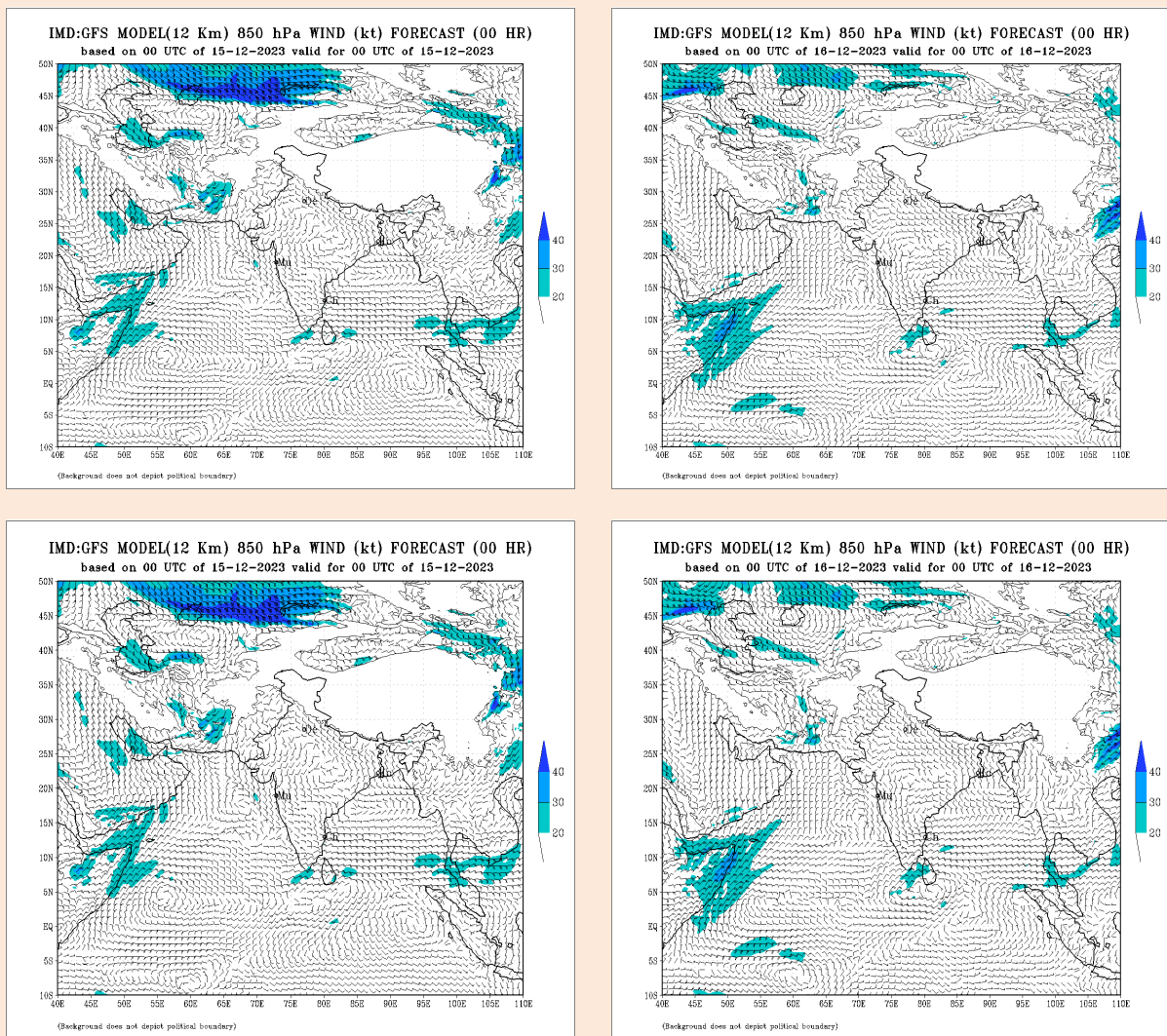


Fig.3a(i): IMD-GFS analysis based on 0530 IST of 15th, 16th, 17th & 18th Dec 2023

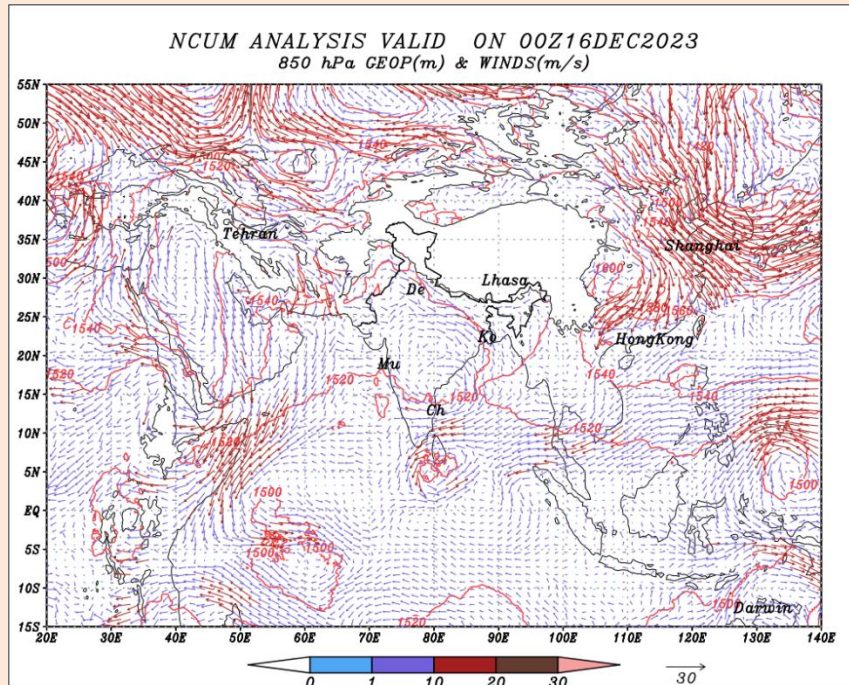


Fig.3a(ii): NCUM, 850 hPa wind analysis as on 0530 IST of 16th Dec 2023

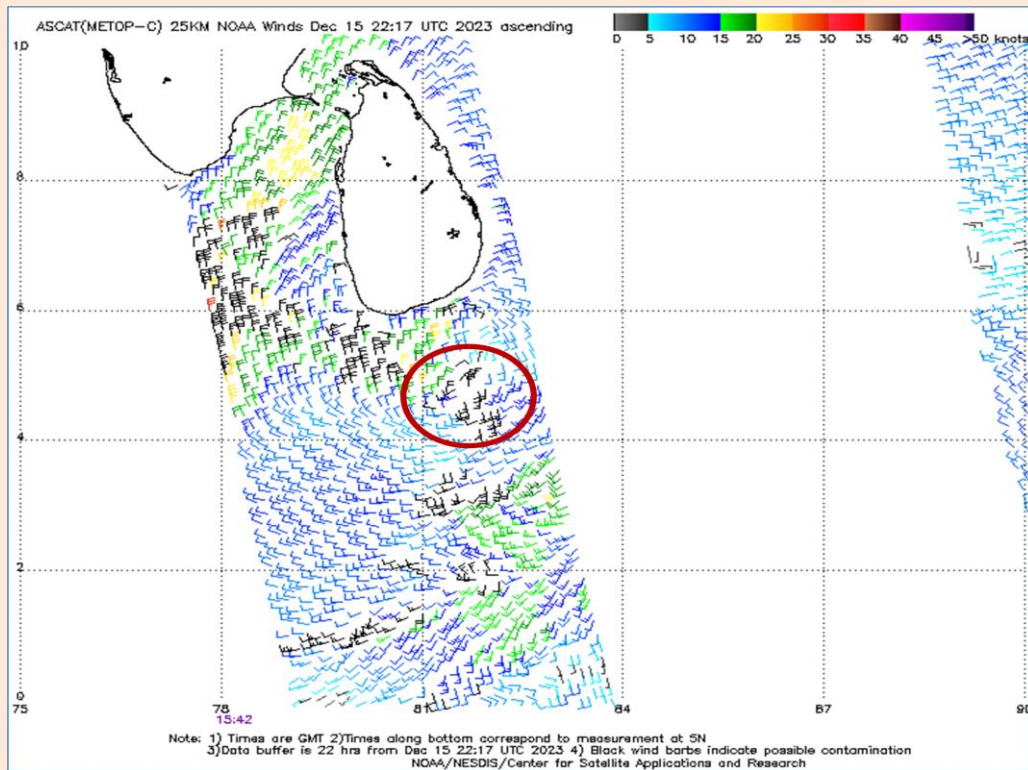


Fig.3b: ASCAT (METOP-C) scatterometer wind as on 21:12 IST of 15th Dec 2023

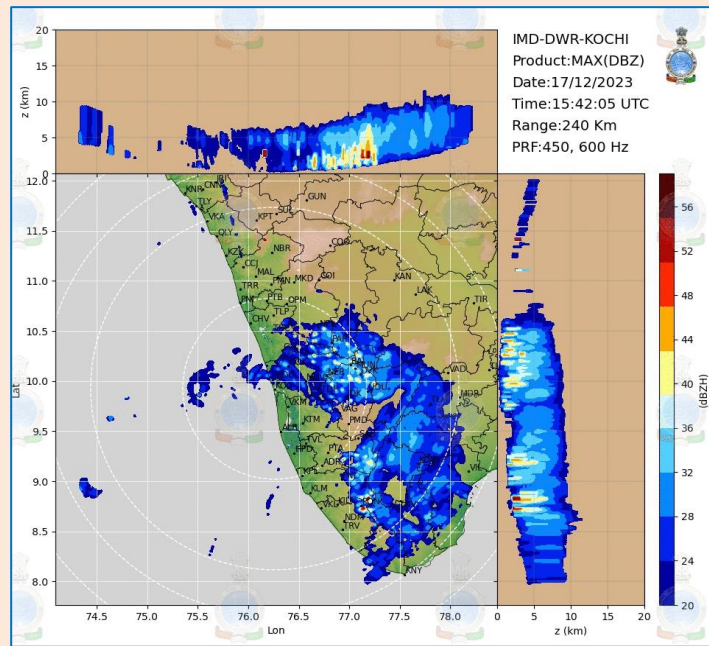
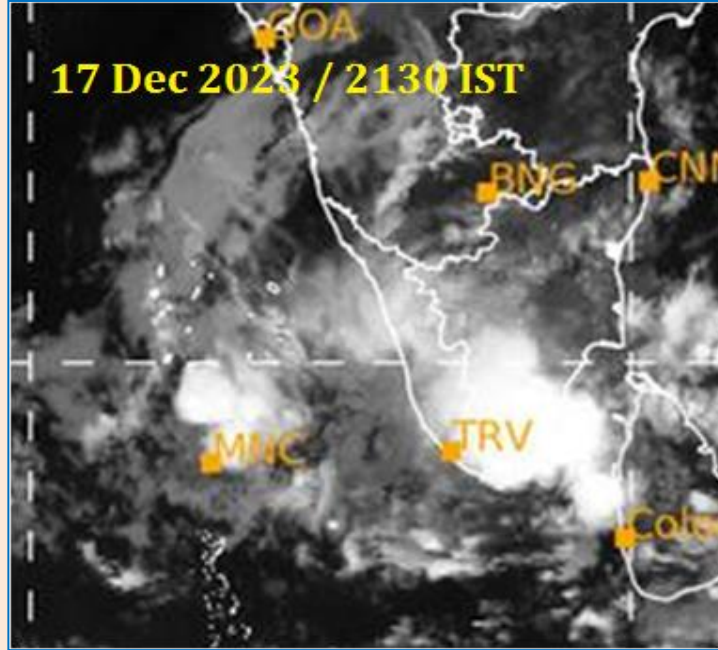


Fig.3c: INSAT-3D, TIR1 product as on 17th/2130 IST & Doppler Weather Radar, Kochi, Maximum Reflectivity product as on 17th/2142 IST

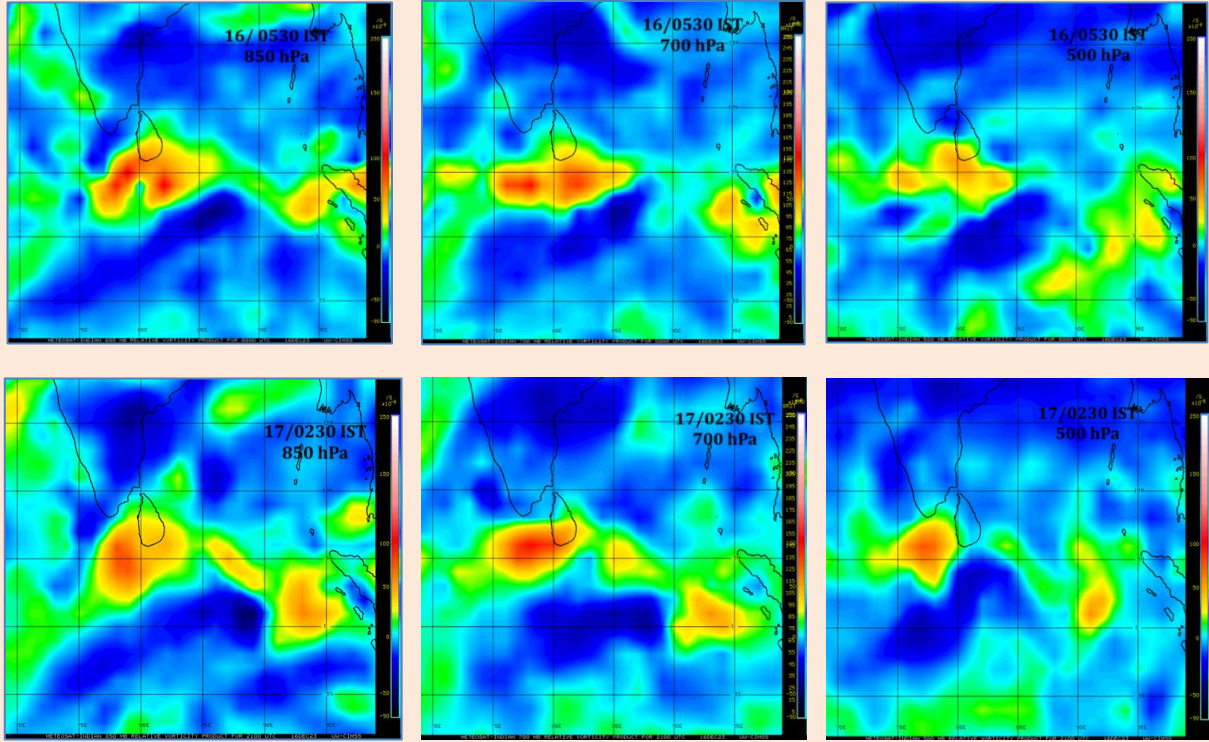


Fig.3d: CIMSS Relative vorticity product for 850 hPa, 700 hPa & 500 hPa levels as on 16th/0530 IST and 17th/0230 IST

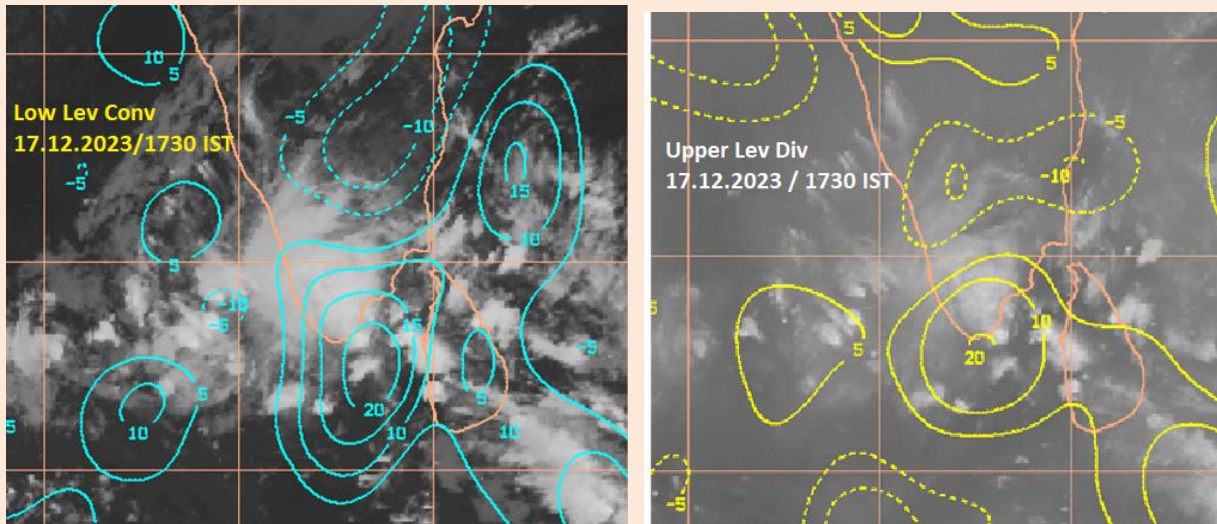


Fig.3e(i): CIMSS Low Level Convergence & Upper Level Divergence products as on 17th/1730 IST of Dec 2023

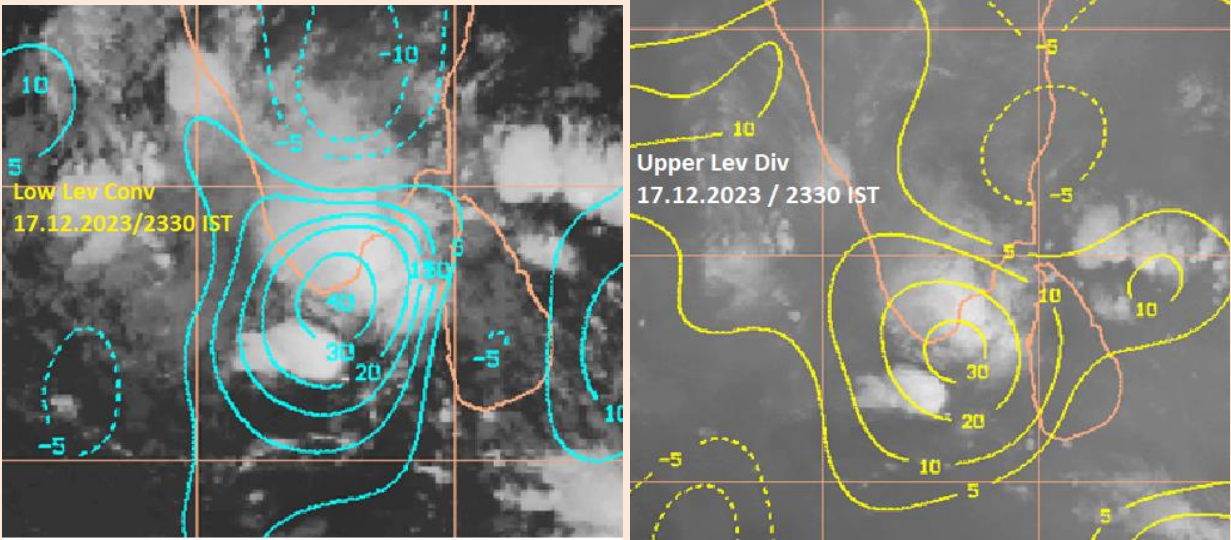
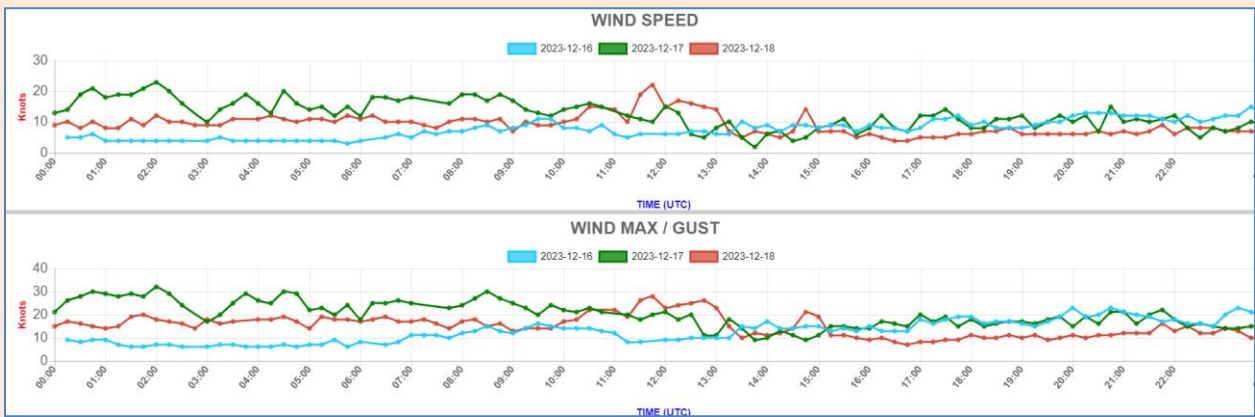


Fig.3e(ii): same as Fig.3e(i), but for 17th/ 2330 IST of Dec 2023



**Fig.3f: Wind speed (mean & gust) recorded by Thiruchendur AWS during 16th / 0530 IST
19th / 0530 IST of Dec 2023**

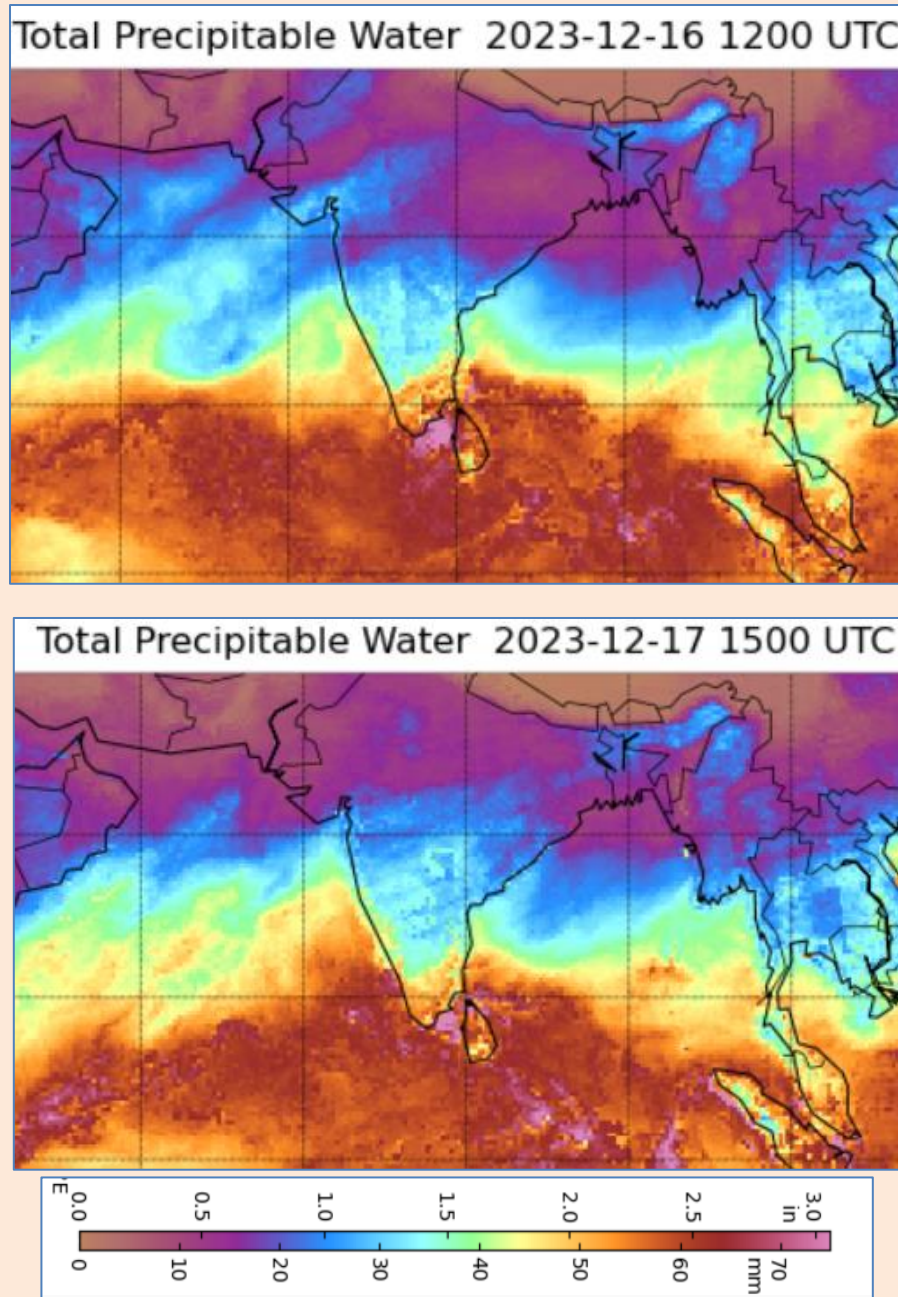


Fig.3g: MIMIC (Morphed Integrated Microwave Imagery at CIMSS) -Total Precipitable Water as on 16th/1730 IST and 17th/ 2030 IST

Under these favourable conditions, *fairly widespread - widespread* rainfall activity occurred over extreme southern districts of Tamilnadu with many places recording *extremely heavy* rainfall over Thoothukudi, Tirunelveli, Thenkasi and Kanyakumari districts during 17th-19th December 2023.

Light to moderate rainfall occurred (i) at *most* places over South Tamilnadu & at *many* places over North Coastal Tamilnadu with *isolated very heavy* rain over **Tirunelveli** district and

isolated heavy rain over **Kanyakumari, Ramanathapuram, Pudukottai, Thanjavur, Tiruvarur & Nagapattinam** districts during the **24 hours ending 08:30 IST of 17th** (ii) at *most* places over South Tamilnadu and at *a few* places over North Tamilnadu with *very heavy to extremely heavy* rain over the **Thoothukudi & Tirunelveli** districts; *heavy to very heavy rain* at many places and *extremely heavy* rain at *one or two* places over **Thenkasi & Kanyakumari** districts; *heavy to very heavy* rain at *a few* places over **Theni, Virudhunagar & Ramanathapuram** districts & at *isolated* places over **Sivagangai** district; and *heavy* rain at *isolated* places over **Madurai, Dindigul & Tiruppur** districts during the **24 hours ending 08:30 IST 18th** and (iii) at *many* places over South Tamilnadu and at *isolated* places over North Tamilnadu with *heavy to extremely heavy* rain over **Thoothukudi** district and *heavy to very heavy* rain over **Tirunelveli** district during the **24 hours ending 08:30 IST of 19th** December 2023.

On 18th, there were **37 extremely heavy, 37 very heavy** and **36 heavy** rainfall reports (total: **110** stations) from **South Tamilnadu**. All **19** stations that reported rainfall from **Tirunelveli** district recorded *extremely heavy rain*. There were **12 extremely heavy** and **4 very heavy** rainfall reports from **Thoothukudi** district; **5 extremely heavy, 3 very heavy** and **2 heavy** rainfall reports from **Thenkasi** district and **1 extremely heavy, 14 very heavy** and **11 heavy** rainfall reports from **Kanyakumari** district also on that day.

Kayalpattinam in Thoothukudi district reported the highest rainfall of **95 cm** followed by **Thiruchendur & Srivaikuntam** (both – Thoothukudi district) reported **69 cm** and **62 cm** respectively on **18th Dec 2023**. **12** other stations (9 from Tirunelveli, 2 from Thoothukudi and 1 from Thenkasi district) reported **more than 40 cm** on that day. **Thiruchendur** (Thoothukudi district) reported **23 cm** followed by **Kayalpattinam – 21 cm** on **19th December 2023**.

District-wise list of *heavy to extremely heavy* rainfall reported during 17th-19th December are given in Table-2 and are also presented in map form in Fig.4a. Thiruchendur AWS data indicating more than 60 cm of rain on 17th; with steady increase in rainfall from 17th/1730 IST onwards in presented in Fig.4b.

Prior to this event, the cumulative seasonal rainfall (as on 08:30 IST of 16th December 2023) was **+75% (Large Excess)** over **Kanyakumari** district, **+51% & +35% (Excess)** over **Tirunelveli & Thenkasi** districts respectively. **Thoothukudi** was under *Normal* category (-16%) during the same period. After this event, as on 08:30 IST of **19th December 2023**, cumulative seasonal rainfall figures rose to *Large Excess* for all the four districts with **+151%, +103%, +92% & +81%** for **Tirunelveli, Kanyakumari, Thoothukudi & Thenkasi** districts respectively.

Table -2: District-wise list of heavy-extremely heavy rainfall reports during 17th-19th Dec 2023

17.12.23				
SN	TIRUNELVELI	KANYAKUMARI	RAMANATHAPURAM	PUDUKOTTAI
1	Nalumukku - 19	Kanuakuamri - 11	Theerthandathanam - 8	Manamelkudi - 7
2	Oothu -17	Thirupathisaram AWS - 7	Vattanam - 7	
3	Kakkachi - 15		Tondi - 7	
4	Manjolai - 13		Ramnad KVK AWS - 7	
SN	THANJAVUR	TIRUVARUR	NAGAPATTINAM	
1	Orathanadu - 9	Murhupet -8	Thirkuvalai - 9	
2		Tiruvarur - 7		
3		Needamangalam - 7		

18.12.23				
SN	THOOTHUKUDI	TIRUNELVELI	KANYAKUMARI	THENKASI
1	Kayalpattinam - 95	Moolakaraipatti - 61	Mylaudy - 30	Gundar Dam - 51
2	Thiruchendhur - 69	Manjolai - 55	Nagercoil - 18	Shencottah - 30
3	Srivaikuntam - 62	Kovilpatti - 53	Kottaram - 18	Gadana Dam - 22
4	Thiruchendhur AWS - 61	Oothu - 50	Kanyakumari - 17	Ayikudi - 21
5	Maniyachi - 42	Naalumukku - 47	Kannimar - 16	Ramanadhi Dam - 21
6	Ottapidaram - 37	Palayamkottai - 44	Bhoothapandy - 14	Thenkasi - 17
7	Kadambur - 37	Ambasamudram - 43	Thirupathisaram AWS - 13	Sivagiri - 16
8	Kulasekarapattinam - 33	Cheranmahadevi - 41	Surlakode - 13	Karuppanadhi Dam - 13
9	Vedanatham - 30	Kannadaian Anicut - 41	Mambazhathuraiyaru - 12	Sankaran koil -8
10	Kayathar - 27	Kakkachi - 36	Anaikedanku - 12	Adavinainarkoil Dam - 8
11	Vilathukulam - 26	Nambiar Dam - 36	Pechiparai - 12	
12	Vaippar - 22	Papanasam - 35	Thirparappu - 12	
13	Kalugumalai - 19	Nanguneri - 33	Perunchani Dam - 12	
14	Ettayapuram - 17	Manimutharu - 33	Kurunthancode - 12	
15	Surangudi - 16	Kalakadu - 32	Chittar-I - 12	
16	Kadalkudi - 13	Tirunelveli - 31	Puthan Dam - 11	
17		Kodumudiyaru Dam - 30	Aralvaimozhi - 11	
18		Radhapuram - 27	Kozhiporvilai - 11	
19		Servarlar Dam - 27	Eraniel - 10	
20			Mukkadal Dam - 9	
21			Kalial - 9	
22			Kuzhithurai - 9	
23			Thuckalay - 8	
24			Adayamadai - 8	
25			Colachel - 7	
26			Mullanginavillai - 7	
SN	VIRUDHUNAGAR	RAMANATHAPURAM	THENI	SIVAGANGAI
1	Sattur - 20	Kamudhi - 13	Sothuparai - 13	Manamadurai - 17
2	Vembakottai - 18	Ramnad KVK AWS - 11	Thekkadi - 11	
3	Sivakasi - 17	Kamudhi ARG - 11	Veerapandi - 11	MADURAI
4	Aruppukottai KVK AWS - 17	Kadaladi - 11	Periyakulam - 9	Elumalai - 11
5	Kovilangulam - 17	Ramanathapuram - 10	Aranmanaipudur - 9	Peraiyur - 10
6	Srivilliputhur - 16	Paramakudi - 9	Shanmuganadhi - 9	Kallikudi - 7
7	Thiruchuzhi - 15	Mudukulatur - 9	Andipatti - 9	
8	Virudhunagar AWS - 15	Tondi - 7	Bodinaikanur - 9	DINDIGUL
9	Watrap - 15	Valinokam - 7	Periyar - 8	Kodaikanal - 10
10	Pilavakkal Periyar Dam - 14		Vaigai Dam - 7	
11	Rajapalayam - 14			TIRUPPUR
12	Virudhunagar - 13			Amaravathy Dam - 7
13	Aruppukottai - 12			
14	Kariyapatti - 8			

19.12.23		
SN	THOOTHUKUDI	TIRUNELVELI
1	Thiruchendur - 23	Nalumukku - 19
2	Kayalpattinam - 21	Kakkachi - 18
3	Kulasekarapattinam - 18	Manjolai - 17
4	Srivaikuntam - 17	Oothu - 15
5	Vaippar - 10	Moolaikaraipatti - 13
6	Ottapidaram - 9	Ambasamudram - 12
7	Maniyachi - 9	Papanasam - 11
8	Vedanatham - 8	Kannadaian anicut - 9
9	Surangudi - 8	Manimutharu - 8
10	Kadalkudi - 8	

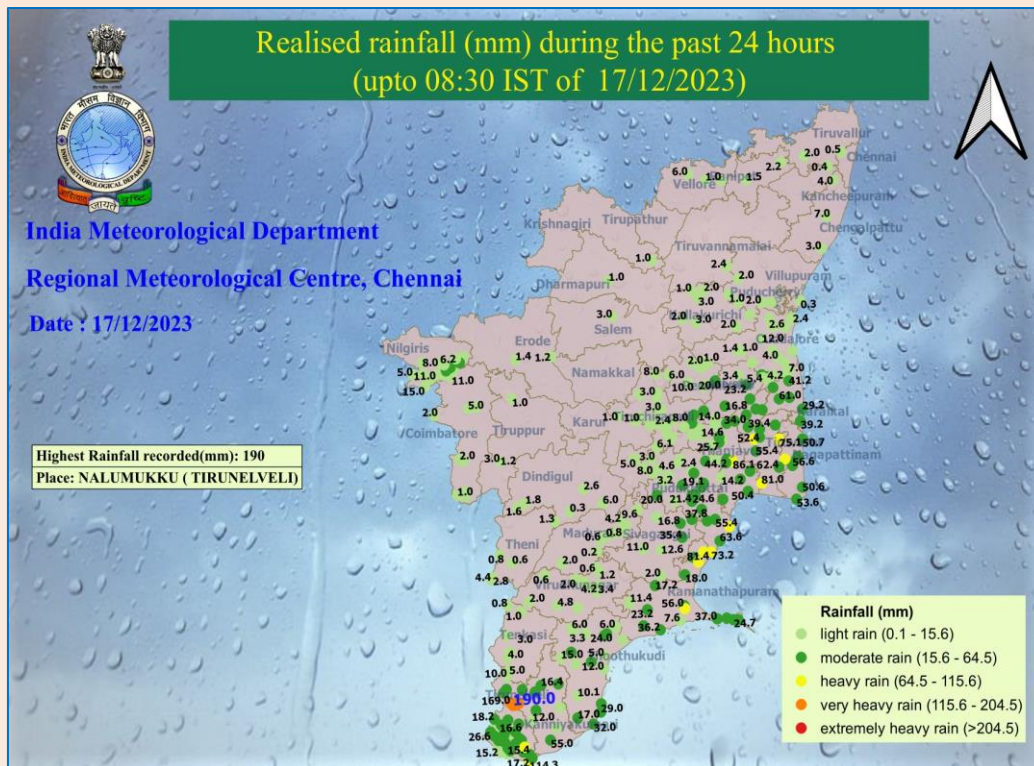


Fig.4a: 24-hr accumulated rainfall over Thoothukudi, Tirunelveli, Thenkasi & Kanyakumari districts as on 0830 IST of 17th, 18th & 19th December 2023

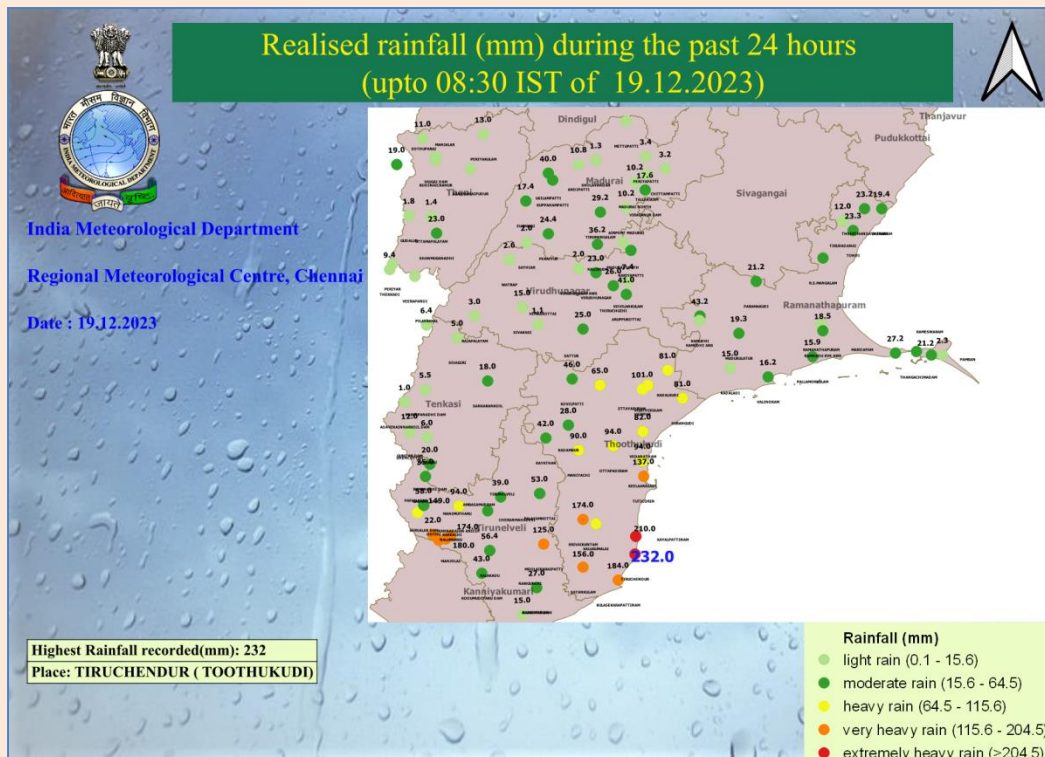
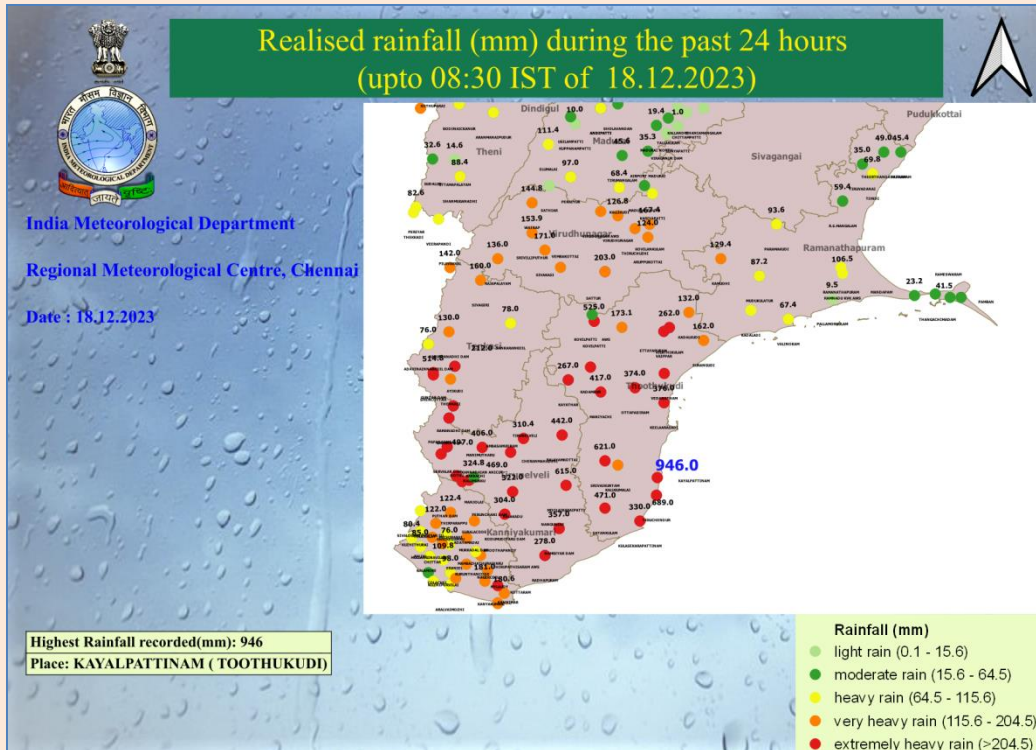


Fig.4a (contd.)

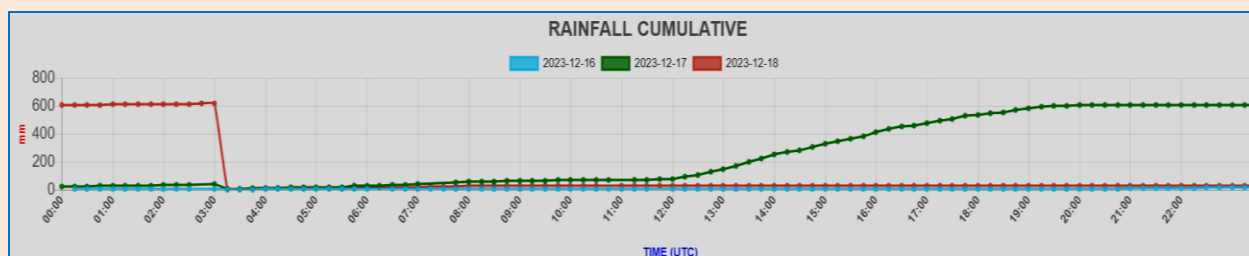


Fig.4b: Thiruchendur AWS data indicating rainfall during 16th-18th December 2023

Forecast and warnings issued

The system was continuously monitored from 13th December. Warning for *isolated heavy* rainfall on 16th & 17th was issued for south coastal districts on 14th; warning for *isolated heavy* to *very heavy* rainfall on 16th & 17th was issued for coastal districts on 15th; warning for *isolated heavy to very heavy* rain on 16th & 17th over **Kanyakumari, Tirunelveli, Thoothukudi & Thenkasi** districts was issued on 16th which was upgraded to *isolated heavy to very heavy rain with extremely heavy rain at one or two places* for the same districts on 17th. Day-1 warning issued for 16th rainfall and Day-2 and Day-1 warning issued on 16th & 17th respectively for 17th rainfall are presented in Fig.4c.

Associated impacts

Devastating floods occurred over Tirunelveli, Thoothukudi, Tenkasi & Kanyakumari districts. Even as low lying areas were inundated due to intense rainfall activity, riverine flooding due to over flowing rivers and breaching of many tanks and other water bodies resulted in cutting of road transport ways and railway tracks. Power supply and communication channels were totally disrupted. Though the torrential rain was the main factor for the floods, another equally significant contribution was from overflowing rivers and breaching of lakes & ponds. River Thamirabarani was in spate as release of water from reservoirs such as Papanasam and Manimuthar dams has been increased manifold when the extreme rainfall event was happening. The cascading effects of torrential rains coupled with release of huge volume of water from reservoirs and breaching of lakes and other water bodies have led to the devastating floods leading to loss of lives and property (Fig.4d&e).

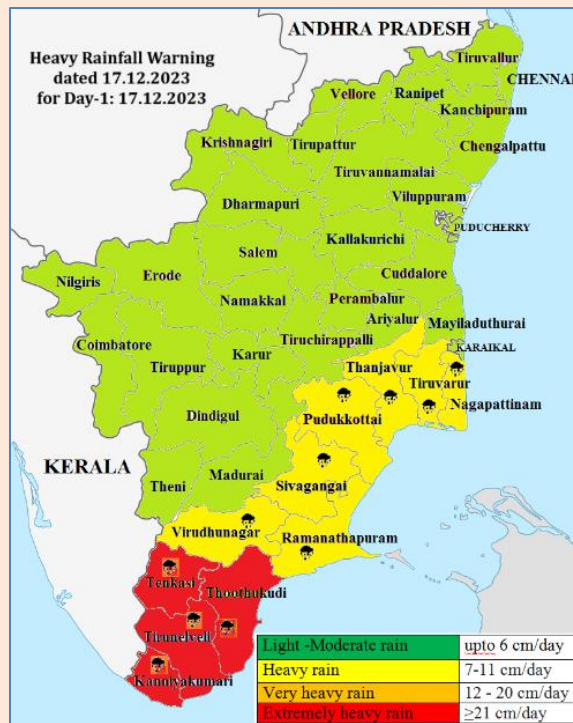
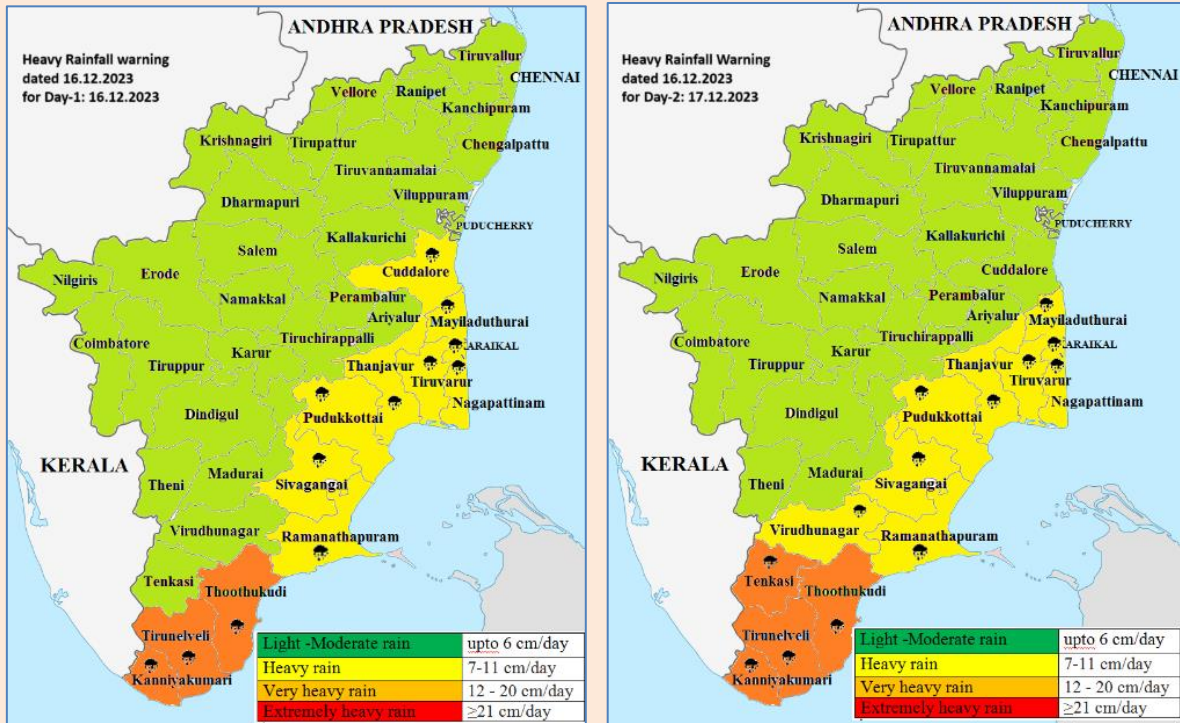


Fig.4c: Heavy rainfall warning issued on 16th for 16th & 17th and on 17th for 17th Dec 2023



Fig.4d: Drone view of an inundated area (Source: Mint dated 19 Dec 2023)

 **THE NEW INDIAN EXPRESS** Thursday

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Tamil Nadu rains: Flooded rly tracks, infra damage hit train services

Train services to the southern parts of the state were disrupted owing to the inundation of tracks and damage to critical railway infrastructure.

Published: 19th December 2023 06:10 AM | Last Updated: 19th December 2023 06:10 AM

 | [A+](#) [A](#) [A-](#)



The flooded Thoothukudi new bus stand.

Fig.4e: An extract of The New Indian Express dated 19th December 2023

4. Subdivisional rainfall performance during NEM 2023

4.1 Seasonal rainfall

During October-December 2023, the northeast monsoon seasonal rainfall was *normal* (-19% to +19%) to *excess* (+20% to +59%) over three meteorological subdivisions benefitted by the NEM viz., KER (+27%, excess), TN (+4%: normal), & CAP (-18%, normal), and was *deficient* (-20% to -59%) over RYS (-30%) and SIK (-26%). Fig.5a and Table-3 present the season ending (01st Oct-31st December 2023) rainfall figures over these subdivisions.

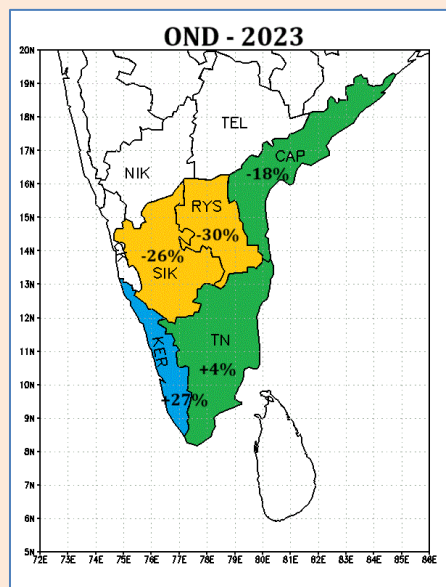


Fig.5a: Seasonal rainfall performance of NEM 2023 over the five meteorological subdivisions benefitted by the NEM

Table-3: Subdivisional seasonal rainfall during October-December 2023

Subdivision	01 st October – 31 st December 2023		
	Actual (mm)	Normal (mm)	PDN (%)
Tamilnadu, Puducherry & Karaikal (TN)	458.9	442.8	+4
Coastal Andhra Pradesh & Yanam (CAP)	265.8	322.9	-18
Rayalaseema (RYS)	164.7	236.4	-30
South Interior Karnataka (SIK)	146.8	199.0	-26
Kerala & Mahe (KER)	624.9	492.0	+27

PDN: Percentage Departure from Normal

Legend:

<i>Largely Deficient</i>	<i>Deficient</i>	<i>Normal</i>	<i>Excess</i>	<i>Large Excess</i>
≤ -60%	-20% to -59%	-19% to +19%	+20% to +59%	≥ +60%

Note: Kindly refer appendix-(i)-(iii) for description of terminologies

4.2 Monthly, Weekly & Daily rainfall scenario

The intra-seasonal rainfall distribution over various sub-divisions during Oct-Dec 2023 is presented in monthly and daily scales. Month-wise rainfall statistics are presented in Table-4 and Fig.5b. Tables-5a&b present the weekly rainfall over the various subdivisions and Tables-6a&b present the daily rainfall scenario in terms of spatial rainfall distribution (*Widespread: WS, Fairly widespread: FWS, Scattered: SCT, Isolated: ISOL and DRY*).

Table-4: Subdivisional monthly rainfall during NEM 2023

2023 SUB-DIVISION	OCT			NOV			DEC		
	Actual rainfall	Normal rainfall	PDN (%)	Actual rainfall	Normal rainfall	PDN (%)	Actual rainfall	Normal rainfall	PDN (%)
	(mm)	(mm)		(mm)	(mm)		(mm)	(mm)	
CAP & Yanam	19.4	182.2	-89	82.7	113.1	-27	171.4	27.6	+521
RYS	12.7	132.1	-90	68.9	78.4	-12	83.2	25.9	+221
TN, PDC & KKL	98.4	171.9	-43	233	181.7	+28	127.5	89.2	+43
SIK	64.0	137.2	-53	76.4	51.2	+49	6.4	10.6	-40
KER & Mahe	310.5	306.5	+1	240.1	153.1	+57	74.3	32.4	+129

Largely Deficient	Deficient	Normal	Excess	Large Excess
≤ -60%	-20% to -59%	-19% to +19%	+20% to +59%	≥ +60%

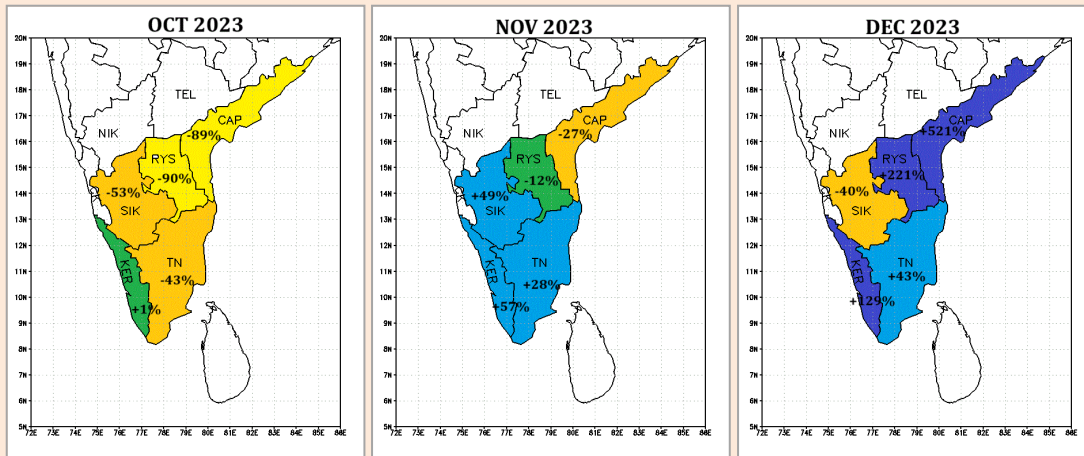


Fig.5b: Subdivisional monthly rainfall performance during October-December 2023

During October, despite setting in of easterlies and commencement of NEM by 16th October (4 days prior to the normal date of 20th October), under the influence of formation and northeastward movement of **VSCS HAMOON** over the BOB during 21st-25th October, there were changes in the flow pattern and sweeping away of moisture from the NEM region such that excepting KER that received *normal* rainfall of +1%, all the other four subdivisions became *deficient* to *largely deficient*. RYS & CAP were reported *largely deficient* rainfall of -90% & -89% respectively; TN & SIK recorded *deficient* rainfall of -43% & -53% respectively. In

November, under the influence of troughs in easterlies and upper air cyclonic circulations, excepting CAP that became *deficient* at -27%, all the other four subdivisions received *normal* to *excess* rainfall with KER, SIK & TN recording excess rainfall of +57%, +49% & +28% respectively. In December, under the influence of the **SCS MICHAUNG** that crossed south AP coast and the historical extreme rainfall event over south TN, excepting SIK that became *deficient* (-40%), all the other four subdivisions received *excess* to *large excess* rainfall. CAP, RYS & KER received *large excess* rainfall of +521%, +221% & +129% respectively and TN received *excess* rainfall of +43% during the month.

Table 5a: Weekly rainfall performance over various subdivisions during Oct-Dec 2023

2023	WEEK-BY-WEEK: PDN (%)												
	04-Oct	11-Oct	18-Oct	25-Oct	01-Nov	08-Nov	15-Nov	22-Nov	29-Nov	06-Dec	13-Dec	20-Dec	27-Dec
CAP	-24	-95	-99	-96	-95	+5	-77	-62	+38	+1753	-31	-96	-100
RYS	-45	-84	-95	-96	-90	+5	-50	-53	+24	+688	-67	-60	-100
TN	-32	-40	31	-88	-53	+49	+33	-34	+49	+64	-37	+220	-63
SIK	-59	-17	-32	-98	-68	+129	+120	-99	0	-35	+56	-99	-100
KER	+163	-72	46	-14	-30	+76	+24	+27	+170	+65	+255	+165	-75

Table 5b: Cumulative week ending scenario during Oct-Dec 2023

2023	CUMULATIVE WEEK ENDING : PDN (%)												
	04-Oct	11-Oct	18-Oct	25-Oct	01-Nov	08-Nov	15-Nov	22-Nov	29-Nov	06-Dec	13-Dec	20-Dec	27-Dec
CAP	-24	-78	-86	-86	-90	-74	-75	-74	-67	-14	-15	-17	-17
RYS	-45	-86	-89	-91	-90	-76	-74	-72	-65	-27	-28	-29	-30
TN	8	-42	-11	-39	-43	-21	-13	-15	-8	-2	-4	6	4
SIK	-64	-19	-36	-51	-54	-30	-22	-27	-26	-26	-24	-25	-26
KER	113	-3	17	9	1	12	13	14	20	21	26	28	28

In the weekly scale (tables 5a&b), the major rainfall weeks were the weeks ending 06th December when four subdivisions received *large excess* rainfall, mainly under the influence of the **SCS MICHAUNG**, and 29th November when four subdivisions received *excess* to *large excess* rainfall. KER received large excess rainfall during six weeks - weeks ending 04th October, 08th & 29th November and 06th, 13th & 20th December and *excess* rainfall during the three weeks ending 18th October, 15th & 22nd November. TN received *large excess* rainfall during the two weeks ending 06th & 20th December and *excess* rainfall during the weeks ending 18th October, 08th, 15th & 29th November. Over CAP & RYS, there was only one week each of *normal*, *excess* & *large excess* rainfall during the weeks ending 08th November, 29th November and 06th December respectively and during all the other 10 weeks, both these subdivisions became *deficient*- *largely deficient*.

Table-6a: Spatial rainfall distribution during 01st October -31st December 2023

Date as on 08:30 IST	TN	CAP	RYS	SIK	KER
01-10-2023	SCT	FWS	SCT	FWS	WS
02-10-2023	ISOL	SCT	ISOL	SCT	WS
03-10-2023	ISOL	ISOL	ISOL	ISOL	FWS
04-10-2023	ISOL	SCT	ISOL	ISOL	SCT
05-10-2023	ISOL	ISOL	ISOL	ISOL	ISOL
06-10-2023	ISOL	ISOL	ISOL	ISOL	ISOL
07-10-2023	ISOL	DRY	ISOL	ISOL	ISOL
08-10-2023	ISOL	ISOL	ISOL	ISOL	ISOL
09-10-2023	ISOL	ISOL	ISOL	SCT	SCT
10-10-2023	SCT	ISOL	ISOL	FWS	SCT
11-10-2023	SCT	ISOL	ISOL	SCT	FWS
12-10-2023	SCT	ISOL	ISOL	FWS	WS
13-10-2023	SCT	DRY	DRY	SCT	FWS
14-10-2023	ISOL	ISOL	ISOL	DRY	FWS
15-10-2023	FWS	DRY	DRY	ISOL	WS
16-10-2023	SCT	ISOL	ISOL	ISOL	SCT
17-10-2023	FWS	DRY	ISOL	SCT	FWS
18-10-2023	SCT	DRY	DRY	SCT	WS
19-10-2023	ISOL	ISOL	DRY	ISOL	SCT
20-10-2023	ISOL	ISOL	DRY	DRY	SCT
21-10-2023	ISOL	ISOL	ISOL	DRY	SCT
22-10-2023	ISOL	ISOL	ISOL	ISOL	SCT
23-10-2023	ISOL	DRY	DRY	ISOL	FWS
24-10-2023	SCT	DRY	DRY	DRY	FWS
25-10-2023	ISOL	ISOL	DRY	DRY	FWS
26-10-2023	ISOL	ISOL	DRY	DRY	ISOL
27-10-2023	ISOL	ISOL	DRY	DRY	SCT
28-10-2023	ISOL	ISOL	DRY	DRY	SCT
29-10-2023	SCT	ISOL	ISOL	ISOL	SCT
30-10-2023	FWS	ISOL	ISOL	SCT	WS
31-10-2023	FWS	ISOL	ISOL	SCT	WS
01-11-2023	SCT	DRY	ISOL	ISOL	FWS
02-11-2023	FWS	ISOL	ISOL	ISOL	SCT
03-11-2023	FWS	SCT	ISOL	ISOL	FWS
04-11-2023	WS	SCT	ISOL	SCT	WS
05-11-2023	WS	SCT	SCT	FWS	WS
06-11-2023	SCT	SCT	FWS	WS	FWS
07-11-2023	FWS	SCT	SCT	WS	WS
08-11-2023	FWS	FWS	SCT	SCT	FWS
09-11-2023	WS	SCT	FWS	WS	WS
10-11-2023	WS	ISOL	ISOL	SCT	WS
11-11-2023	SCT	ISOL	DRY	ISOL	FWS
12-11-2023	ISOL	DRY	DRY	DRY	SCT
13-11-2023	ISOL	DRY	DRY	DRY	ISOL
14-11-2023	FWS	ISOL	ISOL	DRY	ISOL
15-11-2023	SCT	ISOL	ISOL	ISOL	ISOL

Table-6a (contd.)

Date as on 08:30 IST	TN	CAP	RYS	SIK	KER
16-11-2023	SCT	ISOL	ISOL	DRY	ISOL
17-11-2023	ISOL	DRY	DRY	DRY	SCT
18-11-2023	ISOL	ISOL	ISOL	DRY	SCT
19-11-2023	SCT	DRY	DRY	ISOL	SCT
20-11-2023	ISOL	ISOL	ISOL	DRY	ISOL
21-11-2023	ISOL	SCT	ISOL	DRY	ISOL
22-11-2023	FWS	FWS	SCT	ISOL	FWS
23-11-2023	WS	SCT	SCT	SCT	WS
24-11-2023	SCT	SCT	ISOL	SCT	SCT
25-11-2023	SCT	ISOL	SCT	ISOL	ISOL
26-11-2023	FWS	ISOL	ISOL	SCT	SCT
27-11-2023	FWS	ISOL	ISOL	ISOL	ISOL
28-11-2023	SCT	ISOL	SCT	ISOL	ISOL
29-11-2023	SCT	ISOL	ISOL	ISOL	ISOL
30-11-2023	FWS	ISOL	ISOL	ISOL	ISOL
01-12-2023	SCT	ISOL	SCT	ISOL	ISOL
02-12-2023	SCT	ISOL	ISOL	ISOL	SCT
03-12-2023	SCT	ISOL	SCT	ISOL	ISOL
04-12-2023	SCT	SCT	SCT	ISOL	SCT
05-12-2023	ISOL	WS	FWS	ISOL	ISOL
06-12-2023	ISOL	WS	SCT	ISOL	ISOL
07-12-2023	ISOL	FWS	ISOL	ISOL	ISOL
08-12-2023	ISOL	ISOL	ISOL	ISOL	SCT
09-12-2023	SCT	ISOL	ISOL	SCT	WS
10-12-2023	ISOL	ISOL	ISOL	ISOL	SCT
11-12-2023	ISOL	ISOL	DRY	ISOL	SCT
12-12-2023	ISOL	ISOL	DRY	ISOL	ISOL
13-12-2023	ISOL	ISOL	DRY	ISOL	SCT
14-12-2023	ISOL	DRY	DRY	DRY	ISOL
15-12-2023	ISOL	ISOL	DRY	DRY	ISOL
16-12-2023	SCT	ISOL	ISOL	DRY	ISOL
17-12-2023	FWS	ISOL	ISOL	ISOL	ISOL
18-12-2023	FWS	ISOL	DRY	DRY	FWS
19-12-2023	SCT	DRY	DRY	DRY	SCT
20-12-2023	ISOL	DRY	DRY	DRY	ISOL
21-12-2023	ISOL	DRY	DRY	DRY	ISOL
22-12-2023	SCT	DRY	DRY	DRY	ISOL
23-12-2023	ISOL	DRY	DRY	DRY	DRY
24-12-2023	ISOL	DRY	DRY	DRY	ISOL
25-12-2023	ISOL	DRY	DRY	DRY	ISOL
26-12-2023	ISOL	DRY	DRY	DRY	DRY
27-12-2023	DRY	DRY	DRY	DRY	DRY
28-12-2023	ISOL	DRY	DRY	DRY	DRY
29-12-2023	ISOL	DRY	ISOL	DRY	DRY
30-12-2023	ISOL	DRY	DRY	DRY	ISOL
31-12-2023	ISOL	DRY	DRY	DRY	ISOL

Table-6b: Percentage frequency of various categories of daily spatial rainfall distribution

Category	OCT - DEC 2023				
	TN	CAP	RYS	SIK	KER
WS	5	2	0	3	15
FWS	16	4	3	4	16
SCT	29	13	13	16	27
ISOL	48	52	47	40	36
DRY	1	28	37	36	5

WD: Widespread
(76-100% of stations reporting rainfall)

FWD : Fairly widespread
(51-75% of stations reporting rainfall)

SCT: Scattered
(26-50% of stations reporting rainfall)

ISOL: Isolated
(≤25% of stations reporting rainfall)

DRY: No rain

Whereas the seasonal cumulative weekly rainfall figures were generally *normal - excess* during all the weeks over KER, it was *deficient - largely deficient* during all the weeks over RYS. Over TN, it was generally *deficient- normal* till the week ending 08th November and subsequently it was under *normal* category throughout. Over CAP, it was *deficient-largely deficient* till the week ending 29th November. During the week ending 06th December, under the influence of **SCS MICHAUNG**, the seasonal rainfall figures improved from *largely deficient* (-67%) to *normal* (-14%) and thereafter, it remained under *normal* category for the rest of the season. Over SIK, it was generally under *deficient* category throughout.

In the daily scale, *fairly widespread* to *widespread* rainfall occurred over KER on 31% of the days during the season; over TN on 21% of the days and over CAP, RYS & SIK – on about 3 to 7% of the days. TN & KER recorded *isolated to scattered* rainfall activity on about 77% & 63% respectively of the days during the season. On about 28-37% of the days during the season, CAP, RYS & SIK remained *dry*.

4.3 Monsoon activity & heavy rainfall events

Table-7a&b present the frequency of active and vigorous monsoon days and frequency of heavy rainfall days (**Heavy** rainfall ≥ 7cm/day; **Very Heavy** rainfall ≥ 12cm/day; **Extremely Heavy** rainfall ≥ 21 cm/day) during the season.

Active to vigorous monsoon conditions prevailed over TN on 22% of the days during the season (20 days out of 92 days); over KER, 13% of the days; and over CAP, RYS & SIK, on about 3-5% of the days during the season. In October, there were 5 days of **active to vigorous** monsoon conditions over KER; and 2 days each over TN & SIK. In November, 12 days & 5 days of **active to vigorous** monsoon conditions prevailed over TN & KER respectively; and 1-3 days over SIK, CAP & RYS. In December, 6 days of **active to vigorous** monsoon activity occurred over TN; and 1-3 days over CAP, RYS & KER.

Table-7a: Frequencies of active and vigorous monsoon days during Oct-Dec 2023

Subdivision	No. of days of active and vigorous monsoon conditions							
	OCT		NOV		DEC		OCT-DEC	
	ACT	VIG	ACT	VIG	ACT	VIG	ACT	VIG
TN	2	0	11	1	4	2	17	3
CAP	0	0	1	0	1	2	2	2
RYS	0	0	2	0	0	1	2	1
SIK	2	0	0	3	0	0	2	3
KER	4	1	2	3	0	2	6	6

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 3 cm in coastal Tamil Nadu, south coastal Andhra Pradesh and 2 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.

Table-7b: Frequency of heavy rainfall days during Oct-Dec 2023

Subdivision	No. of days of heavy / very heavy / extremely heavy rainfall events during Oct-Dec 2023											
	Oct			Nov			Dec			Oct-Dec		
	≥ 21 cm/day	≥ 12 cm/day	≥ 7 cm/day	≥ 21 cm/day	≥ 12 cm/day	≥ 7 cm/day	≥ 21 cm/day	≥ 12 cm/day	≥ 7 cm/day	≥ 21 cm/day	≥ 12 cm/day	≥ 7 cm/day
TN	0	3	15	2	12	27	5	9	15	7	24	57
CAP	0	0	0	0	1	6	2	5	10	2	6	16
RYS	0	0	0	0	1	6	1	4	8	1	5	14
SIK	0	1	13	0	0	12	0	0	0	0	1	25
KER	1	5	27	0	5	19	0	1	8	1	11	54

Heavy: rainfall ≥ 7cm/day; **Very Heavy:** rainfall ≥ 12cm/day; **Extremely Heavy:** rainfall ≥ 21 cm/day

Regarding heavy rainfall occurrences (≥ 7 cm/day), TN experienced 57 days (62%) of isolated heavy rainfall events during the season including 24 days (26%) of isolated very heavy rain with isolated extremely heavy falls on 7 days (8%). Over Kerala, isolated heavy rain occurred on 59 days including 12 days of isolated very heavy rain and 1 day of isolated extremely heavy rain. Over CAP, isolated heavy rain occurred on 17 days including 7 days of isolated very heavy rainfall & 2 days of isolated extremely heavy rain. There were 15 days of isolated heavy rainfall activity over RYS including 5 days of isolated very heavy rain with isolated extremely heavy falls on 1 day. SIK experienced 27 days of isolated heavy rain including 1 day of isolated very heavy rain. District-wise list of very heavy to extremely heavy rainfall events over various subdivisions is presented in Table-7c.

Table-7c: List of very heavy to extremely heavy rainfall events during Oct-Dec 2023

DISTRICT	Date, Station and 24-hr accumulated rainfall (in cm) (ending 0830 IST of the specified date)
TAMILNADU, PUDUCHERRY & KARAIKAL	
CHENNAI	<p>Nov : 04th : Zone 12 Alandur-12; 15th : DGP Office-12; 30th - Zone 06 D65 Kolathur – 15, Zone 06 T.V.K.Nagar-15, Zone 07 Ambattur-14, Zone 08 Malar Colony-14, Zone 12 Alandhur-13, Anna University-12, Ambattur-12, Zone 13 Adyar Eco Park-12, Zone 11 U32 Maduravoyal-12</p> <p>Dec : 04th : Zone 14 Perungudi-29, Alandur-25, Chennai (AP)-25, Zone 13 Adyar- 23, Zone 12 Meenambakkam-23, Meenambakkam AWS-23, Chennai (N)-23, MGR Nagar-22, , Zone 10 Kodambakkam-22, CD Hospital Tondiarpet-22, Zone 11 Valasaravakkam-21, Zone 15 Sholinganallur-21, DGP Office-21,NIOT_Pallikaranai ARG -21,Chennai (N) AWS -21, Anna University -21, Zone 03 Puzhal -20,Perambur -20, Zone 09 Ice House -20, Ayanavaram Taluk Office -19, Taramani ARG -19, Anna Nagar -19, Chennai Collector Office -18, Sholinganallur -18,Zone 09 Teynampet -18, Zone 08 Malar Colony -18, Ambattur-18, Anna University ARG -18, Valasaravakkam -18, YMCA Nandnam ARG-18, Kodambakkam -18, Ambathur-2 -17, Zone 06 T.V.K Nagar-16, Zone 04 Tondiarpet-16, Teynampet-16, Zone 01 Kathivakkam-16, Thiru-Vi-Ka Nagar -16, Zone 03 Madhavaram -16, Zone 08 Anna Nagar-15, Sholinganallur-15, Zone 06 D65 Kolathur-15, Tondairpet -15, Zone 14 U41 Perungudi-15, Ennore AWS-15, Zone 05 GCC-14, Zone 07 Ambattur -14, Zone 13 Adyar Eco Park-14, Zone 12 Alandur-14, Zone U39 Adyar-13, Zone 02 Manali-13, Zone 15 Uthandi-12, Zone D156 Mugalivakkam-12, Royapuram-12, Zone 07 U18 D81 Vanagaram-12; 05th : Chennai (N) -24, Chennai(N) AWS -24, Zone 09 Ice House-22, Royapuram-21, Zone 13 Adyar-21, Zone 05 GCC-21, Thiru-Vi-Ka Nagar -21, ,Zone 10 Kodambakkam-21, Zone 15 Sholinganallur -19, Kodambakkam-19, Chennai (AP)-19, Meenambakkam AWS-19, Taramani ARG-19, Teynampet-18,Valasaravakkam-18, Anna University ARG-18,Zone 11 Valasaravakkam -18, NIOT_Pallikaranai ARG-17, Zone Alandhur-12</p>
CHENGALPATTU	<p>Dec : 04th : Mahabalipuram-22, VIT_Chennai AWS-19, Tambaram-17, Kelambakkam-17, Thirukalukundram-14, Thirupporur-13, Chengalpattu-12 ; 05th : Kelambakkam-16, Alandur-14, Thirupporur-14, Tambaram-24, Mahabalipuram-22</p>
CUDDALORE	<p>Nov: 14th : Cuddalore-12,Parangipettai-12; 22nd : Parangipettai-13; 26th : Sethiathope-17;</p>
COIMBATORE	<p>Nov : 04th : Pillur Dam Mettupalayam -13; 05th : Valparai PAP-13, Valparai Taluk Office-13; 09th : Pillur Dam Mettupalayam-15; 23rd</p>

	: Mettupalayam-37
ERODE	Nov: 07th : Bhavani-12; 23rd : Kavundapadi-15
KANCHIPURAM	Dec : 04th : Satyabama Uty ARG-19, KVK Kattukuppam AWS -18, Chembarapakkam_Rev -16, Sriperumbudur-13, Chembarabakkam_CMWSSB-13, Kundrathur-12; 05th : KVK Kattukuppam AWS-27, Chembarapakkam_Rev-21, Kundrathur-19, Sriperumbudur-17, Chembarabakkam_CMWSSB-12
KANYAKUMARI	Oct : 03rd : Kurunthancode-13; 15th : Mambzhathuraiyaru-17, Anaikedanku-17, Mullanginavillai -16, Kalial -16, Kuzhithurai -15, Thirparappu-14, Kozhiporvilai-14, Chittar-13, Sivalogam-12 Nov: 07th : Sivalogam (Chittar II)-12; 23rd : Kozhiporvilai-13, Thuckalay-12 Dec: 18th : Mylaudy-30, Nagercoil-18, Kottaram-18, Kanniyakumari-17, Kannimar-16, Bhoothapandy-14, Thirupathisaram AWS-13, Suralacode-13, Mambzhathuraiyaru-12, Anaikedanku-12, , Pechiparai-12, Perunchani Dam-12, Kurunthancode-12, Chittar-I-12, Thirparappu-12
KARUR	Oct : 15th : Karur Paramathi-14, Anaippalayam-13
KARAIKAL	Nov: 14th : Karaikal-14; 15th : Karaikal-14
MADURAI	Oct: 12th : Madurai City-12, Madurai North-12 Nov: 22nd : Andipatti-14
NAGAPATTINAM	Nov: 14th : Velankanni-17, Nagapattinam-15; 30th : Thalaingnayer -13
NILGIRIS	Nov: 09th : Kil Kotagiri Estate-23; 23rd : Kil Kotagiri Estate-24, Coonoor PTO-13 Dec : 09th : Kil Kotagiri Estate-12
PUDUKKOTTAI	Nov : 23rd : Vamban KVK AWS-13
PUDUCHERRY	Nov: 14th : Puducherry-12; 15th : Puducherry-12
RAMANATHAPURAM	Nov: 04th : Kamudhi -12; 11th : Thangachimadam-15, Mandapam-14; 23rd : Kadaladi-17, Valinokam-15 Dec : 18th : Kamudhi -13
SIVAGANGAI	Dec : 18th : Manamadurai-17
THENI	Oct : 16th : : Periyakulam PTO-14, Periya kulam AWS -12 Dec : 18th : Sothuparai-13
THENKASI	Nov: 04th : Sivagiri-12; 06th : Thenkasi-12; 23rd : Ayikudi-13 Dec : 18th : Gundar Dam-51, Shencottah-30, Gadana Dam-22, Ayikudi - 21, Ramanadhi Dam Section-21, Thenkasi-17, Sivagiri-16, Karuppanadhi Dam-13

THOOTHUKUDI	<p>Nov : 20th : Kulasekarapattinam-16, Satankulam-12</p> <p>Dec : 18th : Kayalpattinam-95, Tiruchendur-69, Old Taluk Office Srivaikuntam-62, Thiruchendur AWS-61, Kovilpatti-53, Maniyachi-42, Ottapadiram-37, Kadambur-37, Kulasekarapattinam-33, Vedanatham-30, Kayatha-27, Vilathikulam-26, Vaippar-22, Kalugumalai-19, Ettayapuram-17, Surangudi-16, Kadalkudi-13; 19th : Tiruchendur-23, Kayalpattinam-21, Kulasekarapattinam-18, Old Taluk Office Srivaikuntam-17</p>
TIRUNELVELI	<p>Nov: 09th : Moolaikaraipatti-14</p> <p>Dec : 17th : Nalumukku-19, Oothu-17, Kakkachi-15, Manjolai-13</p> <p>18th : Moolaikaraipatti-61, Manjolai-55, Oothu-50, Nalumukku-47, Palayamkottai-44, Ambasamudram-43, Cheranmahadevi-41, Kannadaian Anicut-41, Kakkachi-36, Nambiyar Dam-36, Papanasam-35, Nanguneri-33, Manimutharu-33, Kalakadu-32, Tirunelveli-31, Kodumudiyaru Dam-30, Radhapuram-27, Servalar Dam-27; 19th: Nalumukku-19, Kakkachi-18, Manjolai-17, Oothu-15, Moolaikaraipatti-13, Ambasamudram-12; 29th: Kakkachi-16, Oothu-16, Nalumukku-15; 30th: Oothu-22, Nalumukku-21, Kakkachi-20</p>
THIRUVARUR	<p>Nov: 14th : Nannilam-12; 15th : Nannilam-12</p>
THIRUVALLUR	<p>Nov: 30th: Avadi-19, Ponneri-15, Choloavaram-13, Puzhal ARG-12, Red Hills-12</p> <p>Dec : 03rd : Pallipattu-15, Uthukottai-13; 04th : Avadi-28, Puzhal ARG-23, Cholavaram-23, Ponneri-21, Red Hills-20, Thamaraiykkam-18, Good Will School Villivakkam ARG-18, Gummidipoondi-17, Tiruvallur-16, Uthukottai-15, Tirur KVK AWS-15, Poonamallee-14, Koratur-14; 05th : Poonamallee-34, Avadi-28, Thamaraiykkam-19, Tirur KVK AWS-19, Tiruvallur-18, Uthukottai-17, Koratur-17, Ponneri-17, Cholavaram-15, Thiruvallangadu-14, Poondi-14, Red Hills-13, Tiruttani-12, Gummidipoondi-12</p>
TIRUPPUR	<p>Nov: 09th : Avinasi-12; 22nd : PWD-17, Avinasi-14</p>
VIRUDHUNAGAR	<p>Nov : 22nd : Watrap-12</p> <p>Dec : 18th : Sattur-20, Vembakottai-18, Sivakasi-17, Aruppukottai KVK AWS-17, Kovilankulam-17, Srivilliputhur-15, Thiruchuzhi-15, Virudhunagar AWS-15, Watrap-15, Pilavakkal Periyar Dam-14, Rajapalayam-14, Virudhunagar-13, Aruppukottai-12</p>
COASTAL ANDHRA PRADESH & YANAM	
ALLURI SITHARAMARAJU	<p>Dec : 06th : Kunavaram-19, Chintur-15, Chintapalle-12, Paderu-12</p>

ANAKAPALLI	Dec : 06th : Narsipatnam-20, Anakapalle-19, Yelamanchili-19, Chodavaram-15, Anakapalle-13
B R AMBEDKAR KONASEEMA	Dec : 05th : Amalapuram -17; 06th : Amalapuram-19
BAPATLA	Dec : 05th : Bapatla-22, Addanki-17, Karamchedu-17; 06th : Santhamaguluru-16
ELURU	Dec : 06th : Bhimadole-24, Kukunoor-22, Chintalapudi-21, Koyyalagudem-20, Kaikalur-16, Polavaram-16, Velairpad-13, Nuzvid-12
KAKINADA	Dec : 06th : Prathipadu -16, Kakinada-14, Tuni-12
KRISHNA	Dec : 05th : Masulipatnam Cdr-16, Avanigada-14
NTR	Dec : 06th : Tiruvuru-13
PALNADU	Dec : 06th : Sattenapalle-18
PRAKASAM	Dec : 05th : Ongole-12; 06th : Darsi-14
WEST GODAVARI	Dec : 06th : Narsapuram-21, Bheemavaram-20, Palakoderu-18, Tanuku-17, Tadepalligudem-14
SPSR NELLORE	Nov : 06th : Kandukur-12 Dec : 04th : Nellore-19; 05th : Nellore-22, Rapur-21, Atmakur-19; Kavali-15, Vinjamur-14, Udayagiri-13
VISHAKHAPATNAM	Dec : 06th : Visakhapatnam-15
VIZIANAGARAM	Dec : 06th : Denkada-15, Srungavarapukota-13, Mentada-12
RAYALASEEMA	
ANNAMAYYA	Dec : 05th : Penagaluru -23, Rajampet-12
CHITTOOR	Dec : 04th : Nagari-12; 05th : Nagari-13
YSR	Dec : 05th : Kodur-24
TIRUPATI	Dec : 03rd : Thottambedu-15, Srikalahasti-14, Tirupati Aero-13; 04th : Sullurpeta-20, Tada-19, Gudur-14, Srikalahasti-13, Thottambedu-13, Satyavedu-13; 05th : Gudur-28, Srikalahasti-24, Thottambedu-23, Sullurpeta-23, Tada-20, Venkatagiri-18, Satyavedu-14, Tirupati Aero-13
SOUTH INTERIOR KARNATAKA	
CHIKKAMAGALURU	Oct : 01st : Kottigehara-12

KERALA & MAHE	
ALAPPUZHA	Oct : 15 th : Cherthala-20, Mavelikara-17, Alapuzha-13 Nov : 04 th : Mancompu-12
ERNAKULAM	Oct : 12 th : Neeleswaram Arg-18; 15 th : Ernakulam South-13 Nov : 05 th : Kochi C.i.a.l.-19, Neeleswaram Arg-17
IDUKKI	Nov : 23 rd : Peerumedu -12
KANNUR	Oct : 01 st : Taliparamba -13 Nov : 09 th : Kannur-16, Kannur Icar AWS-13
KOTTAYAM	Oct : 01 st : Vaikom-13
KOLLAM	Oct : 15 th : Paripalli Aws-12; 24 th : Chavara AWS-12 Nov : 07 th : Punalur-14
KOZHIKODE	Nov : 09 th : Peruvannamuzhi ARG-13
THIRUVANANTHAPURAM	Oct : 15 th : Trivandrum Aero-21, Pirappancode Aws-13, Thiruvananthapuram -12 Nov : 23 rd : Thiruvananthapuram-15
THRISSUR	Oct : 15 th : Lower Sholayar Aws-13 Nov : 05 th : Irinjalakuda-12, Peringalkuthu Aws-12
PALAKKAD	Oct : 15 th : Palakkad-12, Malampuzha Dam Aws-12 Dec : 09 th : Chittur-13
PATHANAMTHITTA	Oct : 15 th : Thiruvalla Aws-15, Kunnathanam Aws-12 Nov : 23 rd : Kunnathanam Aws-15, Enadimangalam Aws-13 Dec : 09 th : Kurudamannil-18

4.4 District rainfall scenario

Fig.5c presents the district wise seasonal rainfall during October to December 2023. As seen, all districts in KER received *normal – excess* rainfall with Pathanamthitta receiving *large excess* rainfall (+94%) during the season. In TN, all southern districts received *normal to largely excess* rainfall; and in north TN, western ghat & some adjoining districts, and extreme northeastern districts received *normal-excess* rainfall; generally *normal* rainfall was recorded in the delta districts; and all other north interior districts came under *deficient* category. In SIK, excepting Mysuru that received *excess* rainfall (+32%), all other districts received *deficient-normal* rainfall. In RYS, excepting Tirupati that received normal rainfall (+5%), all other districts ended up *deficient-largely deficient* (-26% to -89%). In CAP, Eluru, Konaseema & Palnadu received *excess* rainfall; East Godavari & Srikakulam ended up *largely deficient* at -98% & -75% respectively; and all other districts recorded *deficient-normal* rainfall during the season.

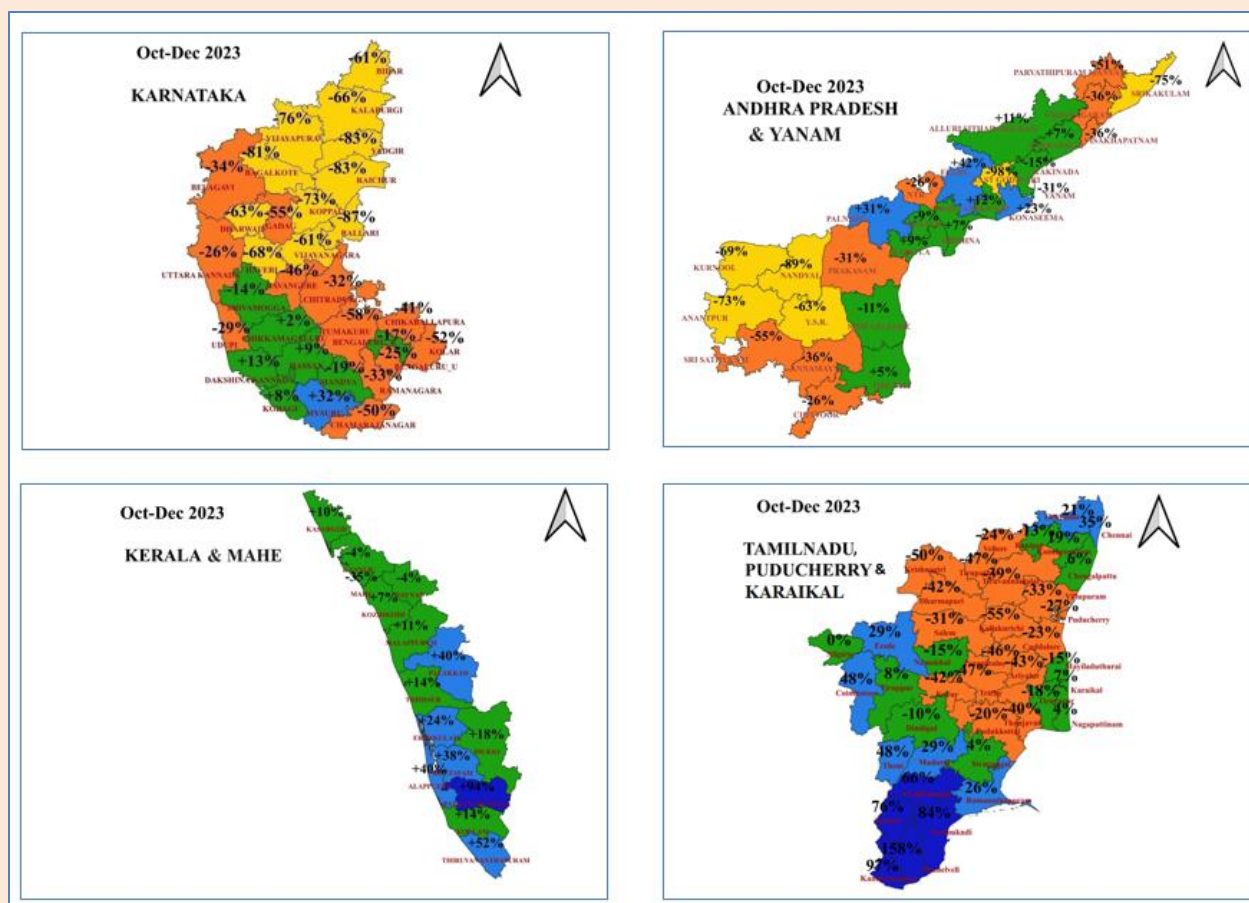


Fig.5c: District-wise rainfall performance in various subdivisions during Oct-Dec 2023

5. Rainfall distribution over Tamil Nadu and Puducherry

Spatial and temporal distribution of rainfall over the TN subdivision during Oct-Dec 2023 are depicted by the district-wise rainfall distribution and area averaged daily rainfall distribution over TN. Fig.6a presents the daily rainfall distribution over the TN subdivision (including Puducherry and Karaikal) during Oct-Dec 2023. The daily TN subdivisional rainfall was below normal from 20th-30th October and above normal on many days during the period from 30th October to 20th December.

State / UT & District-wise seasonal rainfall during Oct-dec 2023 are presented in Tables-8a&b and Fig.5c and district-wise monthly rainfall performance is depicted in Fig.6b. as seen, the extreme southern districts of Kanyakumari, Tirunelveli, Thootukudi, Tenkasi and Virudunagar districts of TN received *large excess* rainfall (+76% to +158%) during the season. The other southern districts of Ramanathapuram, Sivagangai, Madurai, Dindigul & Theni districts, the western ghat & adjoining districts of Nilgiris, Coimbatore, Tiruppur, Erode & Namakkal in north interior TN, the extreme northeastern districts of Chennai, Tiruvallur,

Ranipet, Kancheepuram & Chengalpattu districts received *normal to excess* rainfall. Mayiladuthurai, Nagapattinam, Tiruvarur & Karikal area of the delta districts received *normal* rainfall and the rest of the 15 districts in north TN & Puducherry ended up *deficient* at the end of the season.

In the monthly scale, in October, but for Kanyakumari that received *large excess* rainfall and the western ghat districts of Coimbatore, Tiruppur, Theni, Tenkasi, Tirunelveli & Madurai adjoining the Theni district that received *normal* rainfall all the other 33 districts (including Puducherry & Karaikal) became *deficient-largely deficient*.

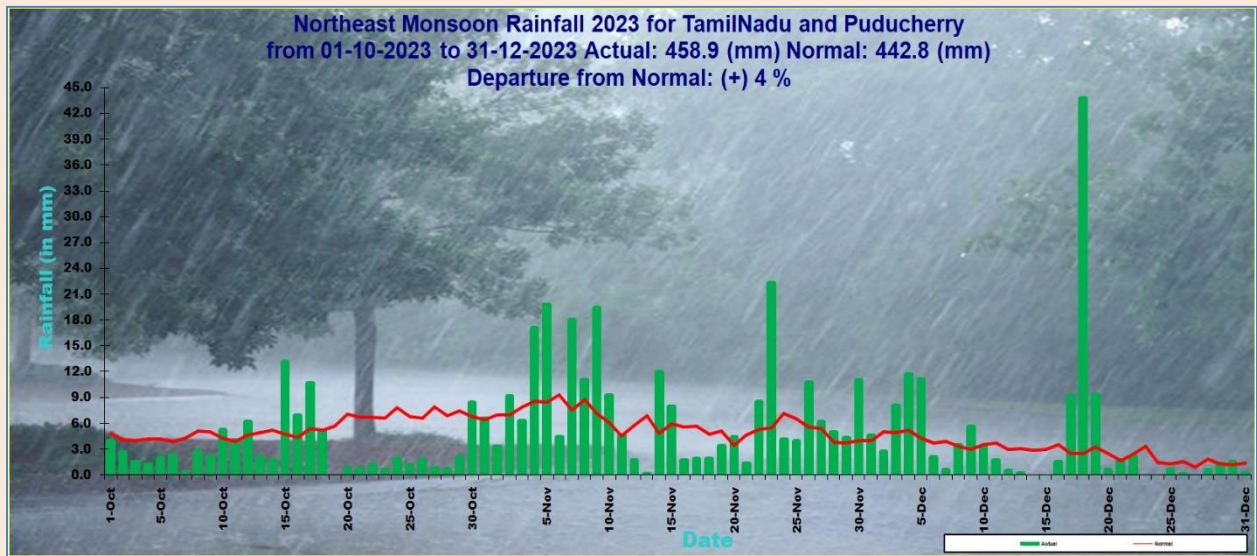


Fig.6a: Area averaged daily rainfall over TN subdivision during Oct-Dec 2023

Table-8a: State /UT wise rainfall figures of Tamil Nadu, Puducherry& Karaikal during Oct-Dec 2023

Subdivision / State / UT	Actual rainfall (mm)	Normal rainfall (mm)	Percentage departure from normal (%)
TN subdivision	458.9	442.3	+4
Puducherry& Karaikal (UT)	776.8	896.0	-13
Tamil Nadu State	457.8	441.2	+4

Table-8b: District-wise rainfall figures of Tamil Nadu, Puducherry & Karaikal during Oct-Dec 2023

District	Oct-Dec 2023		
	<i>Actual</i>	<i>Normal</i>	<i>PDN</i>
	(mm)	(mm)	(%)
Ariyalur	284.2	501.9	-43
Chengalpattu	747.1	707.7	+6
Chennai	1088.9	809.6	+35
Coimbatore	500.8	337.6	+48
Cuddalore	537.7	701.5	-23
Dharmapuri	182.8	314.2	-42
Dindigul	416.2	460.0	-10
Erode	396.0	307.1	+29
Kallakurichi	206.8	455.5	-55
Kancheepuram	703.5	591.7	+19
Kanyakumari	1050.9	532.6	+97
Karaikal	1083.4	1014.2	+7
Karur	181.4	313.2	-42
Krishnagiri	139.1	278.7	-50
Madurai	475.5	370.0	+29
Mayiladuthurai	752.5	888.1	-15
Nagapattinam	969.0	935.3	+4
Namakkal	230.6	270.4	-15
Nilgiris	502.4	501.3	0
Perambalur	232.5	432.0	-46
Puducherry	609.5	831.6	-27
Pudukkottai	309.0	385.6	-20
Ramanathapuram	667.6	531.4	+26
Ranipet	351.3	406.0	-13
Salem	229.3	331.7	-31
Sivaganga	440.3	422.7	+4
Tenkasi	821.3	465.7	+76
Thanjavur	345.5	579.4	-40
Theni	537.7	364.3	+48
Tirunelveli	1329.6	514.9	+158
Tirupattur	141.7	266.3	-47
Tiruppur	329.8	305.7	+8
Tiruvallur	754.5	623.9	+21
Tiruvannamalai	276.5	450.4	-39
Tiruvarur	598.0	725.4	-18
Toothukudi	812.4	441.9	+84
Trichy	202.5	379.4	-47
Vellore	286.8	375.8	-24
Villupuram	353.4	531.3	-33
Virudhunagar	660.0	398.5	+66

In November, but for Thanjavur, Thiruchirapalli, Karur, Kallakurichi & Ranipet districts that received *deficient* rainfall all the other 35 districts received *normal to large excess* rainfall. In south TN, excepting Dindigul that received *normal* rainfall, all the other districts received *excess-large excess* rainfall. In the north interior districts of Nilgiris, Coimbatore, Tiruppur, Erode & Namakkal and north coastal districts of Tiruvallur, Mayiladuthurai, Nagapattinam, Tiruvarur & Karaikal area received *excess to large excess* rainfall. All the other northern districts received normal rainfall during the month.

In December, the western ghat & the other southern districts, the extreme northeastern districts and Nagapattinam district received *normal to large excess* rainfall. All the other northern districts became *deficient to largely deficient*. Whereas the southern districts largely benefitted from the **historical rainfall event** of 17th-19th December, the extreme northeastern districts of Chennai, Chengalpattu, Kancheepuram, Tiruvallur, Ranipet & Vellore benefitted from the passage of **SCS MICHAUNG** close to the coast.

6. Standardised Precipitation Index

The Standardized Precipitation Index (SPI) is an index used for monitoring drought and is based on precipitation. This index is negative for dry and positive for wet conditions. As the dry or wet conditions become more severe, the index becomes more negative or positive. For October to December 2023, SPI indicated *Severely-Extremely wet* conditions over Tirunelveli, Tenkasi, Thootukudi, Kanyakumari & Virudunagar districts of TN & Pathanamtitta district of Kerala; and *mild-moderately wet* conditions over all other districts of KER & Mahe area, and neighbouring Kodagu, Mysuru, Hassan & Chikmagalur districts of SIK, Nilgiris, Coimbatore, Erode, Tiruppur, Theni, Madurai, Sivagangai, Ramanathapuram, Nagapattinam, Mayiladuthurai, Chennai, Chengalpattu, Kancheepuram, Tiruvallur districts & Karaikal area of TN, Eluru, Krishna, NTR & West Godavari districts of CAP. *Severely-Extremely dry* conditions prevailed over Kakinada, B.R.Ambedkar Konaseema, East Godavari districts of AP & Yanam area; Anantapuramu. Sri Sathyasai & YSR districts of Rayalaseema; and Ballari & Vijayanagara districts of SIK. All other districts in TN, RYS, SIK & CAP were *mildly-moderately dry* during Oct-Dec 2023 (Fig.7).

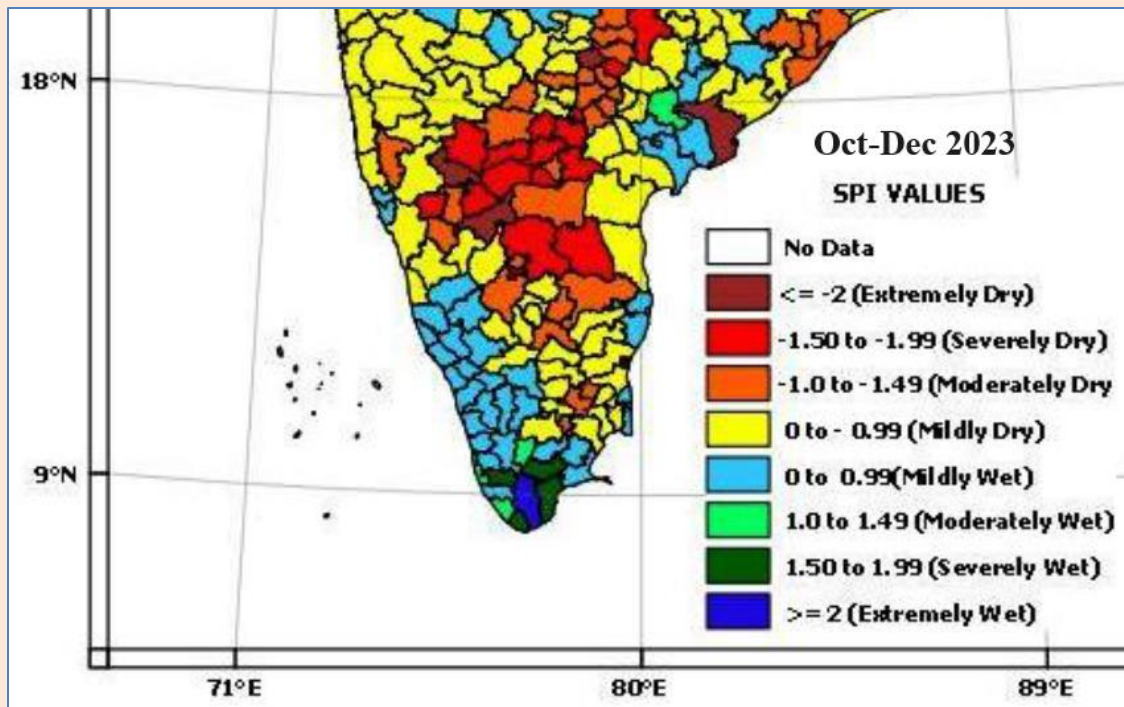


Fig.7: Standardised Precipitation Index for October-December 2023 over the southern peninsular India.

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 2023 are presented in Fig.8a(i)-(iii). The 250 hPa velocity potential & 850 hPa stream function over the Indian region during October-December 2023 are presented in Fig.8b & Fig.8c respectively.

In October 2023, unfavourable anomalous anticyclonic circulation was observed in the lower tropospheric levels (850 hPa) over the southern peninsular region [Fig.8a(i) & Fig.8c] and anomalous northwesterlies were observed over the central and adjoining peninsular region in the mid levels (500 hPa). In the upper tropospheric levels (250 hPa), anomalous cyclonic circulation was present over the Himalayan and neighbouring regions [Fig.8a(i)]. There was anomalous upper level convergence over the southern parts of Bay of Bengal and equatorial Indian ocean that restricted the upper level divergence to the eastern parts of Bay of Bengal and unfavourable upper level convergence over the southern peninsular region & adjoining western parts of Bay of Bengal [Fig.8b].

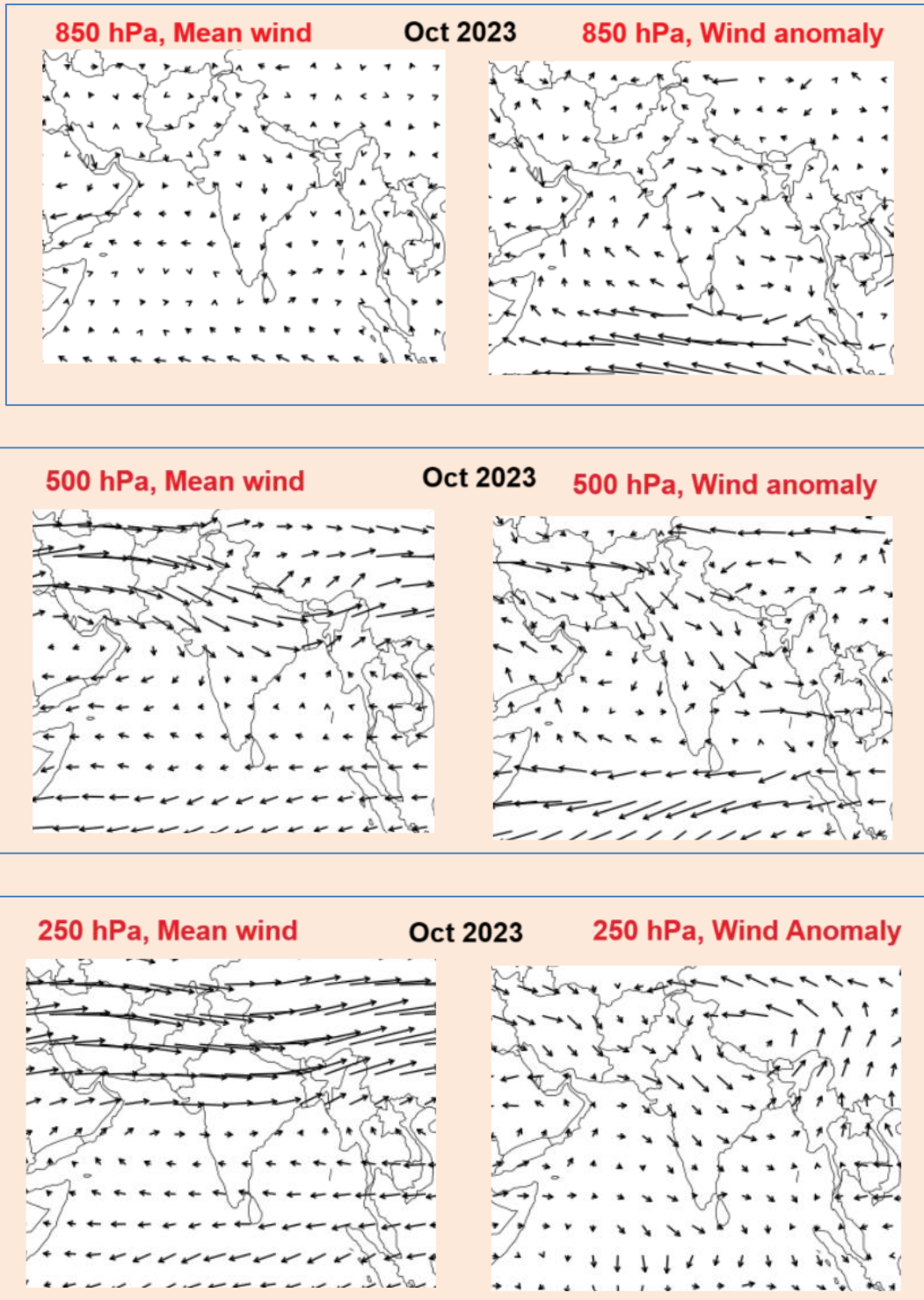


Fig.8a(i): Mean and anomalous wind pattern over the Indian region at 850 hPa, 500 hPa and 250 hPa levels during October 2023 (Source: Climate Diagnostic Bulletin of India, IMD Pune)

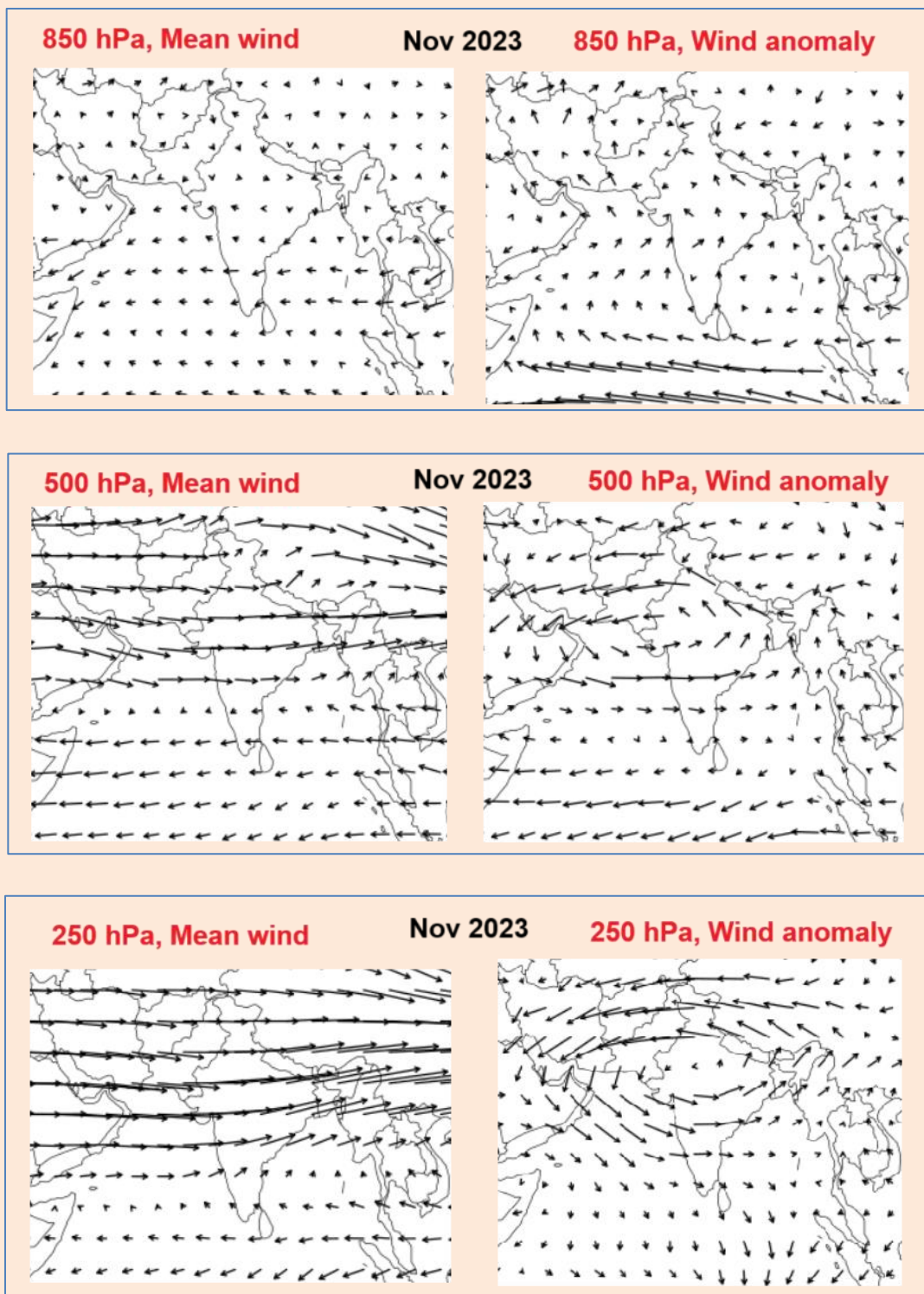


Fig.8a(ii): Mean and anomalous wind pattern over the Indian region at 850 hPa, 500 hPa and 250 hPa levels during Nov 2023 (Source: Climate Diagnostic Bulletin of India, IMD Pune)

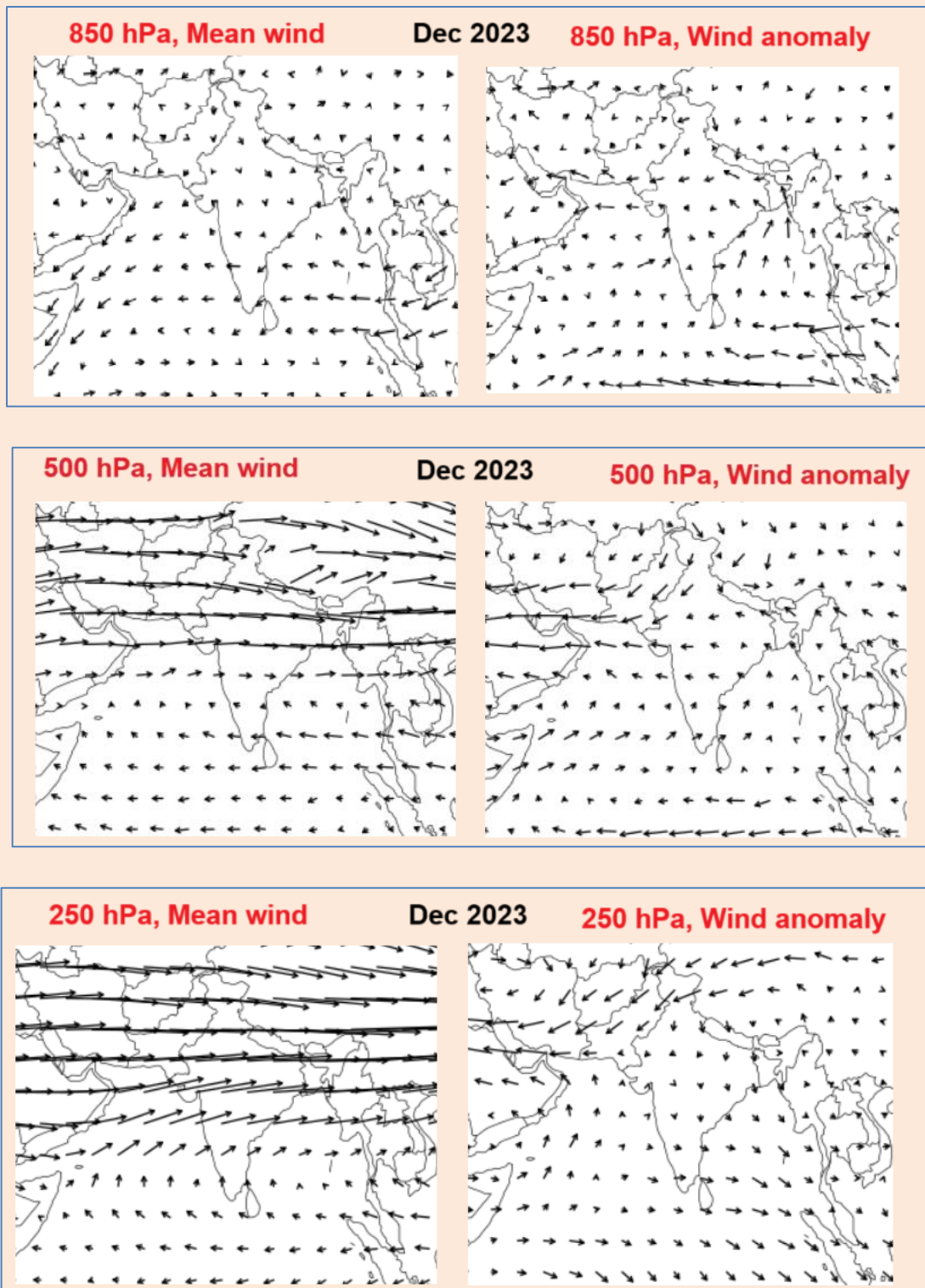


Fig.8a(iii): Mean and anomalous wind pattern over the Indian region at 850 hPa, 500 hPa and 250 hPa levels during December 2023 (Source: Climate Diagnostic Bulletin of India, IMD Pune)

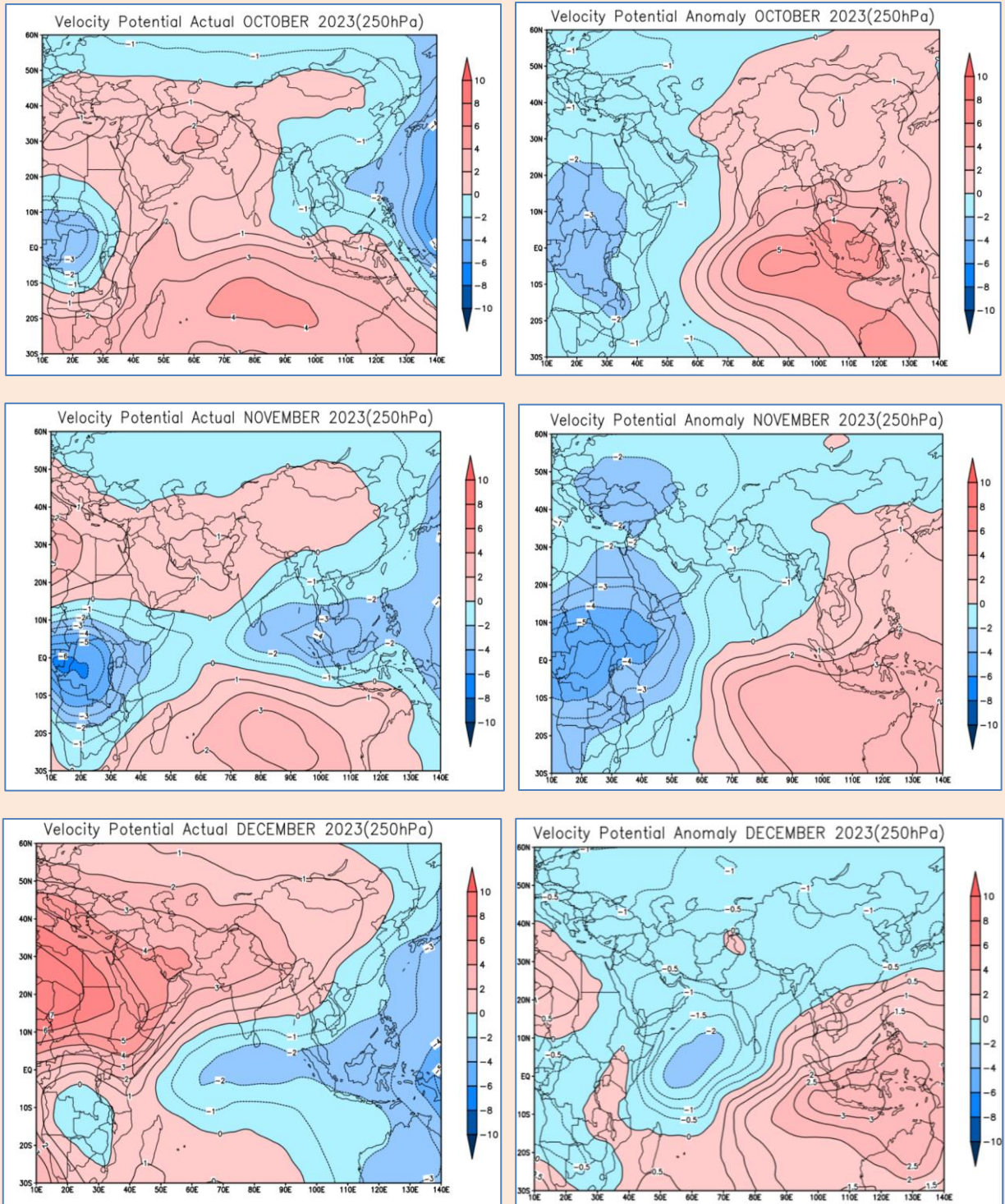


Fig.8b: 250 hPa velocity potential ($\times 10^6 \text{ m}^2/\text{s}$) over the Indian region during Oct, Nov & Dec 2023 (Source: Climate Diagnostic Bulletin of India, IMD Pune)

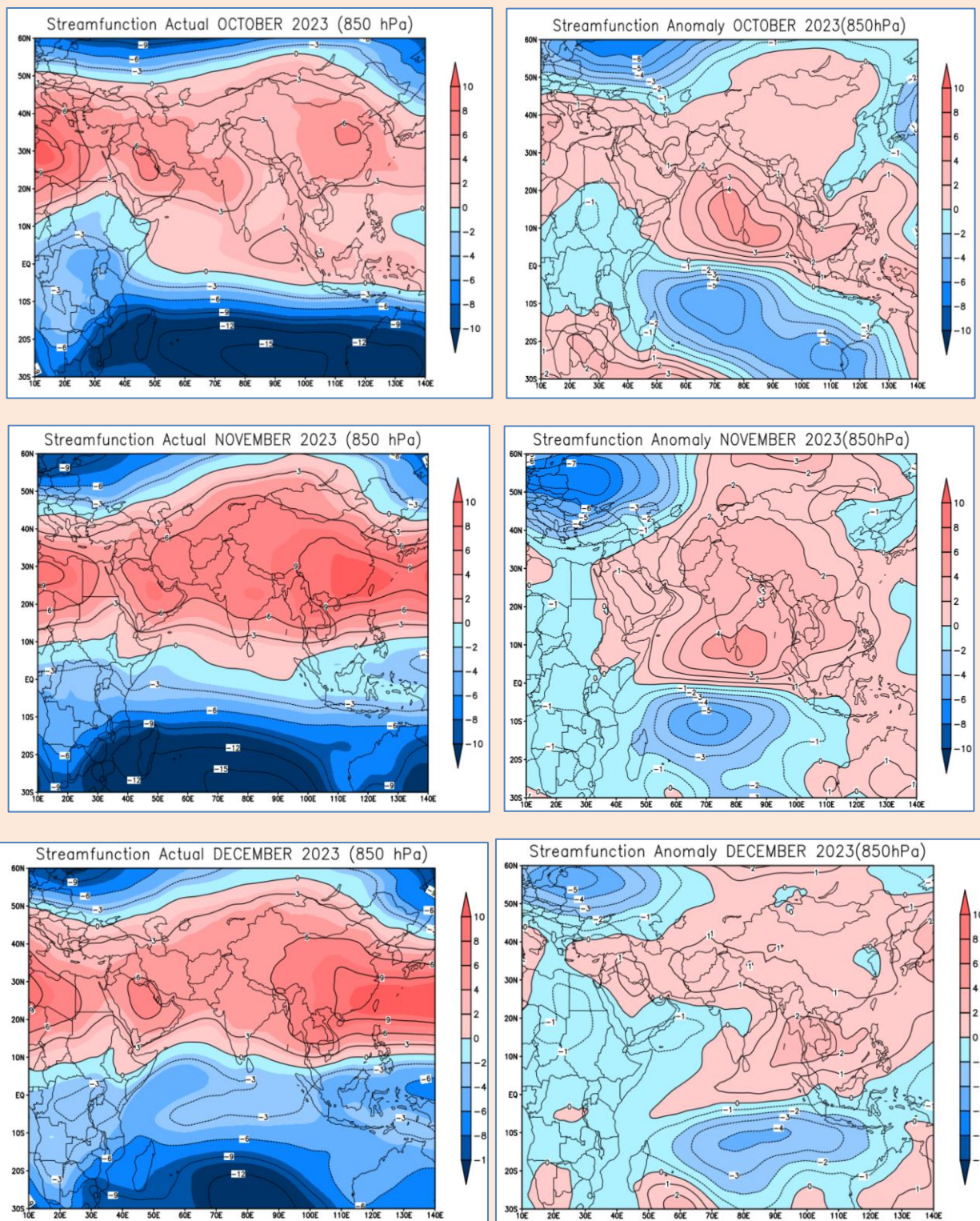


Fig.8c: 850 hPa stream function ($\times 10^6 \text{ m}^2/\text{s}$) over the Indian region during Oct, Nov & Dec 2023 (Source: Climate Diagnostic Bulletin of India, IMD Pune)

In November 2023, at 850 hPa level, there was anomalous anticyclonic circulation over the peninsular region [Fig.8c] and anomalous easterlies over the equatorial Indian Ocean and adjoining southern parts of Bay of Bengal and anomalous southerlies / southwesterlies over the southern peninsular region and the Arabian sea [Fig.8a(ii)]. In the mid-upper tropospheric levels there was anomalous cyclonic circulation over the central and northern parts of India [Fig.8a(ii)]. Upper level divergence was present over the southern peninsular and eastern parts India and it was more over the southern parts of Bay of Bengal and adjoining equatorial Indian ocean [Fig.8b].

In December 2023, at 850 hPa level, there was anomalous cyclonic circulation over the central Arabian sea and adjoining central India [Fig.8a(iii)]. Upper tropospheric divergence was present over the southern parts of peninsular region, southern Bay of Bengal and equatorial Indian ocean [Fig.8b] and low level cyclonic vorticity was observed over the extreme southern parts of the southern peninsular region [Fig.8c].

(b) Monthly OLR patterns: Monthly OLR anomalies over the Indian region are shown in Fig.8d.

In October 2023, positive OLR anomalies were observed over the southern and the southern peninsular region.

In November, negative OLR anomalies were observed over the NEM region. The anomalies were upto about -20 W/m^2 to -30 W/m^2 over coastal TN, -10 W/m^2 to -20 W/m^2 over interior TN & most parts of KER & upto -10 W/m^2 over the rest of the NEM region.

In December, negative OLR anomalies of about -30 W/m^2 were observed over southern parts and -20 W/m^2 to -30 W/m^2 over northern parts of TN and KER.

(c) Large scale features: Based on MoES- MMCFS (Ministry of Earth Sciences- Monsoon mission: Climate Forecasting System) analysis and reports of various global climate monitoring centres, the large scale climate parameters during October-December 2023 were as follows:

(i) El Nino conditions (positive sea surface temperature anomalies) prevailed over the equatorial Pacific region.

(ii) Indian Ocean Dipole was also strongly positive during the season.

(iii) MJO was in the western hemisphere or significant during the entire October 2023. It was in phase 2-3 for a brief period of 02nd-05th November and again during 22nd-30th November, but was insignificant or in the western hemisphere during the other days of the month. In December 2023, it was in phase 3-4 during the first week and was in the western hemisphere or insignificant on most of the days during the rest of the month. (Fig.8e (i)-(iii)).

Even though both El Nino & positive IOD were favourable for good NEM, MJO was not favourable on many days during the season.

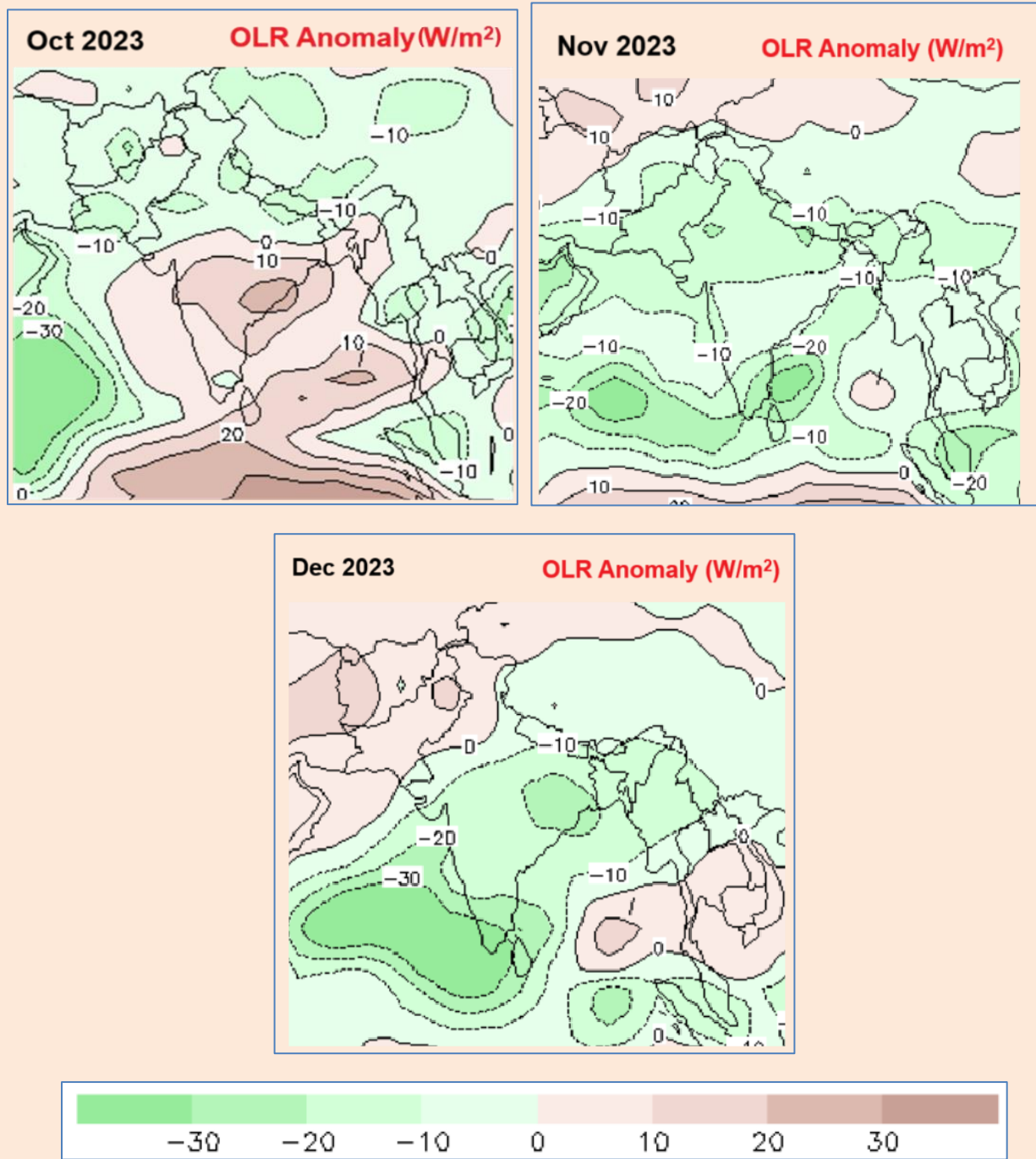


Fig.8d: OLR anomalies over the Indian region during Oct, Nov & Dec 2023 (Source: Climate Diagnostic Bulletin of India, IMD Pune)



Fig.8e(i): Sea surface temperature over the equatorial Pacific Ocean (Source: Bureau of Meteorology, Australia)

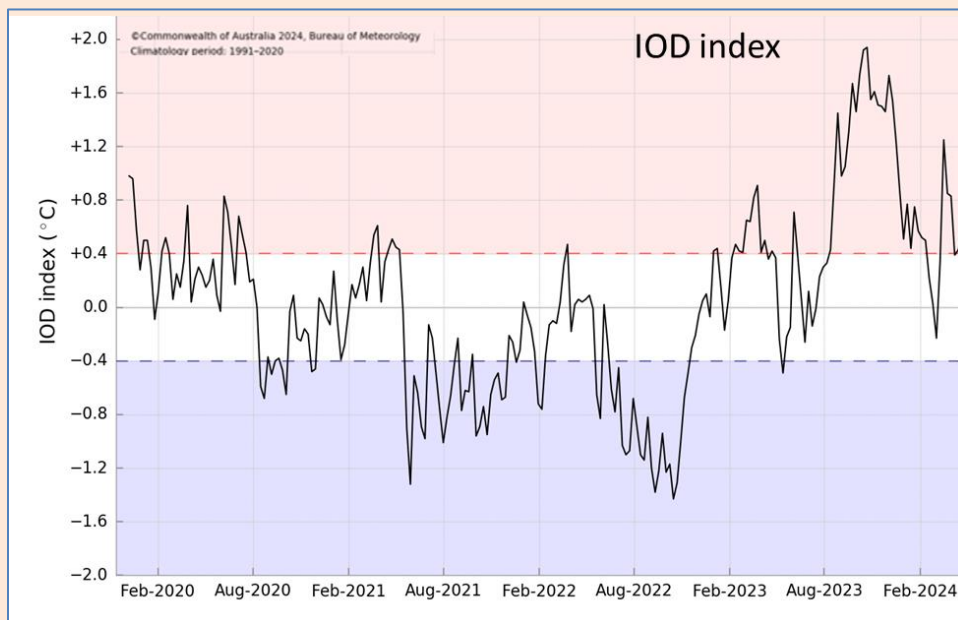


Fig.8e(ii): Indian Ocean Dipole mode index (Source: Bureau of Meteorology, Australia)

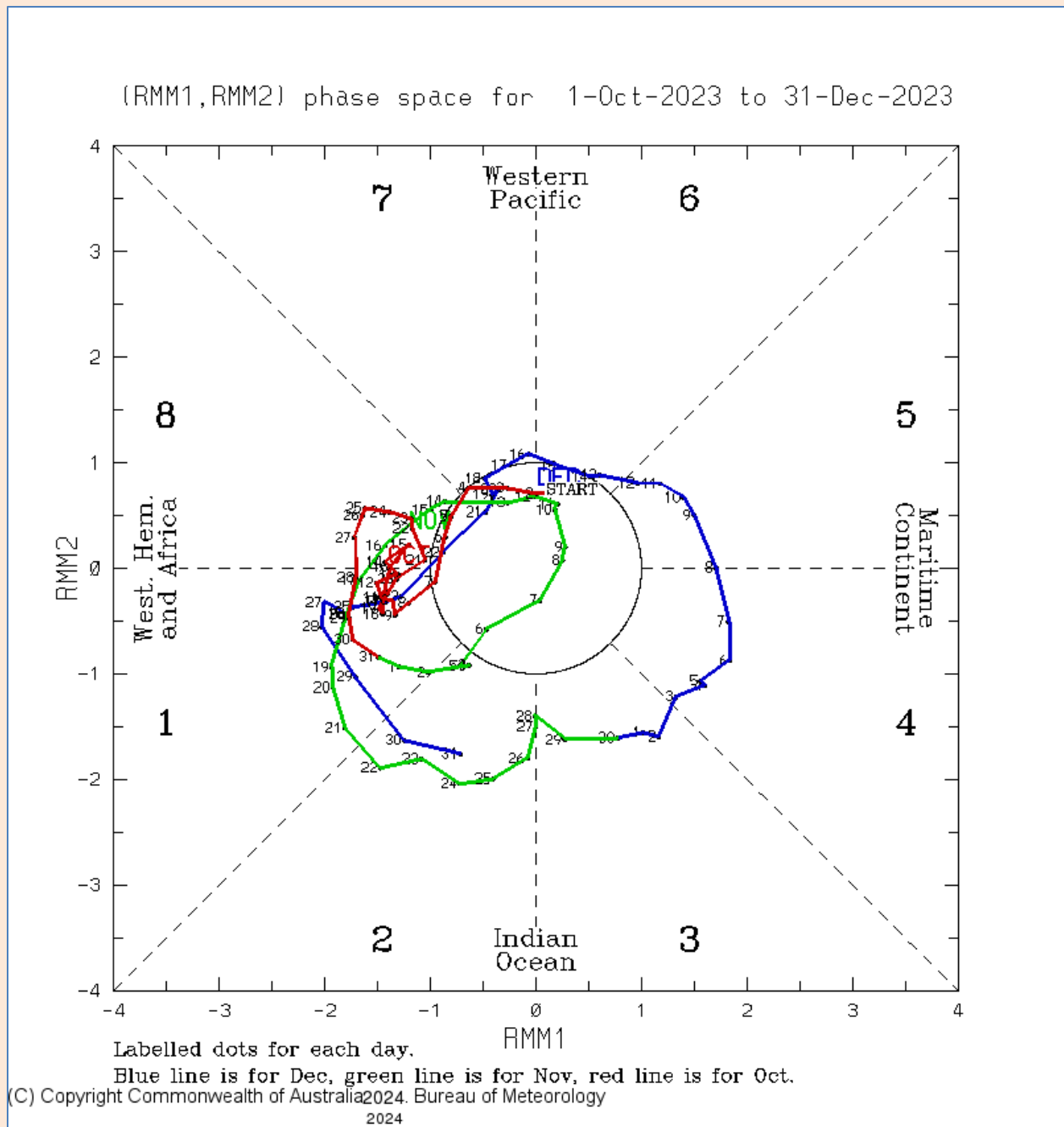


Fig.8e(iii): MJO during Oct-Dec 2023 (Source: Bureau of Meteorology, Australia)

8. Cessation of NEM rains over peninsular India

Subsequent to the historical rainfall event over south TN in December 2023, with the gradual decrease in rainfall activity, cessation of NEM rains over southern peninsular India was declared on 14th January 2024.

9. Summary

During the year 2023, the southwest monsoon withdrew from the Indian region on 16th October and the Northeast monsoon (NEM) of 2023 commenced simultaneously over the southeastern parts of peninsular India on **16th October 2023** against the normal date of 20th October.

Of the five meteorological sub divisions benefitted by the NEM, three subdivisions - Tamil Nadu (including Puducherry & Karaikal) (TN), Coastal Andhra Pradesh (CAP) & Kerala (KER) received **normal to excess** rainfall and the other two subdivisions - Rayalaseema (RYS), and South Interior Karnataka (SIK)] received **deficient** rainfall during the NEM season (October-December) 2023.

Active to vigorous monsoon conditions prevailed over TN on 20 days, over KER on 12 days and over RYS, CAP & SIK – 3-5 days during the season. There were **57** days of *isolated heavy* rainfall activity with 24 days of *isolated very heavy* rain including 07 days of *isolated extremely heavy rainfall* activity over TN.

Four cyclones affected the Indian seas during the season – ***Extremely Severe Cyclonic Storm (ESCS) TEJ*** over the **Arabian Sea (AS)** and ***Very Severe Cyclonic Storm (VSCS) HAMOON***, ***Cyclonic Storm (CS) MIDHILI*** and ***Severe Cyclonic Storm (SCS) MICHAUNG*** over the Bay of Bengal (BOB).

The **SCS MICHAUNG** over the BOB during 01st-06th December **crossed south Andhra Pradesh coast**, south of **Bapatla** on 05th afternoon as SCS with maximum sustained surface wind speed of **90-100 kmph gusting to 110 kmph**. Associated with the passage of this system, ***very heavy to extremely heavy*** rainfall occurred over **Chennai** and neighbouring districts of extreme north Tamilnadu, Rayalaseema & Coastal Andhra Pradesh during 04th-06th December.

The other three cyclones ESCS TEJ that affected AS during 20th-24th Oct 2023 moved westwards and crossed Yemen coast, VSCS HAMOON that affected BOB during 21st-25th Oct 2023 tracked northeastwards and crossed Bangladesh coast and CS MIDHILI that affected BOB during 15th-18th Nov 2023 also tracked northeastwards and crossed Bangladesh coast leading to weak NEM rainfall activity over the peninsular India during the respective periods.

However, associated with an upper air cyclonic circulation over the Comorin area and neighbourhood, historical *extremely heavy* rainfall occurred over south Tamilnadu during 17th-19th December, with **Kayalpattinam** in Thoothukudi district recording **95 cm/day** and 30 other stations over Thoothukudi, Tirunelveli, Kanyakumari and Thenkasi districts recording over 30 cm/day on 18th December leading to devastating floods over extreme south Tamilnadu.

Thereafter, with the gradual decrease in rainfall activity, the cessation of NEM 2023 rainfall over the southern peninsular India was declared on **14th January 2024**.

Acknowledgements

This report is a compilation of real-time observational data and analytical products generated by various IMD offices including IMD New Delhi, Pune, Thiruvananthapuram, Hyderabad, Bangalore & Amaravati as well as raingauge networks of state government departments. Contribution from all officials involved in generation of data and analytical products used for preparation of this report is duly acknowledged. Use of US-NCEP reanalysis data, analytical product of Bureau of Meteorology, Australia and local media reports are also duly acknowledged.

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 3 cm in coastal Tamil Nadu, south coastal Andhra Pradesh and 2 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.