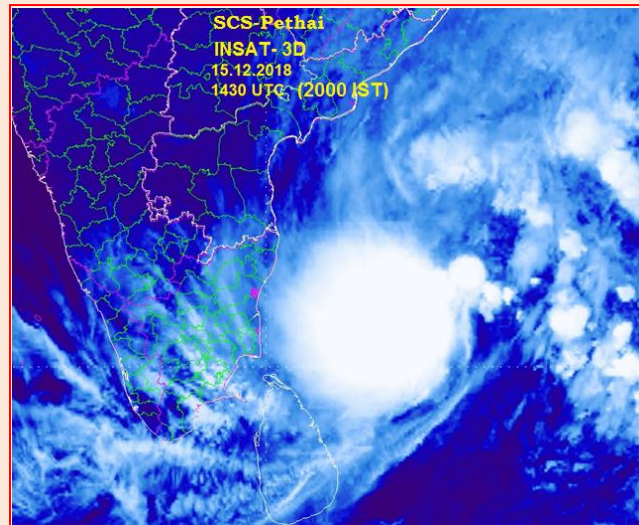
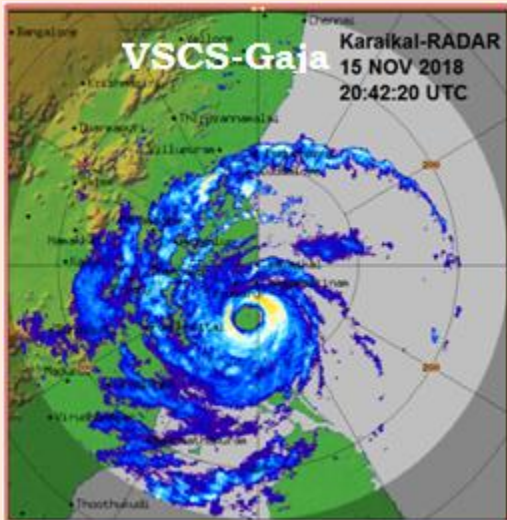
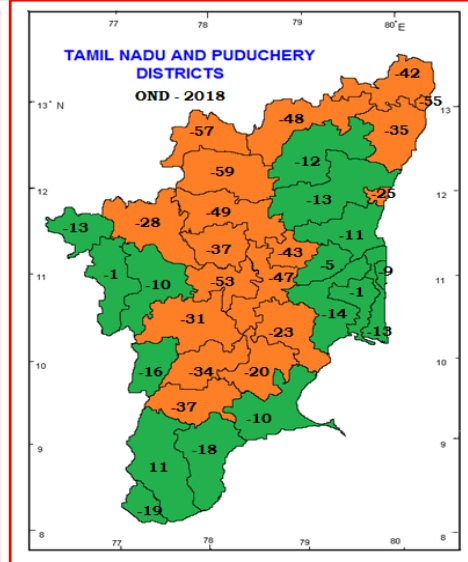
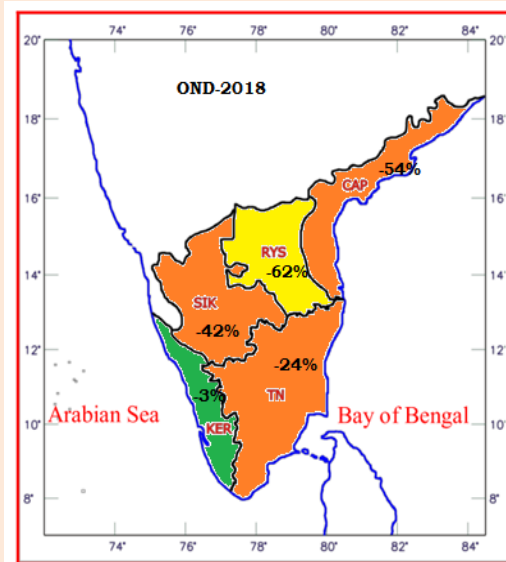




REPORT ON NORTHEAST MONSOON – 2018



Regional Meteorological Centre, Chennai
April 2019

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 (TN), Kerala (KER), Coastal Andhra Pradesh (CAP), Rayalaseema (RYS) and South Interior Karnataka (SIK) occurs. For the subdivision of TN [comprising of the state of Tamil Nadu and the Union Territory of Puducherry (PDC)], the normal SWM seasonal rainfall realised is only about 35% (317.2 mm) of its annual rainfall (914.4 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% (438.2 mm) of its annual rainfall realised during this season and hence its performance is a key factor for this regional agricultural activities.

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

Prior to the commencement of NEM rains, after the withdrawal of SWM upto 15°N, reversal of low level winds from southwesterly to northeasterly occurs. The normal date of setting in of easterlies over the southeastern peninsular India is 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 mm, KER-480.7 mm, CAP-327.4 mm, RYS-219.2 mm and SIK-209.5 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. During OND 2018, neutral ENSO and IOD conditions prevailed and MJO was favourable in phase 2-4 with amplitude >1 only on 26 days during the season.

2. Onset phase

During the year 2018, the onset of NEM over southeast peninsular India took place on 01-02 November (delayed by 11 days from the normal date of 20 October) due to extended SWM activity.

Extended southwest monsoon activity during October 2018 prior to onset of NEM 2018:

Due to extended SWM activity over the peninsular India, generally *scattered* (SCT) to *widespread* (WS) rainfall activity occurred over the sub-divisions of KER, CK, SIK & TN during 01-09 October. Subsequently with the formation and movement of two very severe cyclonic storms (VSCS) - ***VSCS Titli*** over the BOB during 8-13 October which made landfall near Palasa in Srikakulam district of North CAP and ***VSCS Luban*** over the AS during 6-15 October which moved towards Yemen and adjoining Oman coasts –which led to prevalence of westerlies over the Indian region, southwest monsoon extended over the Indian region up to 21 October. Prevalence of westerlies and sweeping of moisture away from the NEM region delayed the onset of NEM over the CTN and south CAP. Easterlies set in over CTN and south CAP only during the last week of October (around 25 October) and gradually conditions became favourable for the commencement of NEM rains. During October 2018, *fairly widespread* (FWS)-WS rainfall activity occurred over Kerala on 19 days and over CK, SIK & TN on 10 days, 9 days and 7 days respectively, under extended SWM conditions. RYS reported 1 day of WS rainfall during this period. *Active to Vigorous* monsoon conditions prevailed over KER on 6 days, over TN on 5 days, over CK and SIK on 3 days and over RYS on 1 day. Isolated *heavy* rainfall occurred on 20 days over TN, 15 days over KER, 6 days each over CAP, CK & SIK and 2 days over RYS of which isolated *very heavy* rain was reported over TN, KER and CAP on 6 days, 4 days and 2 days respectively with isolated *extremely heavy rain* over CAP on 11 October (associated with landfall of VSCS Titli). (Kindly refer Appendix(i) for explanations on terminologies used for categorization of spatial rainfall distribution and Appendix (ii) &(iii) for description of *heavy* rainfall and NEM activity). Pentad mean wind during October 2018 and streamline analysis depicting the reversal of wind from westerlies to easterlies during the last week of October 2018 are presented in Fig.1a-b.

NEM onset:

Under the influence of low level cyclonic circulation over southwest BOB and adjoining Sri Lanka during 27-31 October and trough of low at mean sea level extending from this circulation which ran over southwest – west central BOB off TN / south CAP / Sri Lanka coast during 30 October – 05 November, NEM rains commenced over coastal Tamil Nadu, Puducherry, south interior Tamil Nadu and adjoining areas of south CAP and south Kerala on 01 November 2018 and over remaining parts of Tamil Nadu and Kerala as well as SIK and RYS on 02 November 2018. Mean sea level pressure charts and INSAT-3D based cloudiness associated with the onset of NEM 2018 are depicted in Fig.1c-d.

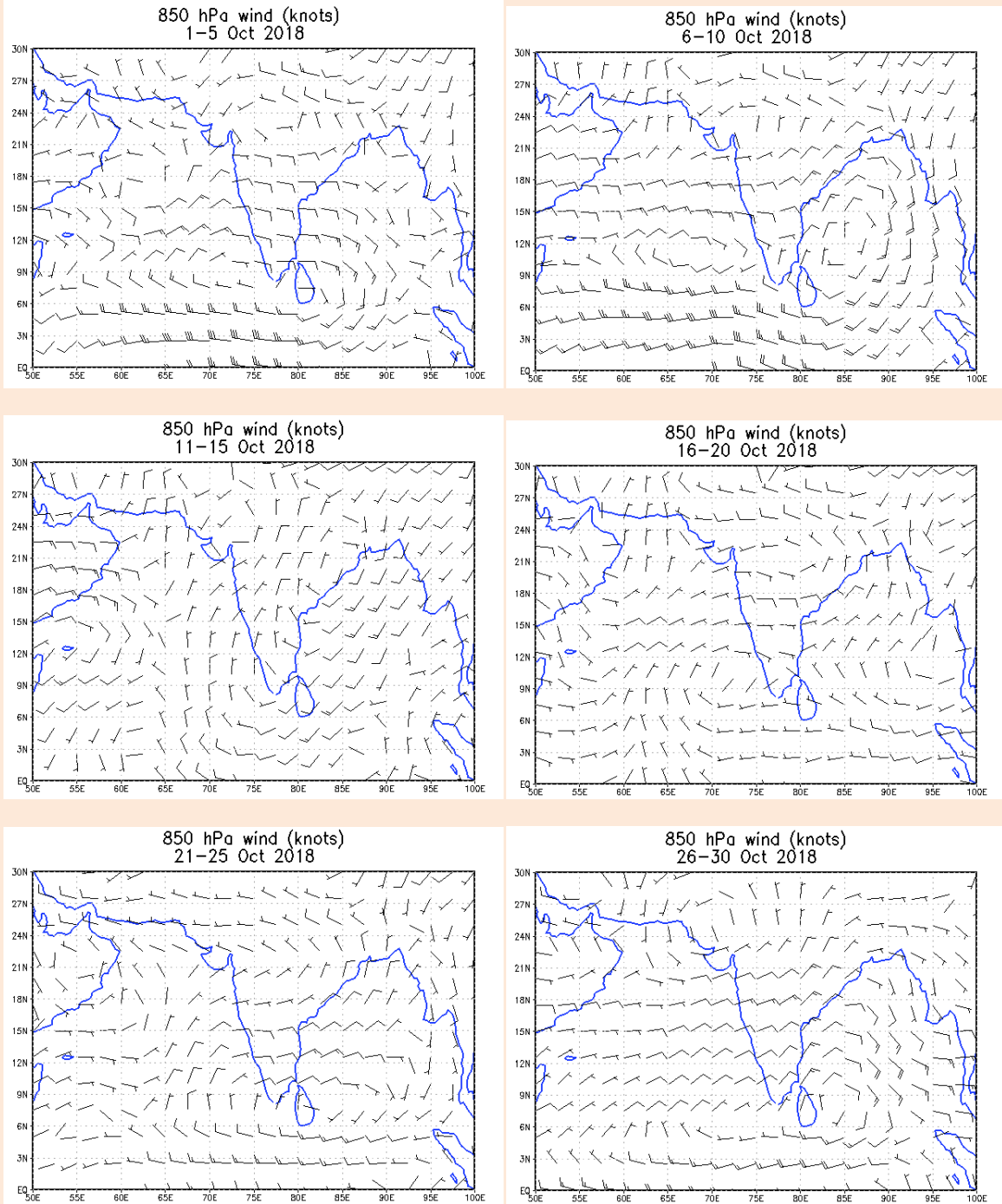


Fig.1a: NCEP reanalysis 850 hPa pentad mean wind (kt) during 01-30 Oct 2018

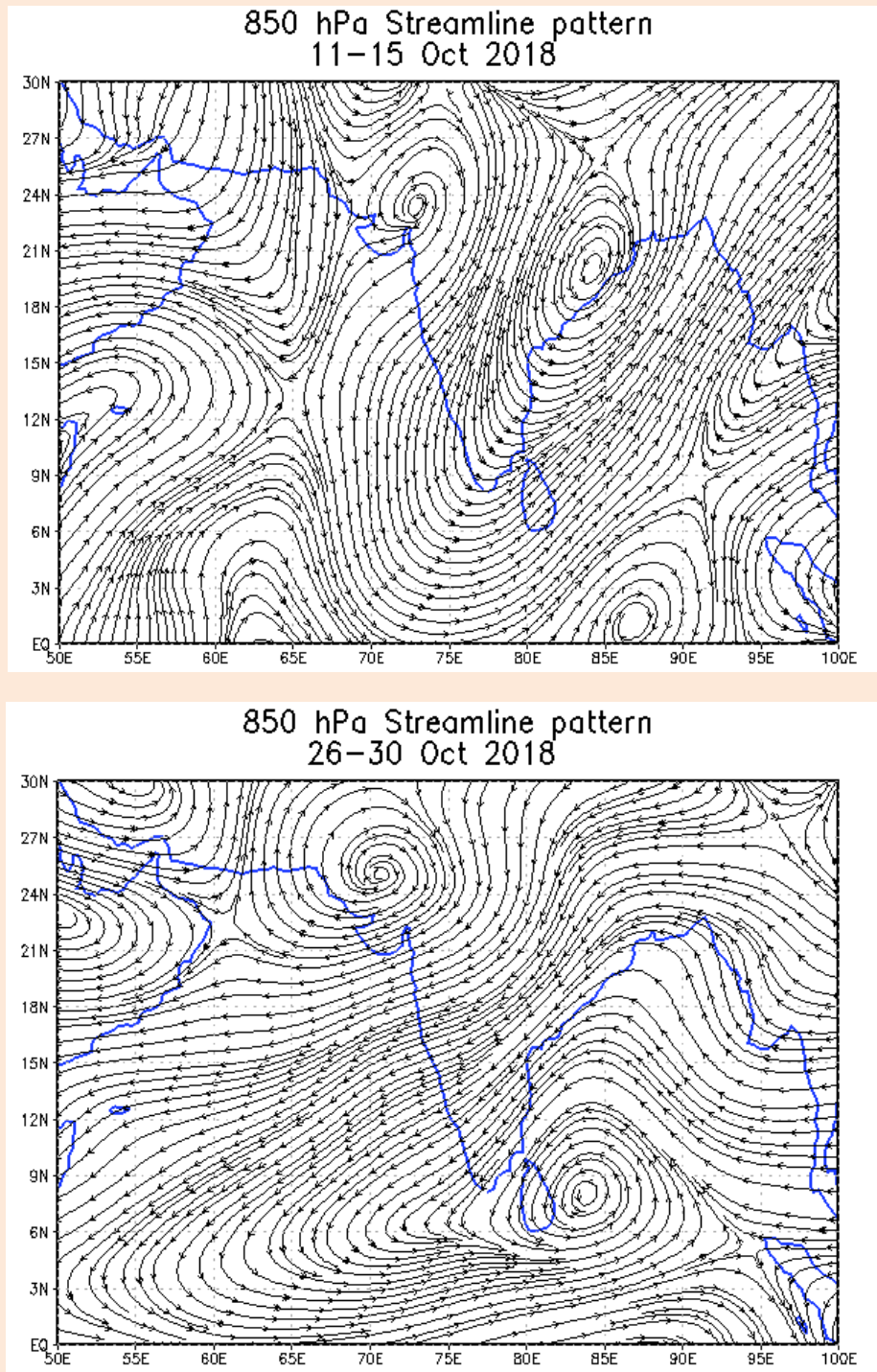


Fig.1b: NCEP reanalysis 850 hPa streamline analysis indicating reversal wind over peninsular India during the onset phase of NEM 2018

During the onset period (01-05 November) SCT to *fairly widespread* (FWS) rainfall occurred over TN on all the five days, over KER and SIK on two days (3-4 November); SCT rainfall occurred over CAP on two days (2-3 November). *Isolated* (ISOL) rainfall occurred over KER, SIK and CAP on the other three days. RYS reported only ISOL rainfall on all the five days. *Active* monsoon conditions prevailed over TN on 3 November with Manimutharu (Tirunelveli district) and Satankulam (Thoothukudi district) recording *extremely heavy* rainfall of 29 cm and 22 cm respectively on that day.

Rainfall depicted by (i) Doppler Weather Radar, Chennai as on 24-hr ending 0830 IST of 01 & 02 November and (ii) by satellite based GPM-Gauge merged rainfall as on 24-hr ending 0830 IST of 01-04 November 2018 are presented in Fig.1(e-f).

After 05 November, under the influence of a low pressure area (LOPAR) / well marked low pressure area (WML) over the southwest BOB and Comorin area generally, ISOL to SCT rainfall occurred over TN and KER during 6-14 November [one day of SCT rainfall over TN (on 9 November) and two days of SCT rainfall over KER (on 10 & 11 November)]. CAP and RYS were generally *dry* during this period.

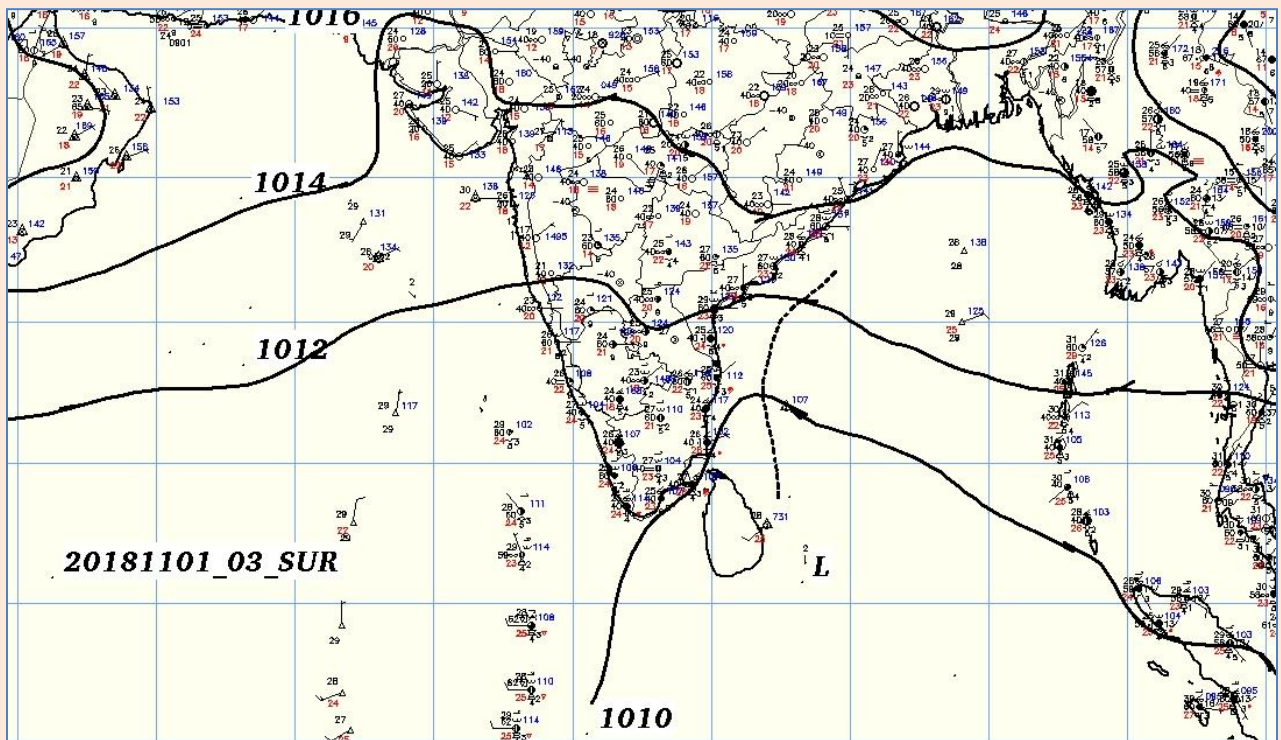
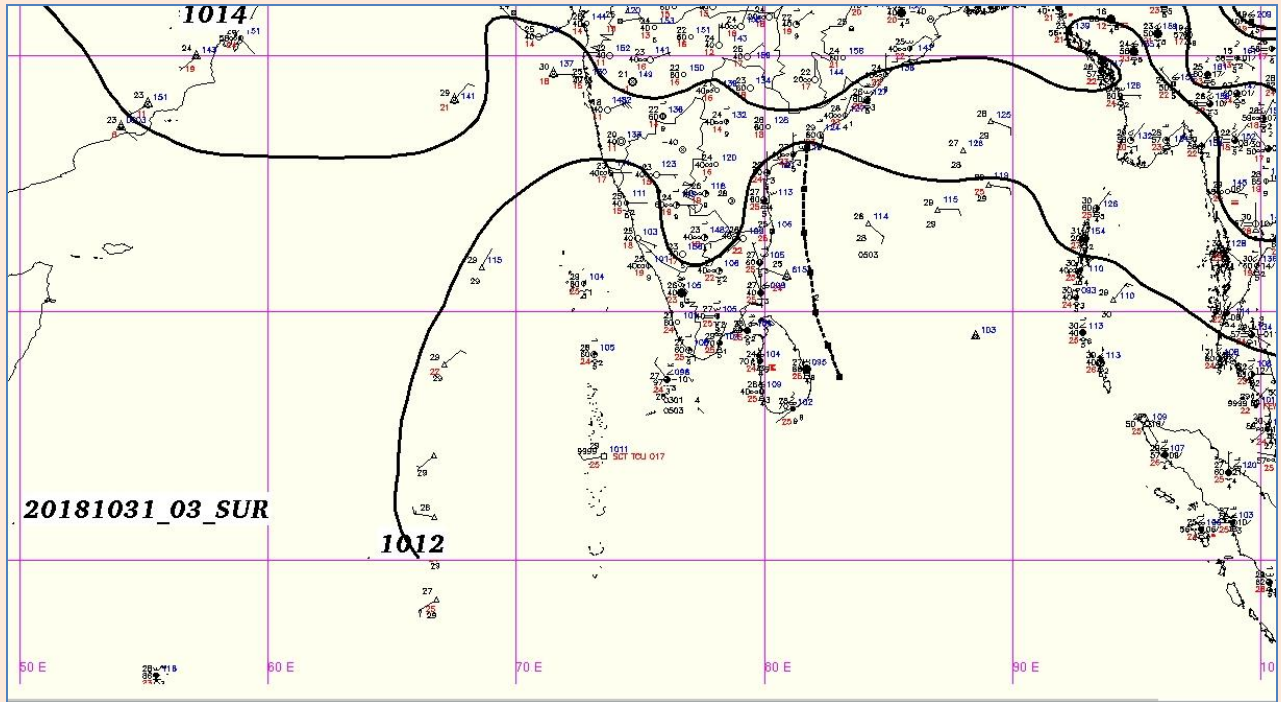


Fig.1c: Mean sea level pressure analysis charts as on 31 Oct & 01 Nov 2018, 0830 IST

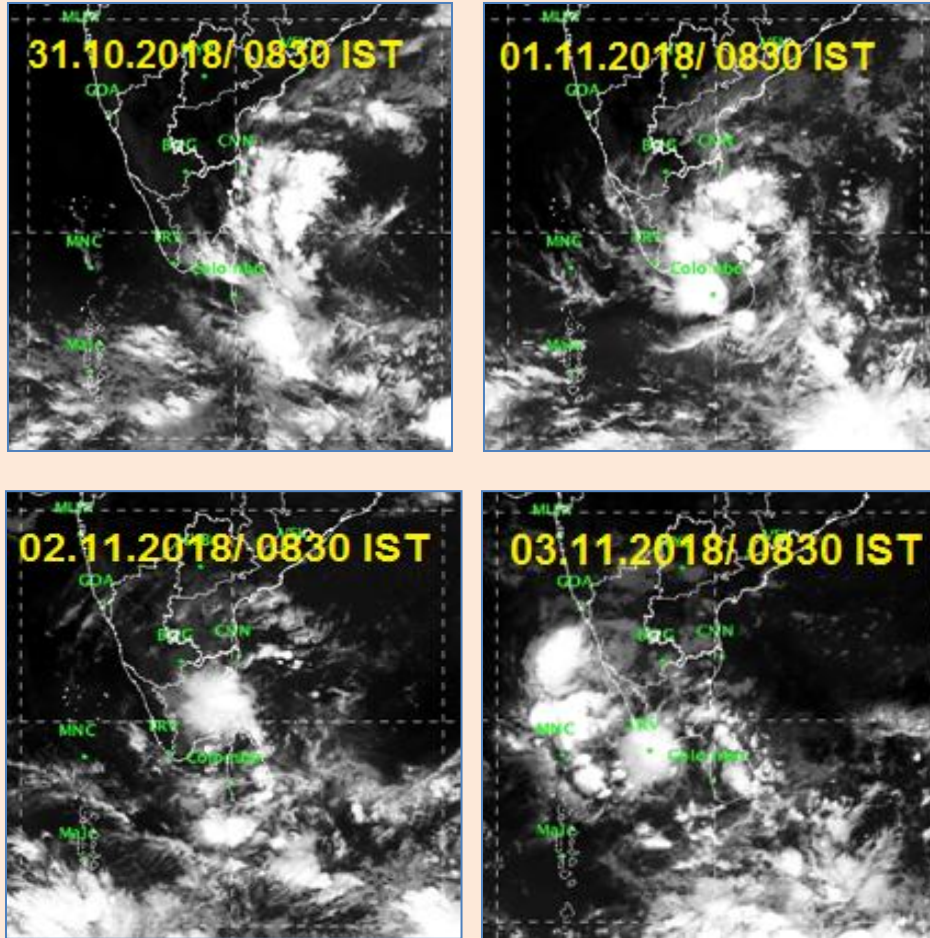


Fig.1d: INSAT-3D infra-red imageries during 31 Oct-03 Nov 2018/ 0830 IST

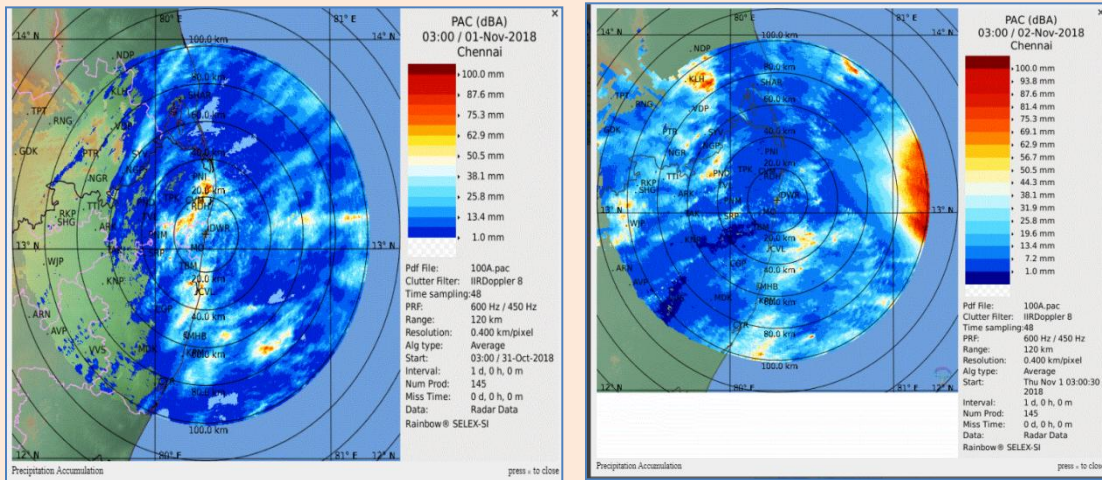


Fig.1e: DWR Chennai 24-hr precipitation accumulation product as on 01 & 02 Nov 2018 / 0830 IST

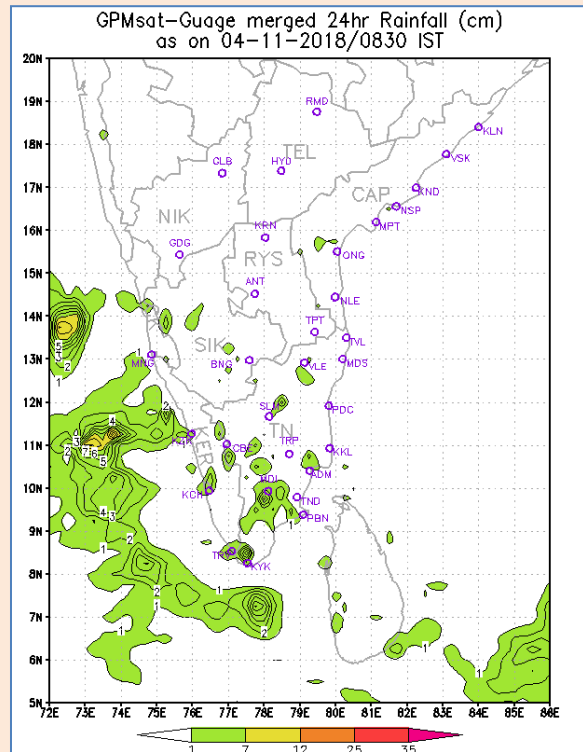
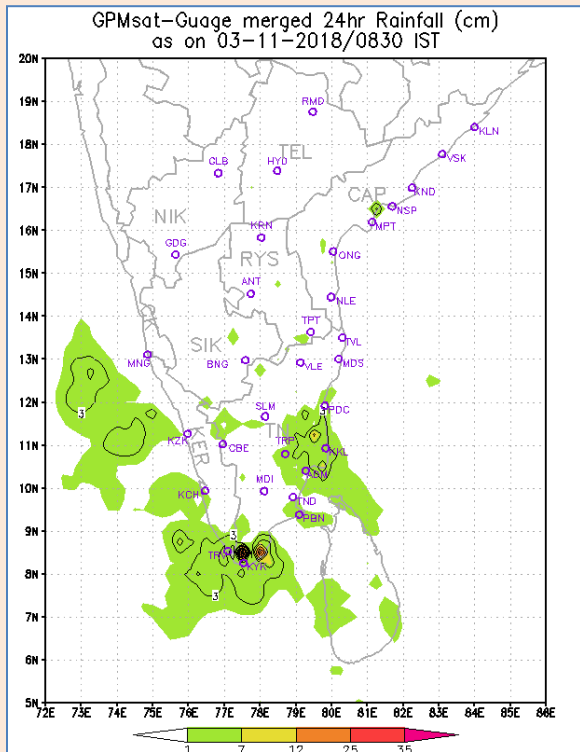
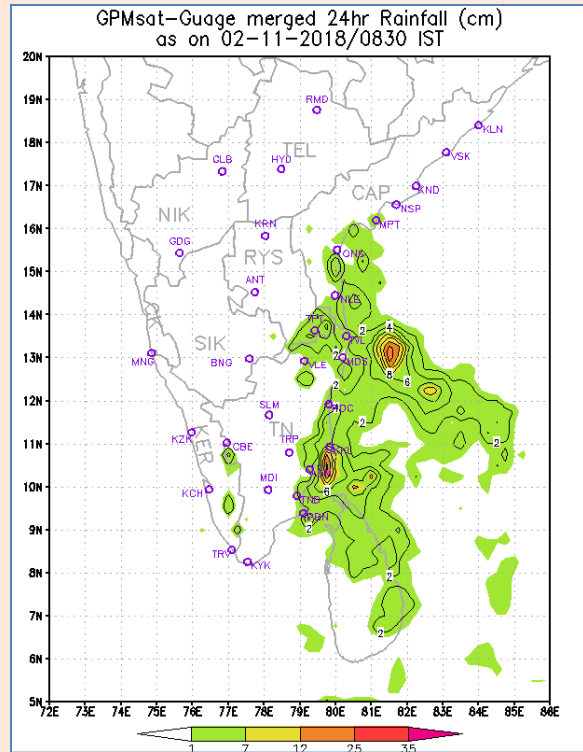
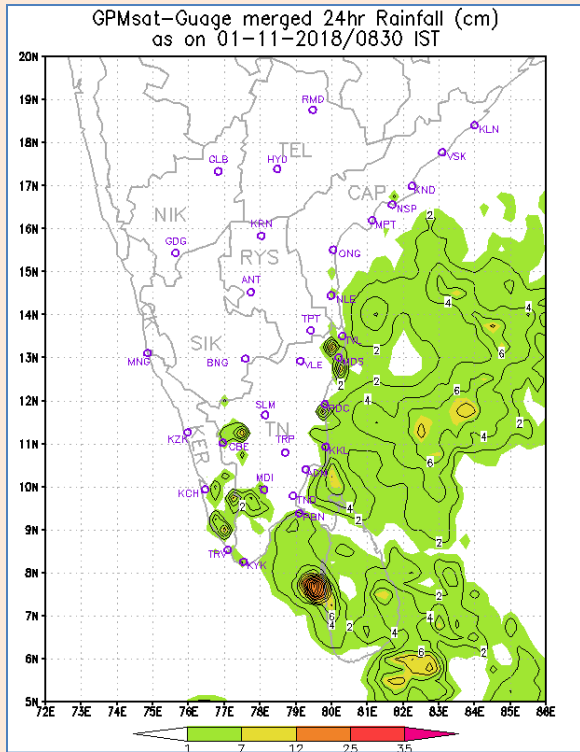


Fig.1f: GPM satellite+Gauge merged 24-hr rainfall (in cm) as on 01-04 Nov 2018, 0830 IST.

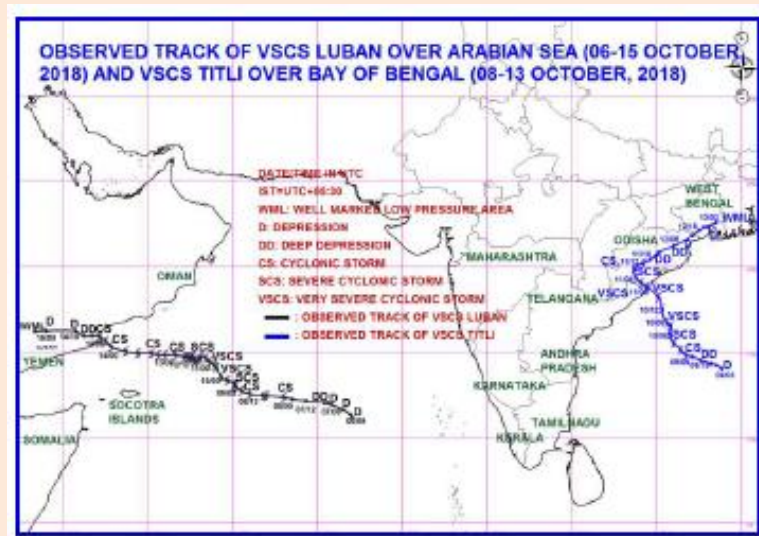
3. Synoptic scale weather systems during Oct-Dec 2018

During October-December 2018, four major low pressure systems (LPS) formed over the BOB and AS (i) VSCS Luban over AS during 6-15 October 2018 (ii) VSCS Titli over BOB during 8-13 October 2018 (iii) VSCS Gaja over BOB during 10-19 November and (iv) SCS Phethai over BOB during 13-18 December 2018. Brief life history of these systems (based on IMD's preliminary reports on these systems) are presented below:

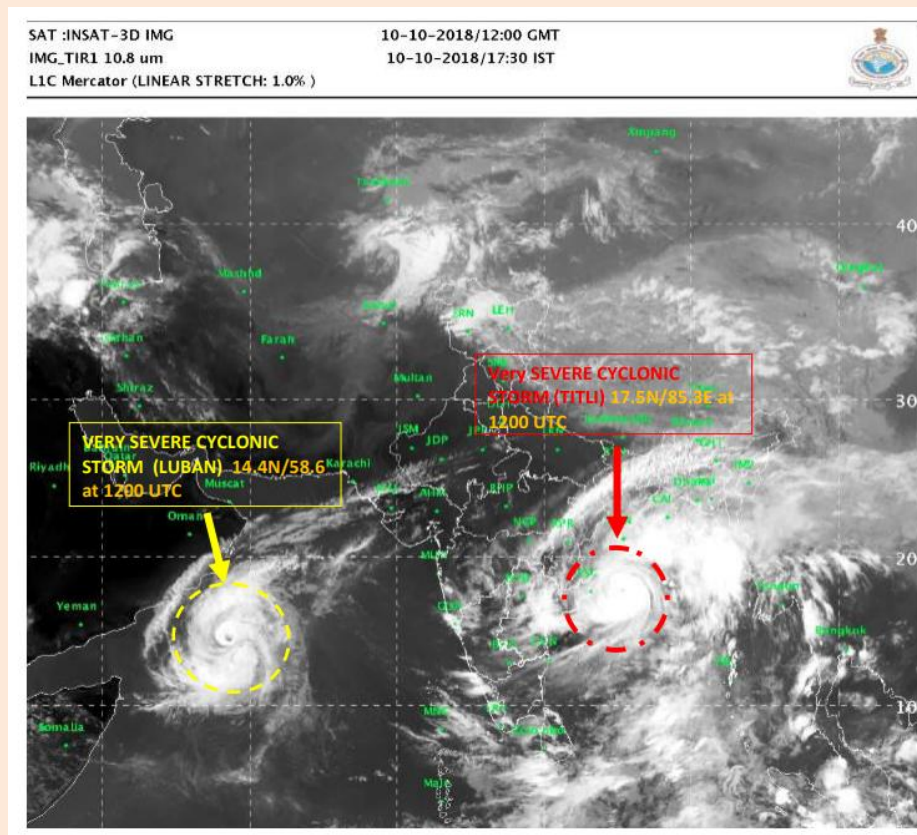
(i) VSCS Luban over AS during 6-15 October 2018: VSCS Luban originated from a low pressure area that lay over southeast AS on the morning of 5th October (0830 IST). It concentrated into a depression (D) over southwest and adjoining eastcentral AS on 6th/ 1430 IST. Moving west-northwestwards, it intensified into cyclonic storm (CS) 'Luban' on 08th/0530 IST and further into SCS and VSCS by 10th/0530 IST. It attained its peak intensity of 75 kts around 1130 IST of 10th and maintained its peak intensity till early morning (0530 IST) of 11th. Subsequently, under unfavourable environmental conditions, it gradually weakened to SCS on 12th morning (0830 IST) and further into CS in the same night (2330 IST). It crossed Yemen and adjoining south Oman coasts near 15.8°N and 52.2°E during 1100-1130 IST of 14th as a CS with wind speed of 70-80 kmph gusting to 90 kmph. After landfall, it weakened into a D in the same night (2330 IST) and lay as a well marked low pressure area over Yemen and adjoining Saudi Arabia on 15th morning (0830 IST).

(ii) VSCS Titli over BOB during 8-13 October 2018: VSCS Titli formed from a LOPAR which lay over southeast BOB and adjoining north Andaman sea in the morning (0830 IST) of 7th October. It concentrated into a D over eastcentral BOB in the morning (0830 IST) of 8th October. Moving west-northwestwards, it intensified into CS 'Titli' around noon (1130 IST) of 9th October. Moving northwestwards / north-northwestwards, it gradually intensified into SCS by the early hours of 10th (0230 IST) and further into VSCS around noon (1130 IST) of 10th. It crossed north Andhra Pradesh – south Odisha coast near Palasa (18.8°N/84.5°E), Srikakulam district (CAP) during 0430-0530 IST of 11th as a VSCS with wind speed of 140-150 kmph gusting to 165 kmph. Moving west-northwestwards, it gradually weakened into a CS by the same evening (1730 IST). Subsequently, it recurved northeastwards from 11th evening and further weakened in to D by 12th afternoon (1430 IST) and lay as a LOPAR over Gangetic West Bengal and adjoining Bangladesh and north BOB on 13th morning (0830 IST). Associated with the landfall of the system *heavy to extremely heavy* rain occurred over a few places in Srikakulam district on 10th and 11th October. Ichchapuram and Tekkali, both in Srikakulam district reported extremely heavy rainfall of 237.6 mm and 234.6 mm respectively on 11th October.

As mentioned in Sec.2, simultaneous occurrence of these two intense LPSs over NIO - VSCS Titli over BOB and VSCS Luban over AS – played a vital role in modulating the atmospheric flow pattern and transporting moisture away from the chief NEM area which delayed the setting in of easterlies and commencement of NEM rains over the southeastern peninsular India. Observed tracks and INSAT 3D satellite imagery of these systems as on 10.10.2018 / 1730 IST are presented in Fig.2(a).



(i)



(ii)

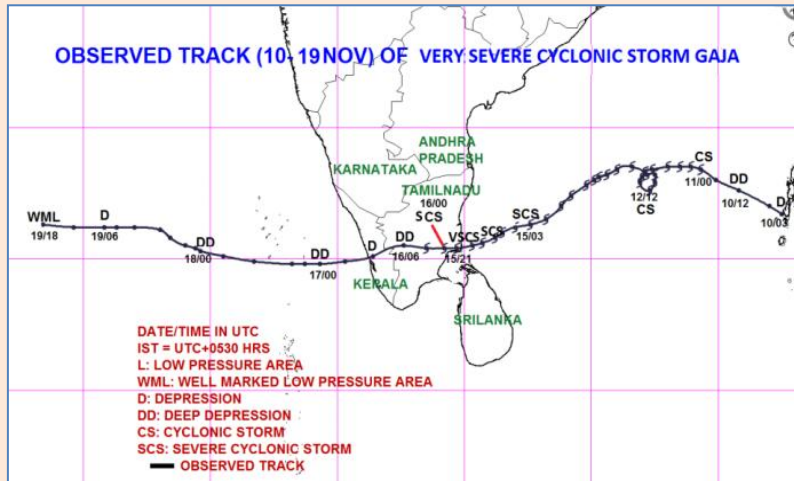
Fig.2a: (i) Observed tracks of VSCS Luban over AS during 6-15 October 2018 & VSCS Titli over BOB during 8-13 October 2018 and (ii) INSAT-3D imagery as on 10.10.2018/ 1730 IST depicting VSCS Titli over BOB off the coast of north Andhra Pradesh – south Odisha and VSCS Luban over AS off Yemen and Oman coasts.

(iii) VSCS Gaja over BOB during 10-19 November: VSCS Gaja originated from a LOPAR which formed over Gulf of Thailand and adjoining Malay peninsula in the morning (0830 IST) of 8th November. It concentrated into D over southeast BOB in the morning (0830 IST) of 10th. Moving west-northwards it intensified into CS ‘Gaja’ over eastcentral and adjoining westcentral and southeast BOB in the early morning (0530 IST) of 11th. It gradually moved westwards till early morning of (0530 IST) of 12th after which it followed an anticlockwise looping track till 13th morning. Subsequently, moving west-southwestwards, it intensified into SCS over southwest BOB on 15th morning (0830 IST) and further into VSCS in the same night (2030 IST). It crossed Tamil Nadu and Puducherry coast between Nagapattinam and Vedaranniyam near 10.45°N and 79.8°E with wind speed of 130 kmph gusting to 145 kmph during 0030-0230 IST of 16th November. After landfall, moving nearly westwards across interior Tamil Nadu and Kerala, it weakened into D in the same evening (1730 IST) over central Kerala and subsequently it emerged into southeast AS in the same midnight (2230 IST), intensified into DD by 17th early morning (0530 IST) and crossed Lakshadweep islands by the same afternoon. Subsequently, moving further west-northwestwards, it gradually weakened into D over southeast AS on 19th noon (1130 IST) and further into a LOPAR by 21st November. Associated with the movement of the system, widespread rainfall activity with isolated *heavy* to *very heavy* rain occurred over TN on 16th and 17th November. Isolated *extremely heavy* rain of 280.2 mm was recorded at Kozha in Kottayam district in Kerala on 17th. Observed track of VSCS Gaja and Doppler Weather Radar (Karaikal) maximum reflectivity product depicting the landfall are presented in Fig.2(b).

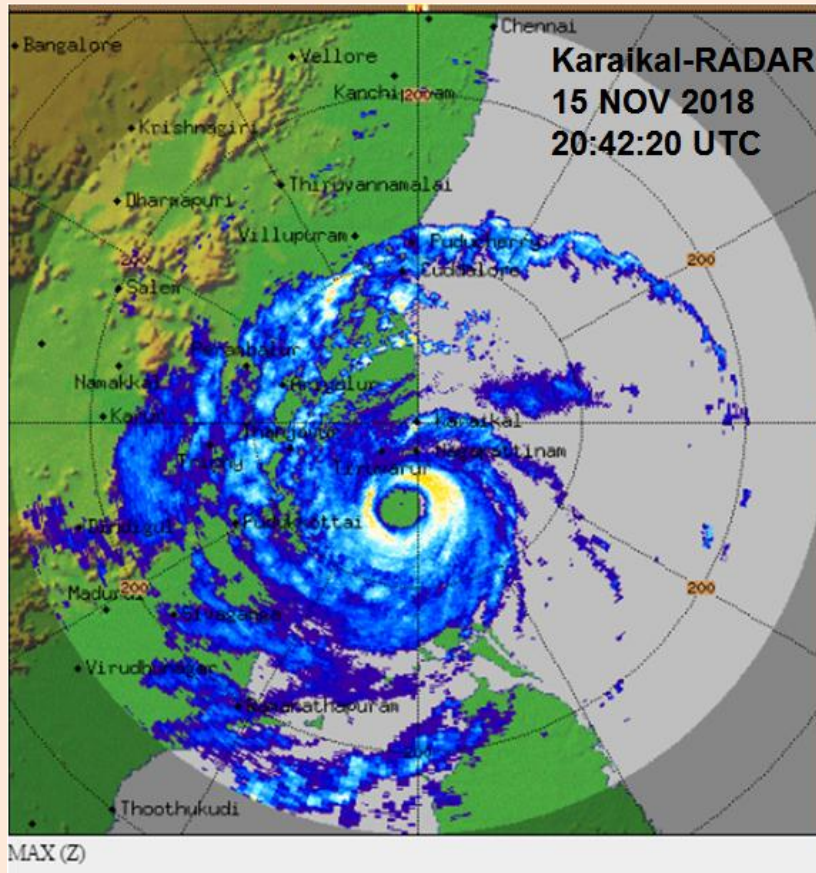
(iv) SCS Phethai over BOB during 13-18 December 2018: The SCS Phethai originated from a LOPAR which formed over equatorial Indian Ocean and adjoining central parts of south Bay of Bengal in the evening (1730 IST) of 9th December. It concentrated into a D over southeast BOB in the early morning (0530 IST) of 13th. Moving north-northwestwards, it intensified into a CS ‘Phethai’ (pronounced as Pay-ti) in the evening (1730 IST) of 15th and further into SCS in the afternoon of 16th. Moving north-northwestwards, it weakened into CS on 17th morning (0830 IST) and crossed Andhra Pradesh coast near 16.55N and 82.25E (close to south of Yanam, 40 km south of Kakinada) during 17th afternoon (1330-1430 IST) as CS with wind speed of 75-85 kmph gusting to 95 kmph. After landfall, its movement north-northeastwards it gradually weakened into D over CAP during the midnight of 17th December (2330 IST) and further into LOPAR over northwest BOB on 18th morning (0830 IST). Associated with the movement of the system, isolated *heavy* to *very heavy* rain occurred over north CAP on 17th & 18th December. The system tracked over southwest – westcentral BOB off TN – south CAP coasts thereby sweeping and transporting the available moisture over the chief NEM area away to north CAP coast without contributing to rainfall over the chief NEM area. Observed track of this system and INSAT-3D imagery as on 15 December, 2000 IST that depicts the associated intense clouding evading the NEM area are presented in Fig.2c.

(v) Aside from the above four major LPSs, another low intensity LPS, a well marked LOPAR formed over BOB on 18th November and moved across Tamil Nadu and Kerala causing FWS

rainfall activity for five days over TN and WS rainfall for three days over Kerala during 20-24 November. Rameswaram recorded *extremely heavy* rainfall of 226.2 mm/day on 24th November.

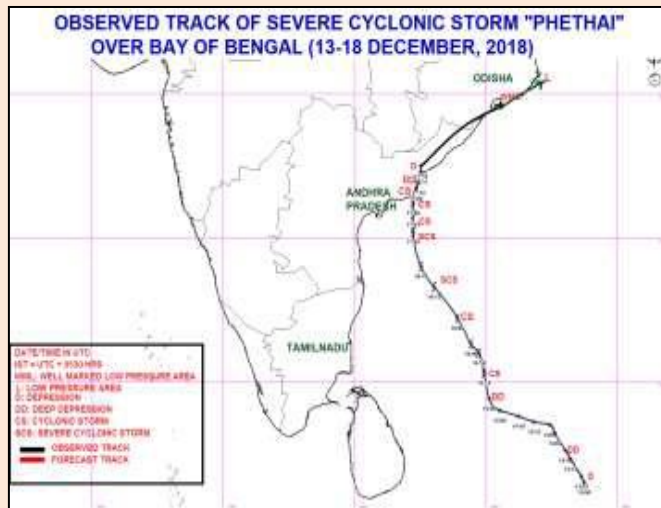


(i)

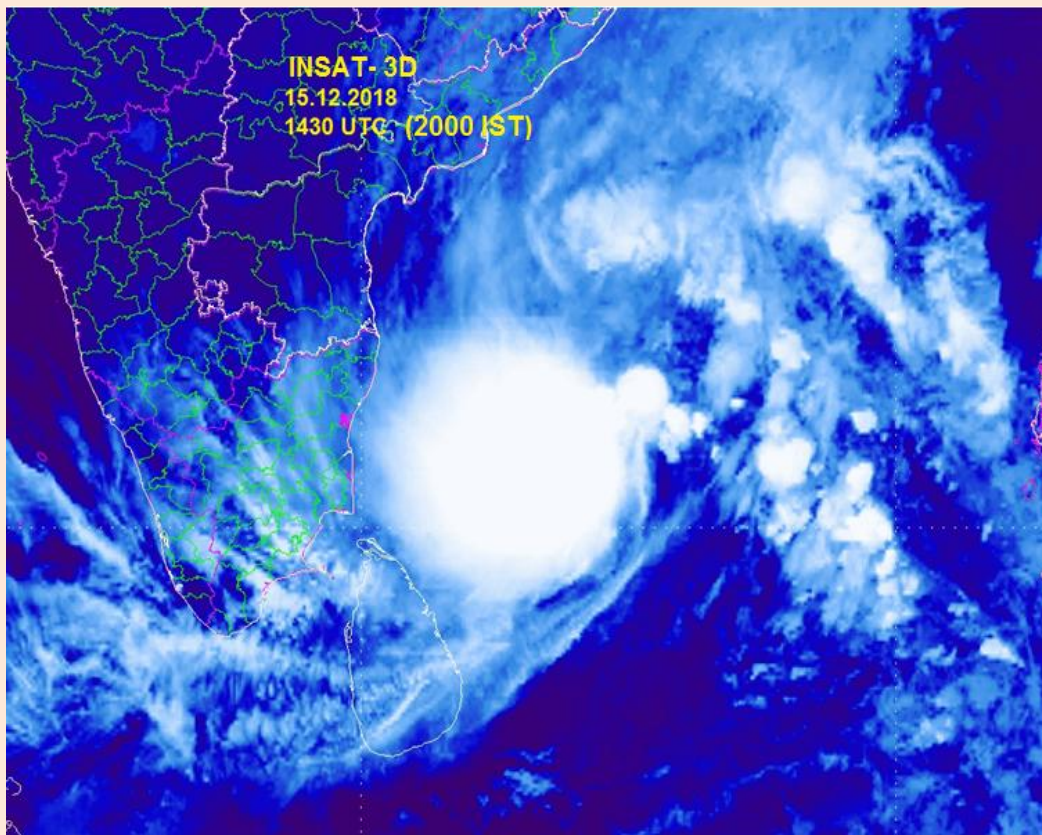


(ii)

Fig.2b: (i) Observed track of (i)VSCS Gaja over BOB-AS during 10-19 November 2018 and (ii) Doppler Weather Radar, Karaikal maximum reflectivity product as on 16 Nov, 0212 IST depicting its landfall between Nagapattinam and Vedaranniyam in Tamil Nadu.



(i)



(ii)

Fig.2c: (i) Observed tracks of SCS Pethai over BOB during 13-18 December 2018 and INSAT-3D imagery as on 15 Dec, 2000 IST 13-18 December 2018.

4. Seasonal rainfall performance during NEM 2018

The northeast monsoon performance during 2018 was *normal* (-19% to +19%) over only one subdivision (KER: -3%). It was *deficient* (-20% to -59%) to *largely deficient* ($\leq -60\%$) over the other 4 subdivisions benefitted by the NEM (TN, CAP, RYS and SIK). Whereas TN, CAP and SIK came under *deficient* category (-24%, -54% and -42% respectively), RYS ended up *largely deficient* (-62%). Fig.3 and Table-1 present the season ending (01st Oct-31st Dec) rainfall figures over these subdivisions.

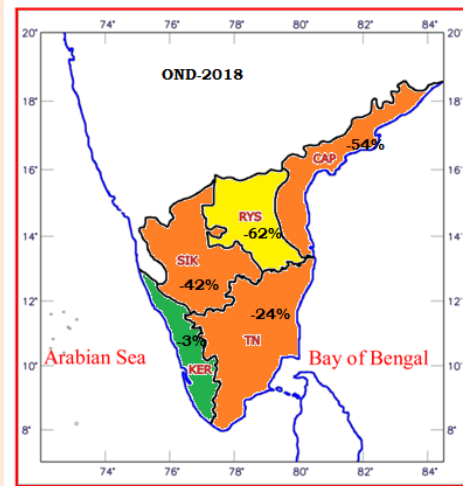


Fig.3: Seasonal rainfall performance of NEM 2018 over the five meteorological subdivisions benefitted by the NEM

Table-1: Sub-divisional seasonal rainfall during October-December 2018

Subdivision	01 st October – 31 st December 2018		
	Actual (mm)	Normal (mm)	PDN (%)
TAMIL NADU	337.9	442.0	-24%
KERALA	465.6	480.7	-3%
COASTAL ANDHRA PRADESH	149.3	327.4	-54%
RAYALASEEMA	83.8	219.2	-62%
SOUTH INTERIOR KARNATAKA	121.2	209.5	-42%

PDN: Percentage Departure from Normal

TN: Tamil Nadu & Puducherry;

KER: Kerala;

CAP: Coastal Andhra Pradesh;

RYS: Rayalaseema;

SIK: South Interior Karnataka

Legend:

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

The intra-seasonal rainfall distribution over various sub-divisions during Oct-Dec 2018 is presented in monthly, weekly and daily scales. Month-wise rainfall statistics are presented in Table-2. Tables-3a&b depict the week by week performance (weekly & cumulative), Table-4a&b present the daily rainfall scenario in terms of spatial rainfall distribution (*Widespread:WD*, *Fairly widespread: FWD*, *Scattered:SCT*, *Isolated: ISOL* and *DRY*), frequency of active and vigorous monsoon days and frequency of heavy rainfall days (*Heavy* rainfall ≥ 7 cm/day; *Very Heavy* rainfall ≥ 12 cm/day; *Extremely Heavy* rainfall ≥ 21 cm/day).

Table-2: Sub-divisional monthly rainfall during NEM 2018

Sub-division	OCT			NOV			DEC		
	Actual (mm)	Normal (mm)	PDN (%)	Actual (mm)	Normal (mm)	PDN (%)	Actual (mm)	Normal (mm)	PDN (%)
TN	157.0	181.1	-13	159.1	171.7	-7	21.8	89.2	-76
KER	307.2	292.4	+5	131.1	150.9	-13	27.2	37.4	-27
CAP	48.4	193.2	-75	41.8	106.6	-61	59.2	27.6	+114
RYS	44.8	129.4	-65	34.4	66.1	-48	4.6	23.7	-81
SIK	97.6	147.8	-34	18.9	49.0	-61	4.7	12.6	-63

(TN, KER, CAP, RYS, SIK and Legend: same as Table-1)

Table-3a: Week by week rainfall departures (%) during NEM 2018

	03/10/2018	10/10/2018	17/10/2018	24/10/2018	31/10/2018	07/11/2018	14/11/2018	21/11/2018	28/11/2018	05/12/2018	12/12/2018	19/12/2018	26/12/2018
CAP	-67	-86	-12	-90	-99	-68	-100	-41	-13	-54	-60	+645	-98
RYS	-70	-72	-62	-12	-99	-65	-100	-16	-36	-74	-26	-99	-82
TN	+28	+144	-48	-44	-88	-29	-86	+50	+70	-30	-84	-99	-49
SIK	-6	-23	+12	+6	-99	-65	-100	-16	-36	-74	-28	-99	-82
KER	+1	+73	+24	+7	-95	-51	-81	+115	+50	-44	-55	-88	+165

Table-3b: Weekly cumulative rainfall departures (%) during NEM 2018

	03/10/2018	10/10/2018	17/10/2018	24/10/2018	31/10/2018	07/11/2018	14/11/2018	21/11/2018	28/11/2018	05/12/2018	12/12/2018	19/12/2018	26/12/2018
CAP	-86	-86	-61	-70	-75	-74	-76	-73	-70	-69	-69	-54	-54
RYS	-93	-79	-74	-58	-65	-66	-69	-67	-59	-59	-60	-61	-62
TN	+8	+104	+39	+9	-13	-17	-28	-19	-12	-14	-19	-22	-23
SIK	-82	-45	-26	-19	-33	-36	-41	-39	-39	-40	-40	-41	-41
KER	+7	+53	+41	+31	+4	-5	-13	-4	-1	-3	-4	-6	-4

(TN, KER, CAP, RYS, SIK & Legend: same as Table-1)

Table-4a: Spatial rainfall distribution

Subdivision	No. of days				
	WD	FWD	SCT	ISOL	DRY
TN	5	14	18	42	13
KER	13	14	10	36	19
CAP	1	1	9	43	38
RYS	1	0	8	29	54
SIK	4	8	9	24	47

WD: Widespread

(76-100% of stations reporting rainfall)

SCT: Scattered

(26-50% of stations reporting rainfall)

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

(51-75% of stations reporting rainfall)

ISOL: Isolated

(≤25% of stations reporting rainfall)

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

Subdivision	No. of days				
	Activity		Heavy Rainfall		
	Vigorous	Active	Extremely Heavy	Very Heavy	Heavy
TN	4	8	2	15	40
KER	2	10	1	5	21
CAP	2	0	1	5	13
RYS	0	1	0	1	6
SIK	1	2	0	0	7

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

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

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

During October and November, TN and KER received *normal* rainfall and the other three sub-divisions (CAP, RYS & SIK) came under *deficient to largely deficient* categories (Table-2). In December, except CAP that received *large excess* rainfall all other sub-divisions (TN, KER, RYS & SIK) came under *deficient to largely deficient* categories.

Under extended SWM conditions, during the first four weeks of October (till week ending 24.10.2019), TN received *excess* to *large excess* rainfall during the first 10 days, but, became deficient during the subsequent two weeks under the influence of formation and movement of VSCS Titli (8-13 Oct 2018); KER & SIK received generally *normal-excess* rainfall during this period; CAP & RYS came under *largely deficient* category during three weeks and received *normal* rainfall only during one week – CAP, during the week ending 17.10.2018 under the influence of movement of VSCS Titli (8-13 Oct 2018) over north CAP and RYS, during the subsequent week. After the withdrawal of SWM on 21.10.2018 and prior to the commencement of NEM rains on 01.11.2018, during the week ending 31.10.2018, there was only meagre rainfall activity and all the five sub-divisions recorded *largely deficient* rainfall (deficiency of 88% to 99%) (Table-3).

Even after the onset of NEM on 01.11.2018, there was only *deficient* to *largely deficient* rainfall over all the five sub-divisions during the first two weeks of November. In fact, CAP, RYS and SIK were completely dry during the week ending 14.10.2018. Subsequently, under the influence of passage of VSCS Gaja during 16-17 November, TN & KER received *excess / large excess* rainfall and RYS & SIK received *normal* rainfall during the week ending 21.11.2018. During the following week (week ending 28.11.2018), under the influence of well marked low pressure area, TN & KER received *large excess / excess* rainfall.

During the subsequent four weeks, excepting for CAP receiving *large excess* rainfall during the week ending 19.12.2018 under the influence of passage of SCS Pethai over CAP and KER receiving *large excess* rainfall during the last week of December (week ending 26.12.2018) when the equatorial trough shifted south of NEM area, NEM activity was generally *deficient* to *largely deficient* over the entire NEM region.

In the daily scale, whereas TN & KER experienced SCT-WS rainfall activity during 40% of the days with 13% of the days under *active-vigorous* monsoon conditions during the season. However, CAP, RYS & SIK experienced only ISOL/DRY conditions on more than 75% of the days. *Active-vigorous* monsoon conditions prevailed over CAP & RYS only on 1 or 2 days during the season. SIK experienced *active-vigorous* monsoon conditions on 3 days in October, prior to the onset of NEM during the season.

Regarding heavy rainfall occurrences (≥ 7 cm/day), TN experienced isolated *heavy* rainfall activity on 40 days during the season, out of which, 15 days were with isolated *very heavy* falls. There were two days of isolated *extremely heavy* rainfall - 03 November and 24 November. On 3rd November, during the onset phase of NEM, Manimutharu (Tirunelveli district) and Satankulam (Thoothukudi district) recorded 286.0 mm and 219.0 mm respectively. On 24th November, under the influence of well marked low pressure area [section 3(v)], Rameswaram reported 226.2 mm. In Kerala, there were 21 days of isolated *heavy* rainfall activity with 5 days of isolated *very heavy* rain. Isolated *extremely heavy* rainfall (Kozha (Kottayam district) - 280.2 mm) occurred on 17 November in association with the passage of

VSCS Gaja [section 3(iii)]. CAP experienced 13 days of isolated *heavy* rainfall activity with 5 days of isolated *very heavy* rain and one day of isolated *extremely heavy* rain. *Extremely heavy* rainfall of 237.6 mm and 234.6 mm were reported from Ichchapuram and Tekkali respectively (both in Srikakulam district) on 11th October in association with the passage of VSCS Titli over this area [section 3 (ii)].

5. Performance of NEM 2018 over Tamil Nadu and Puducherry

Spatial and temporal rainfall distributions over the TN subdivision during Oct-Dec 2018 are depicted by means of district-wise rainfall distribution and area averaged daily rainfall distribution over TN. Fig.4 presents the daily rainfall distribution over the TN subdivision (including the state of Tamil Nadu and UT of Puducherry) during Oct-Dec 2018. The daily subdivisional rainfall was above normal on 10 days before the NEM onset and on 12 days after the onset.

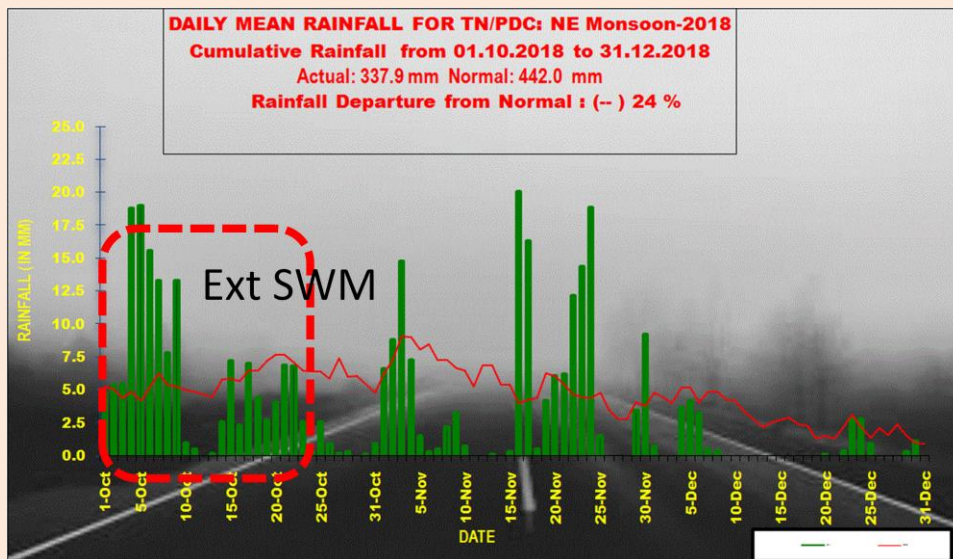


Fig.4: Area averaged daily rainfall over TN subdivision during Oct-Dec 2018

District-wise rainfall realised is presented in Table-5 and Fig.5. As seen, the districts of Nilgiris, Coimbatore, Tiruppur & Theni along the western ghat areas and the eastern coastal districts of Kanyakumari, Tirunelveli, Thoothukudi, Ramanathapuram, Thanjavur, Tiruvarur, Nagapattinam, Karaikal, Cuddalore & Villupuram and two adjoining districts of Ariyalur and Thiruvannamalai received normal rainfall during the season. All the other interior districts and the northeastern coastal districts of Thiruvallur, Chennai, Kanchipuram and Puducherry ended up deficient. Chennai, Dharmapuri, Krishnagiri and Karur recorded deficiency of more than 50%.

Table-5: District-wise rainfall figures of Tamil Nadu and Puducherry during Oct-Dec 2018

State/District/Subdivision	Actual rainfall (mm)	Normal rainfall (mm)	Percentage departure from normal
STATES			
Puducherry (UT)	745.4	915.6	-19
Tamil Nadu	336.5	440.4	-24
DISTRICTS			
ARIYALUR	518.2	545.5	-5
CHENNAI	352.9	789.9	-55
COIMBATORE	325.1	328.9	-1
CUDDALORE	621.0	697.8	-11
DHARMAPURI	133.7	330.1	-59
DINDIGUL	301.8	436.4	-31
ERODE	228.0	314.6	-28
KANCHEEPURAM	417.1	641.8	-35
KANYAKUMARI	402.7	496.4	-19
KARAIKAL (Puducherry)	952.4	1048.5	-9
KARUR	147.4	314.7	-53
KRISHNAGIRI	123.1	289.4	-57
MADURAI	278.4	419.1	-34
NAGAPATTINAM	816.5	941.0	-13
NAMAKKAL	182.5	291.6	-37
NILGIRIS	416.3	478.2	-13
PERAMBALUR	250.0	440.9	-43
PUDUCHERRY	632.4	843.1	-25
PUDUKKOTTAI	313.2	406.2	-23
RAMANATHAPURAM	440.3	491.7	-10
SALEM	187.6	370.5	-49
SIVAGANGA	338.0	422.7	-20
THANJAVUR	471.5	550.3	-14
THENI	302.1	357.9	-16
TIRUNELVELI	519.7	467.2	11
TIRUPPUR	282.1	314.3	-10
TIRUVALLUR	343.2	589.3	-42
TIRUVANNAMALAI	393.1	446.5	-12
TIRUVARUR	710.6	719.1	-1
TOOTHUKUDI	348.7	427.0	-18
TRICHY	208.0	391.5	-47
VELLORE	181.6	348.7	-48
VILLUPURAM	435.8	499.1	-13
VIRUDHUNAGAR	265.5	419.0	-37
TN Subdivision	337.9	442.0	-24

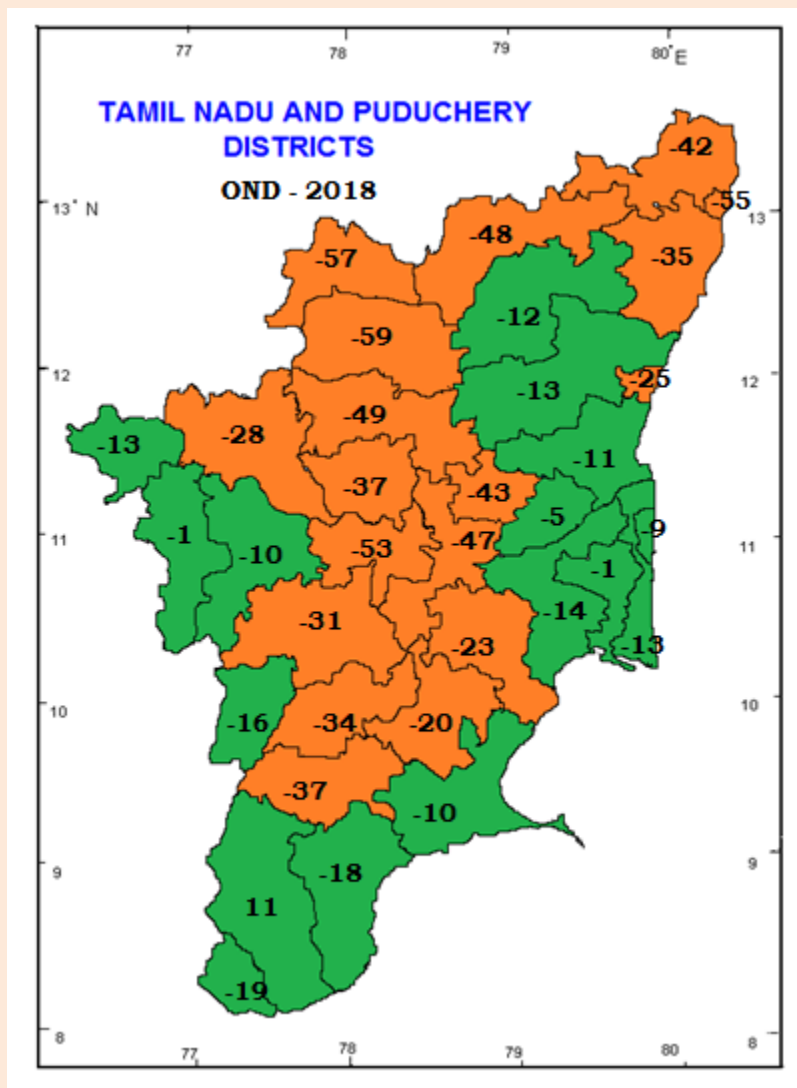


Fig.5 District-wise rainfall distribution over the TN subdivision during Oct-Dec 2018

5.1 Impact of VSCS Gaja over Tamil Nadu and Puducherry

VSCS Gaja (10-19 November 2018) crossed Tamil Nadu and Puducherry coast between Nagapattinam and Vedaranniyam near 10.45°N and 79.8°E with wind speed of 130 kmph gusting to 145 kmph during 0030-0230 IST of 16th November. Associated with the passage of VSCS Gaja, Adiramapattinam recorded MSLP of 977.1 hPa, wind speed of 65 kts (120 kmph) and -31 hPa as 24-hr pressure change at 0230 IST of 16 November. DWR Karaikal reported radial velocity of about 60 kts (111 kmph) during the landfall. Wind and mean sea level pressure (MSLP) observations reported by the coastal stations near the landfall location, observations at Doppler Weather Radar stations at Chennai and Karaikal depicting the landfall location, time and intensity are presented in Fig.6a-c.

Station	15.11.2018 18 UTC	15.11.2018 19 UTC	15.11.2018 20 UTC	15.11.2018 21 UTC	15.11.2018 22 UTC	15.11.2018 23 UTC	16.11.2018 00 UTC
<u>Karaikal</u>	1004.0 -5.4 31	1002.1 -7.7 35	1000.7 -8.0 37	1000.0 41 -8.4	1001.4 44 -6.0	1003.8 48 -3.7	1005.8 52 -1.1
<u>Nagapattinam</u>	1003.1 -5.7 39	1000.3 44	997.2 47	1008.5 -8.7 48	1007.7 52	1003.7 55	1004.0 -1.7 59
<u>Adiramapattinam</u>	1006.2 -3.8 9	1007.5 -4.9 14	1001.0 -8.1 19	995.8 -12.6 50	977.1 -31.0 55	980.1 -28.0 148	998.3 -9.8 160
<u>Thondi</u>	1008.6 -1.8 7	1008.5 -1.5 11	1006.9 -2.5 15	1005.9 -3.5 18	1004.7 -4.1 19	1004.2 -3.8 23	1005.0 -3.6 26

Fig.6a: Hourly coastal observations during 15/2330 IST to 16/0530 IST of November 2018

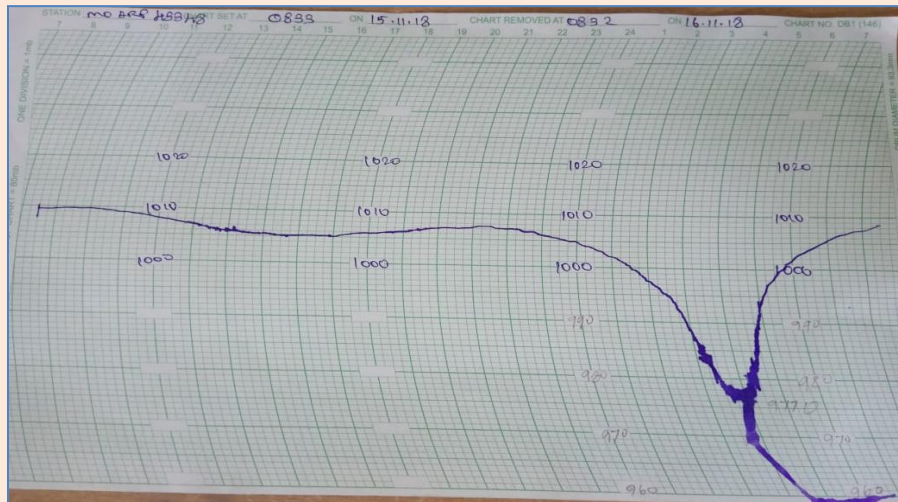


Fig.6b: Barograph recording at Adiramapattinam during 15/0830 IST to 16/0830 IST

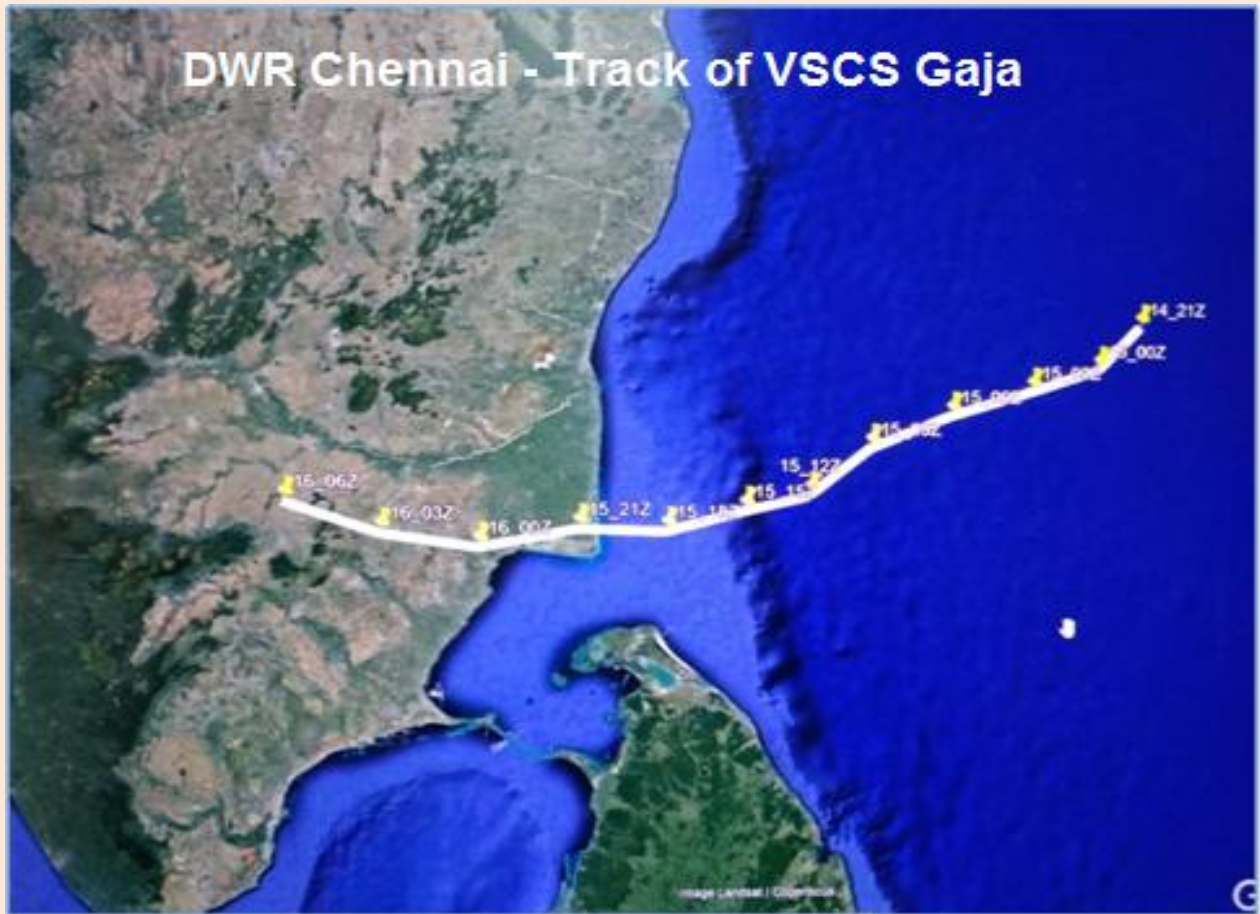


Fig.6c(i): Track of VSCS Gaja during 15/0230IST to 16/1130 IST as observed by DWR Chennai

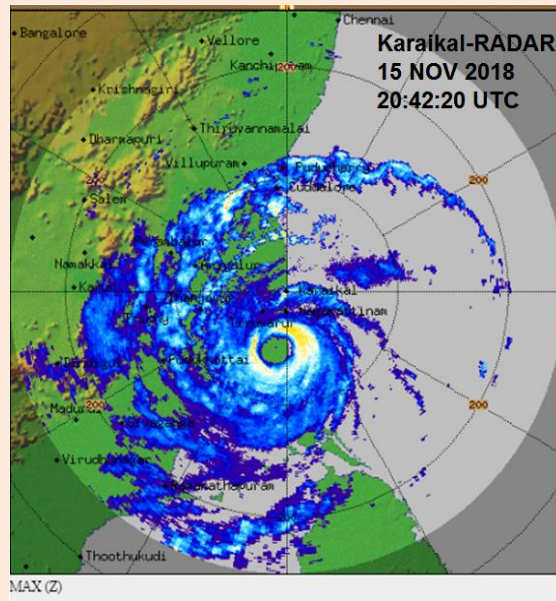


Fig.6c(ii): DWR Karaikal maximum Reflectivity product as on 16/0212 IST

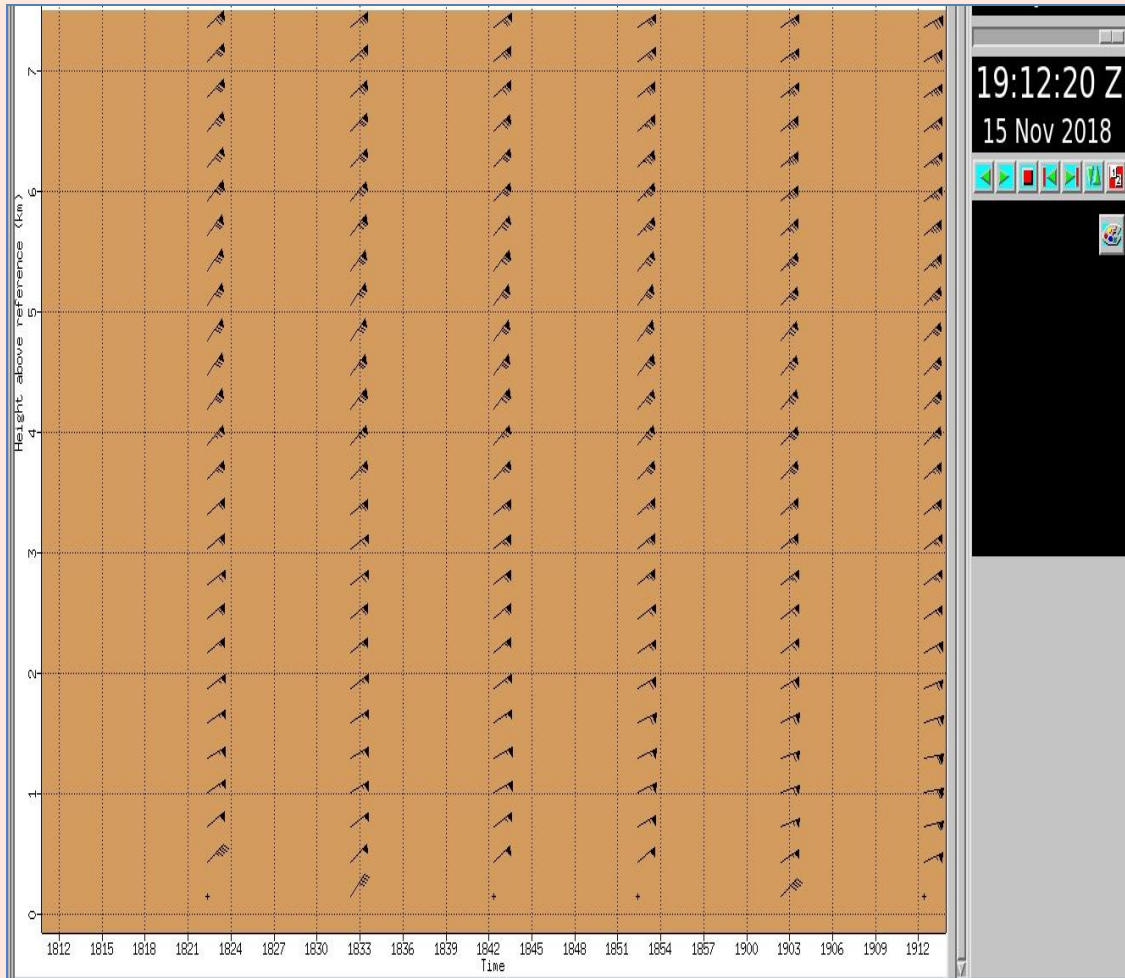


Fig.6c (iii): DWR Karaikal VVP product at 15/1903UTC.

Rainfall: Widespread rainfall activity with isolated *heavy* to *very heavy* rain occurred over TN on 16 & 17 November 2018 [Fig.7d(i) &(ii)] which contributed about 10% of rainfall to seasonal total. Whereas Thanjavur, Sivaganga, Dindigul and Theni districts received more than 20% of the seasonal rainfall during this period, Chennai, Thoothukudi and Tirunelveli districts did not benefit at all from this system.

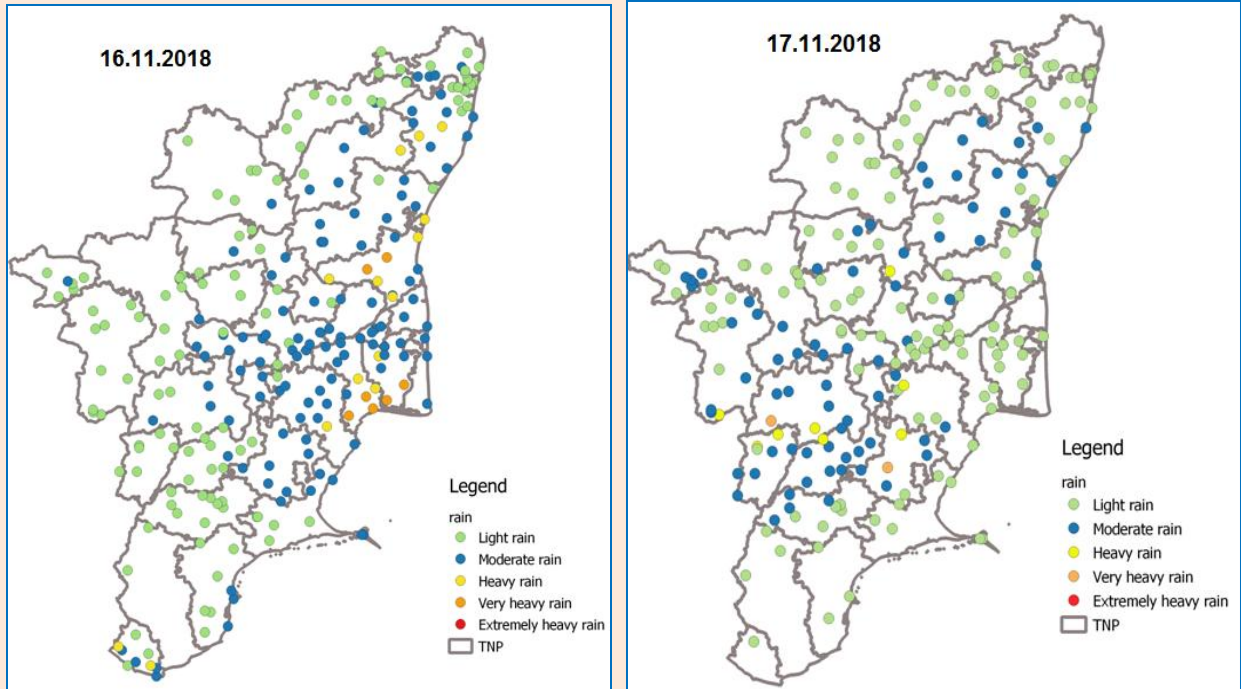


Fig.6d(i): 24-hr accumulated rainfall over TN as on 0830 IST of 16 & 17 November 2018

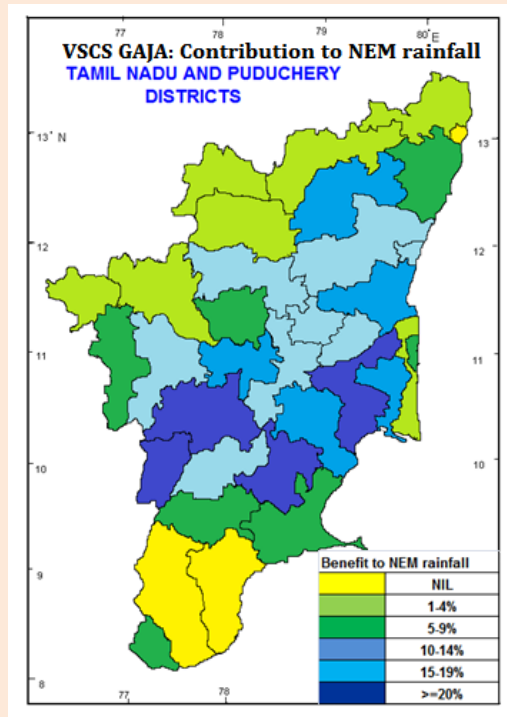


Fig.6d(ii): Benefit to NEM rainfall over various districts of TN due to passage of VSCS Gaja

Damages due to gale winds:

As per media reports (The Indian Express dated 21 Nov 2018), about 45 deaths have been reported. As per reports in The Hindu dated 19 Nov 2018, about 1.7 lakh trees and 40, 000 electricity poles have fallen; 374 electricity distribution transformers have been damaged, about 60, 000 huts completely damages and about 30, 000 huts and 30,000 tiled houses, partially damaged. Boats parked along the sea shore have been flung inland (The Hindu dated 21 Nov 2018 and Puthiya Thalaimurai TV report - screenshot). In the Adiramapattinam-Pamban coastal belt, sea water receded by about 200m near the north sea area in Rameswaram (Maalai Murasu dated 16 Nov 2018). Extensive damages to crops in the Cauvery delta districts of Thanjavur, Tiruvarur, Nagapattinam and Pudukkottai districts have been reported by several local dailies and TV channels. As per a report by Maalai Murasu dated 18 Nov 2018, about 45, 000 acres of coconut farm have been damaged in Thanjavur district alone. Some damage reports / pictures published by the print and electronic media are presented in Fig.6e.

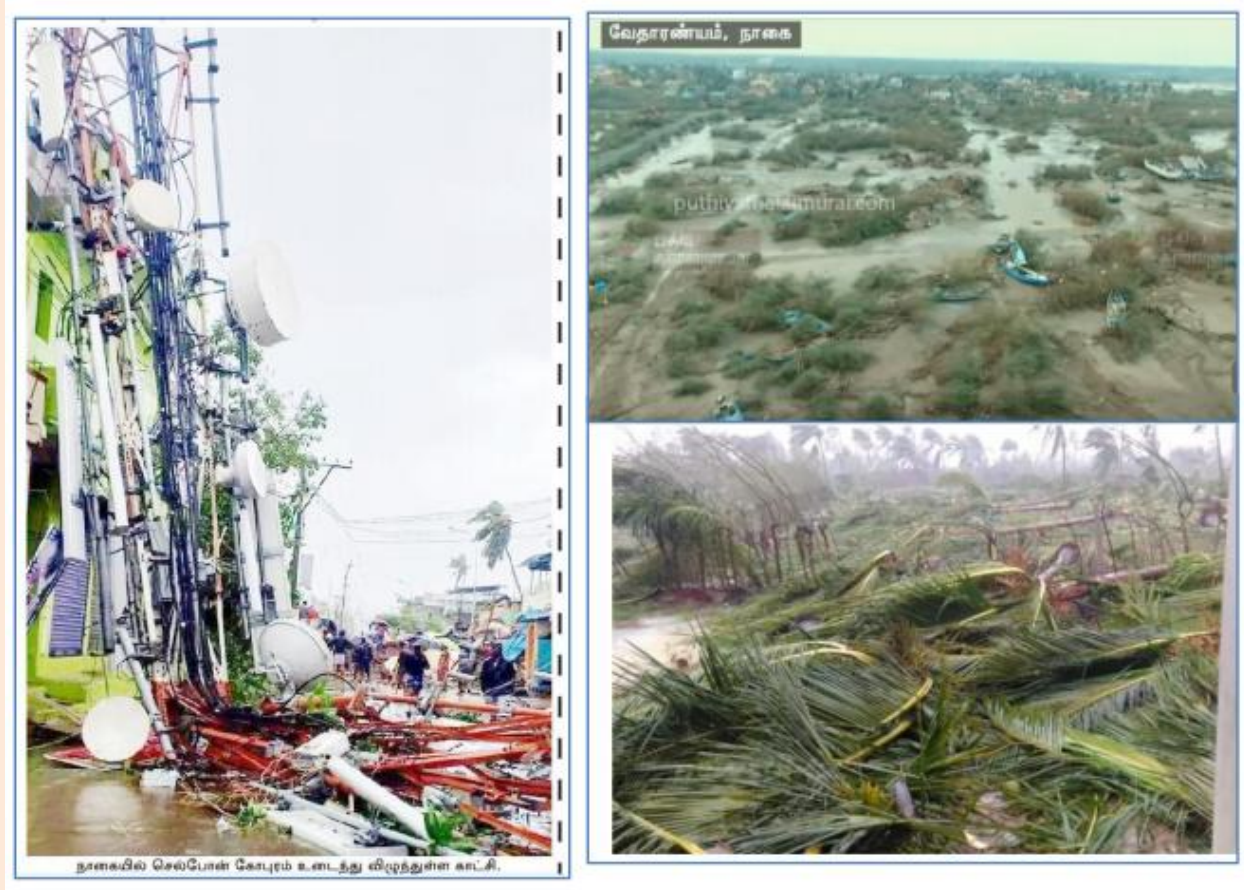


Fig.6e: Damages due to VSCS Gaja



Damaged structures and fallen trees in Velankanni, Nagapattinam district
(Source: puthiyathalaimurai.com)



A destroyed petrol station in Velankanni, Nagapattinam district
(Source: newindianexpress.com)

Fig.6e (contd.)

கஜா புயலால் பேரழிவு:

நிலை குலைந்து போன டெல்டா பகுதி மக்கள்!

தஞ்சை மாவட்டத்தில் மட்டும் 44,460 ஏக்கர் தென்னை பாதிப்பு!!

சென்னை, நவ. 18- கஜா புயலின் தாக்கத்தால் டெல்டா மாவட்டங்களில் பேரழிவு ஏற்பட்டுள்ளது. உணவு, குடிநீர் உள்ளிட்ட அடிப்படை ஆதாரம் ஏதுவுமில்லாதி அப்பகுதி மக்கள் நிலை குலைந்து போயுள்ளனர். தஞ்சாவூர் மாவட்டத்தில் மட்டும் 44,460 ஏக்கர் பரப்பளவில் தென்னை மரங்கள் வேரோடு சாய்ந்துள்ளன. அரசின் போர்கால நடவடிக்கைகளுடன் பொதுமக்களுக்கேரிக் வேண்டும் என்று பலரும் கோரிக்கைவிடுத்துள்ளனர். கஜா புயலின் சீர்தந்தால் டெல்டா பகுதி விவசாயிகள் நிலை குலைந்து போயுள்ளனர். கடந்த 3 நாட்களாக மின்சாரம், உணவு, குடிதண்ணீர், உறைவிடம், மருத்துவப் பொருட்கள், உள்ளிட்ட எந்தவித அடிப்படை வசதிகளும் இல்லாமல் தவித்து வருகின்றனர்.

தஞ்சாவூர், திருவாரூர், வேளாங்கண்ணி, தாகப்பட்டினம், வேதாரண்யம், சிவகங்கை, திண்டுக்கல், ராமநாதபுரம், கும்பகோணம், மலையாளம், மதுரை, முத்துப்பேட்டை, புதுக்கோட்டை மாவட்டங்களில் புயலின் தாக்கம் மிகமோசமாக உள்ளது.

50 ஆயிரத்துக்கும் மேற்பட்ட மின்கம்பங்கள் சாய்ந்தன. சாலைகளில் மரங்கள் விழுந்ததால் டெல்டா மாவட்டங்களில் போக்குவரத்து அடியோடு துண்டிக்கப்பட்டுள்ளது. பல வீடுகளில் மீது மின்கம்பங்கள் சாய்ந்துள்ளன. இதனால் மின்சாரம் அடியோடு துண்டிக்கப்பட்டுள்ளது. மின் இணைப்பு இல்லாததால் தகவல் தொடர்பு சாத



னங்களும் செயல் இழந்துள்ளன.

வாழ்வாதாரம் குறிப்பாக தாகை, தஞ்சாவூர் மாவட்டங்களில் அதிகாரம் பட்டினம், போரூர், பட்டுக்கோட்டை, மதுக்கூர், வெட்டிக்காடு மற்றும் திருத்தூறப்பூண்டி, மன்னார்குடி உள்ளிட்ட பகுதிகளில் 'கஜா' புயல், கொரத்தாண்டவம் ஆடியதில் மக்களின் அடிப்படை வாழ்வாதாரம் தரிந்துள்ளது.

பயிர்கள் சேதமடைந்துள்ளன. பெரும்பாலான கிராமங்களில், ஆயிரக்கணக்கான குடிசைகளை இடித்து விழுத்துள்ளன. கடலோர பகுதிகளில் திறந்திவைக்கப்பட்டிருந்த, நாட்டுப் படகுகள், விசைப்படகுகள் தரக்கி விசப்பட்டன.

இதில், ஆயிரக்கணக்கான படகுகள் சேதமடைந்தன. மக்கள் வீடுகளை இழந்து சாலைகளில் தஞ்சமடையும் நிலை ஏற்பட்டுள்ளது. 82 ஆயிரம் பேர் இதுவரை நிவாரண முகாம்களில் தங்கவைக்கப்பட்டுள்ளனர். ஆயிரக்கணக்கான ஆடு, மாடுகள் கொத்துக் கொத்தாக செத்துக் கிடக்கின்றன. குறிப்பிட்ட பகுதிகளில் மீட்புப் பணிகள்தாமதம் ஆகியுள்ளது.

டெல்டாமாவட்ட பாதிப்புகள் பெரிய அளவில் வெளியே தெரியாத காரணத்தால் அப்பகுதி மக்கள்கடும் கோபத்திற்கு ஆளாகியுள்ளனர்.

னர். தஞ்சாவூர் மாவட்டத்தில் சாகுபடி செய்யப்பட்டுள்ள தென்னை மரங்களில் 50 சதவீதம் புயல் தாக்கத்தில் வேரோடு சாய்ந்தன. ஏறத்தாழ 44,460 ஏக்கர் பரப்பளவில் 5 லட்சத்துக்கும் அதிகமான தென்னை மரங்களை அப்பகுதி மக்கள் இழந்துள்ளனர்.

தனுஷ்கோடியில், 1960ல் ஏற்பட்ட புயலால் விடப்பட்ட புயல் அதிகமாக பாதிப்பை ஏற்படுத்தி விட்டதாக கூறப்படுகிறது.

இந்த புயலில் 37க்கும் மேற்பட்ட பொதுமக்கள் உயிரிழந்துள்ளதாக தகவல்கள் வெளியாகியுள்ள நிலையில், காணக்காணாத காரணங்களில் 50க்கும் மேற்பட்ட மரங்கள், காட்டுப் பன்றிகள், காட்டு குதிரைகள் செத்து கிடக்கும் காட்சி தெஞ்சை பதற வைப்பதாக உள்ளது.

டெல்டா மாவட்ட தென்னை விவசாயிகள்கூறுகையில், தஞ்சாவூர் மாவட்டத்தில் சாகுபடி செய்யப்பட்டிருந்த 3 லட்சம் தென்னை மரங்களும், திருவாரூர் மாவட்டத்தில் 2 லட்சம் மரங்களும் பாதிக்கப்பட்டுள்ளன. கஜா புயலால் பாதி மரங்கள்கூட மிஞ்சவில்லை. பாதிப்பை கணக்கெடுத்து உரிய நிவாரணம் வழங்க வேண்டும் என்று கோரிக்கை விடுத்தனர்.

பாதிக்கப்பட்ட மக்கள் கூறுகையில், சென்னை வெள்ளத்தில் போது ஏற்பட்ட பாதிப்பை விட தற்போது டெல்டா பகுதி மக்கள் மிக அதிகமாக பாதிக்கப்பட்டுள்ளோம். 20 வருடங்கள் பின்தங்கிய நிலை ஏற்பட்டுள்ளது.

10 ஆண்டுகளாக வளர்த்த பயிர்களும் தாசமடைந்துள்ளது. எங்கள் அடிப்படை வாழ்வாதாரத்தை காக்க உதவிக்ரம் நீட்ட வேண்டும் என்று பலரும் கோரிக்கை விடுத்துள்ளனர்.

-Maalai Murasu dated 18 Nov 2018

Fig.6e (contd.)

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-December 2018, SPI indicated dry conditions over most parts of the NEM region (Fig.7). In TN, excepting the districts of Tiruvarur, Ariyalur and Tirunelveli which came under *mildly wet* category, generally, all other districts were *mildly- severely* dry. Kerala was generally *mildly dry* excepting the districts of Ernakulam, Kottayam and Pathanamthitta which came under *mildly-moderately wet*. All districts in RYS ended up *moderately-severely* dry. In CAP, excepting the Srikakulam district which came under *mildly wet* category, all other districts came under *mildly-severely* dry. SIK was generally *mildly-severely* dry.

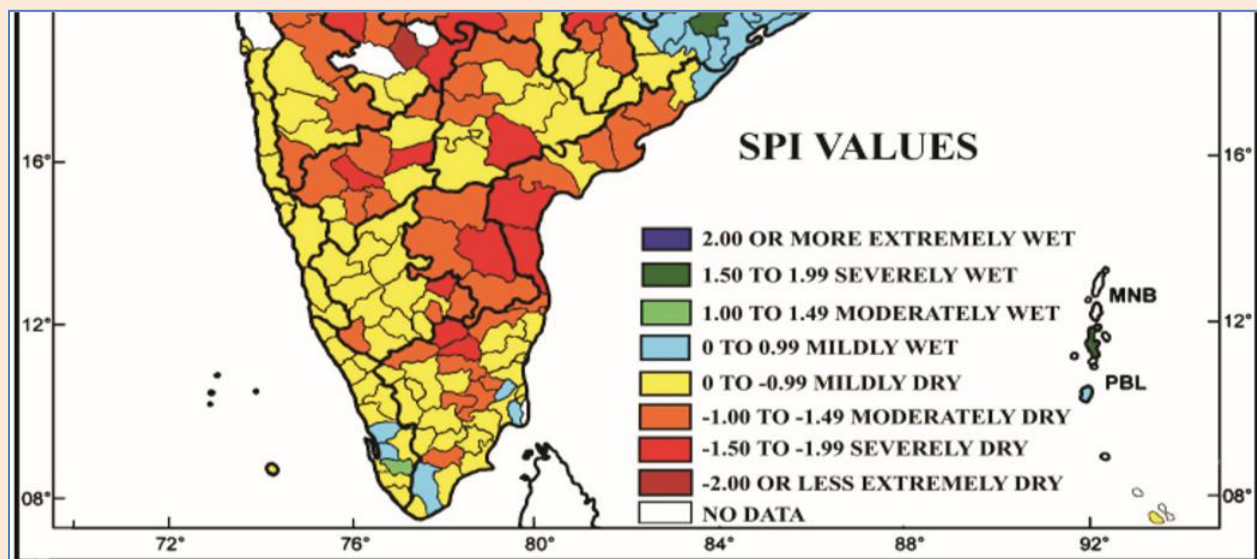


Fig.7: Standardised Precipitation Index for October-December 2018 over the southern peninsular India.

7. Chief circulation features

(a) *Synoptic scale features:* The mean and anomalous wind pattern over the Indian region at 850 hPa, 500 hPa and 250 hPa levels during October –December 2018 (Fig.8a-c) indicate the following:

In October, in the lower troposphere, at 850 hPa level, an anomalous anti cyclonic circulation over the central parts of the country and anomalous cyclonic circulation over the south Arabian sea were observed. The anomalous anti cyclonic circulation over central parts at 850hPa level was seen over the south peninsula and central parts at 500hPa level also. At 250 hPa level, anomalous westerlies prevailed over the entire country.

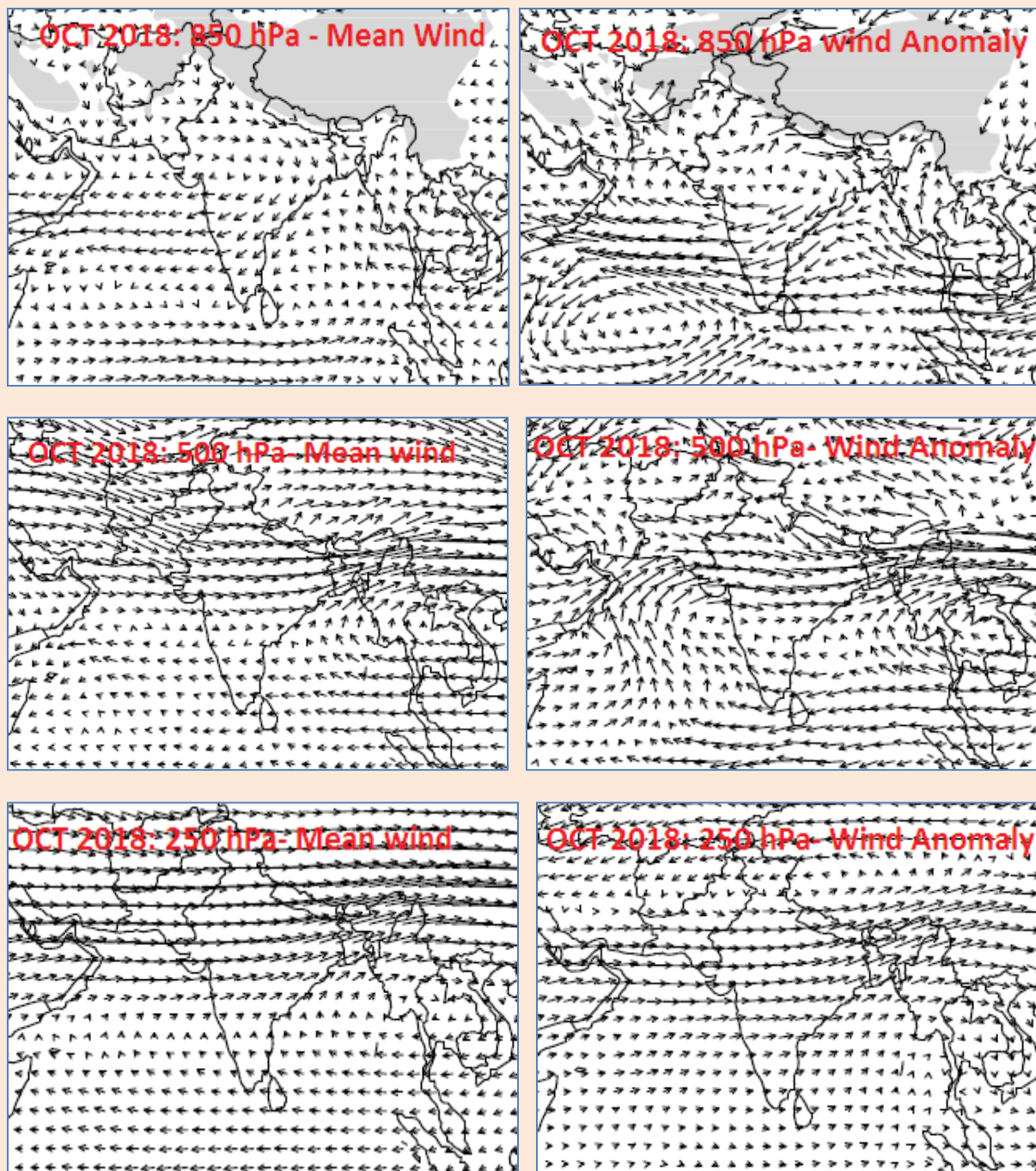


Fig.8a: Mean and anomalous wind pattern over the Indian region at 850 hPa, 500 hPa and 250 hPa levels during October 2018 (Source: Climate Diagnostic Bulletin of India, IMD Pune)

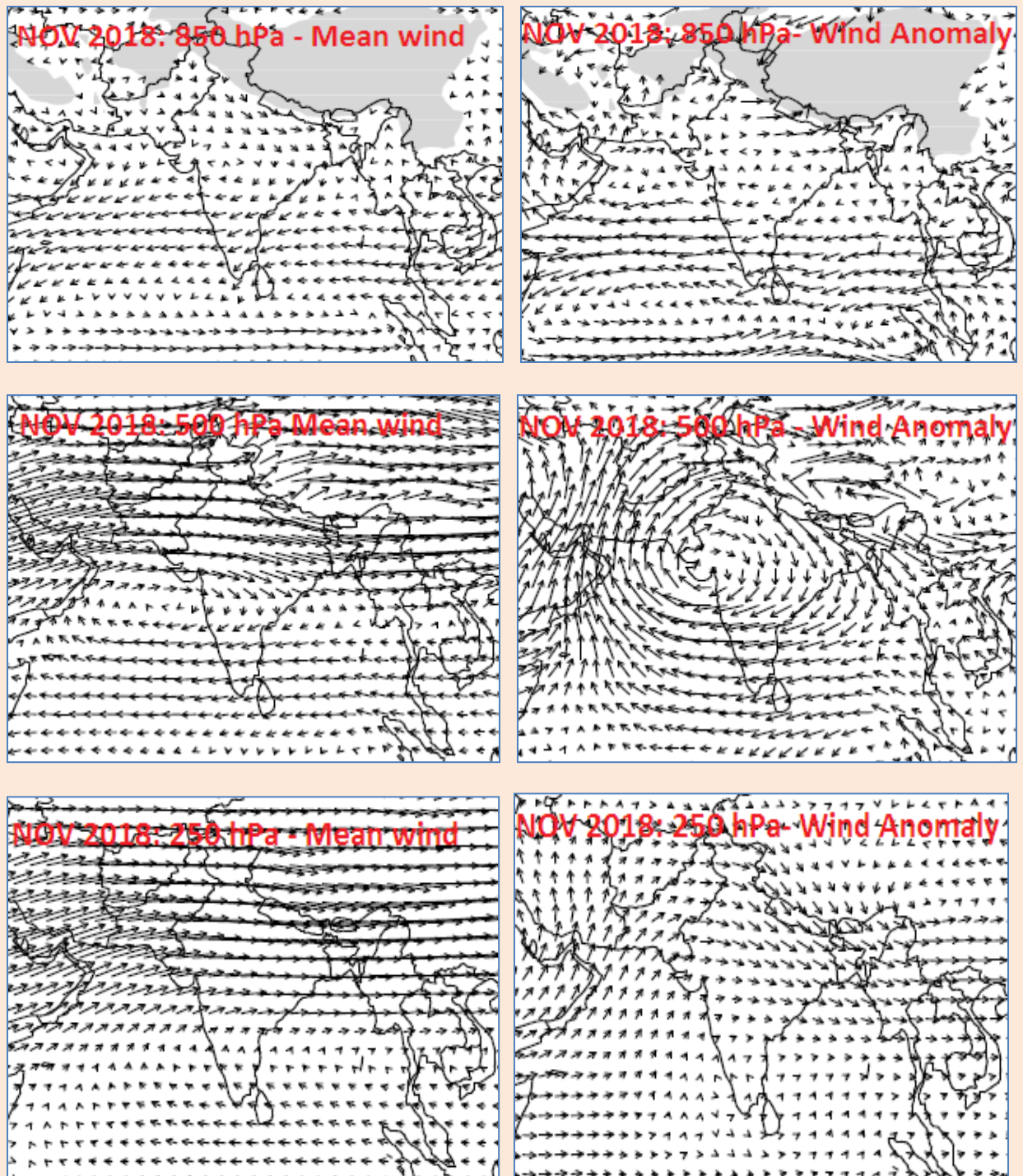


Fig.8b: Mean and anomalous wind pattern over the Indian region at 850 hPa, 500 hPa and 250 hPa levels during November 2018 (Source:Climate Diagnostic Bulletin of India, IMD Pune)

In November, at 850 hPa level, anomalous easterlies prevailed over the south peninsula. At 500 hPa level, an anomalous anti cyclonic circulation was observed throughout the country with

centre over the central India. At 250 hPa level, anomalous westerlies were observed throughout the country.

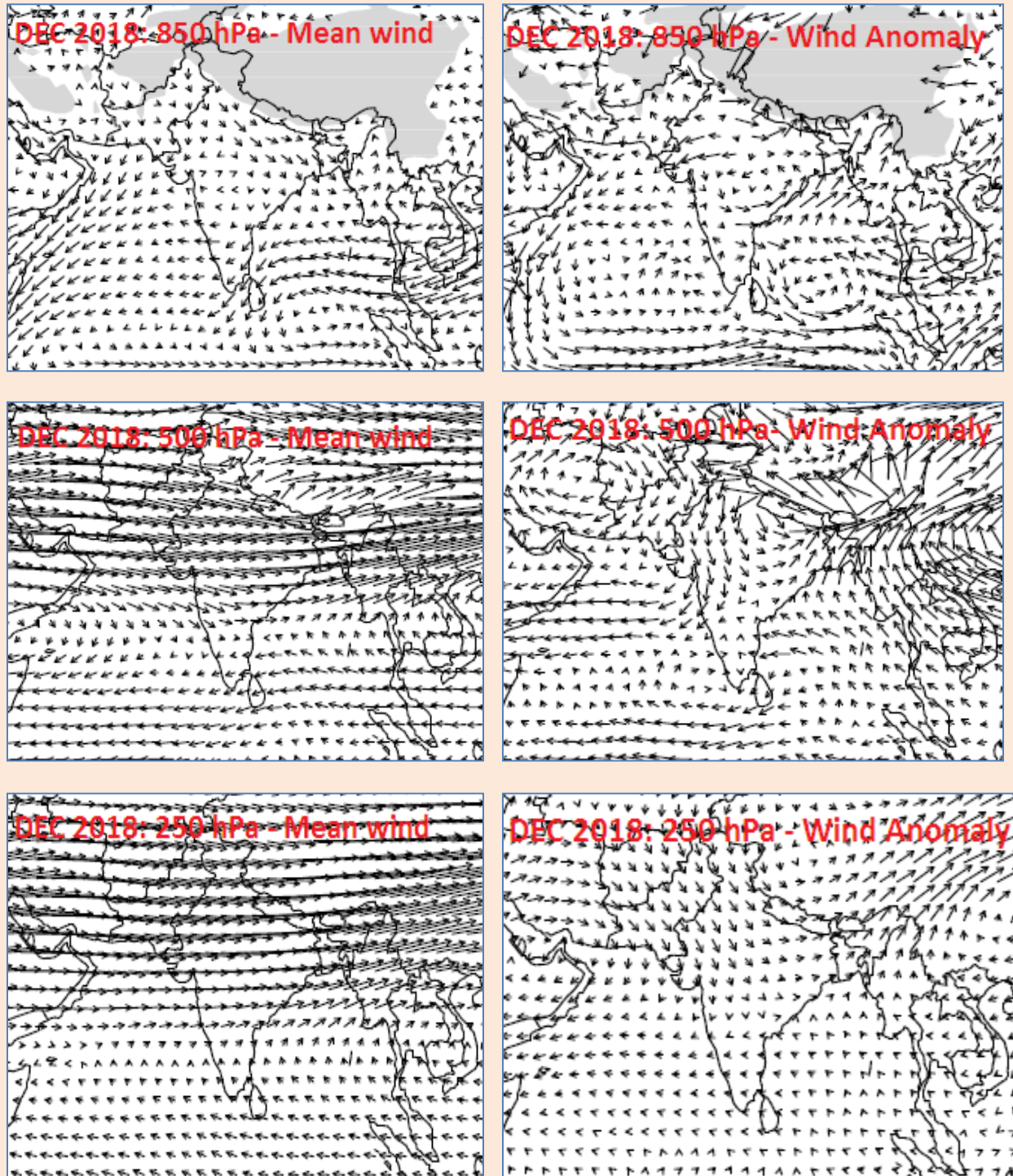


Fig.8c: Mean and anomalous wind pattern over the Indian region at 850 hPa, 500 hPa and 250 hPa levels during December 2018 (Source:Climate Diagnostic Bulletin of India, IMD Pune)

In December, at 850 hPa level an anomalous cyclonic circulation was observed over the north peninsula and adjoining eastern coast and anomalous cyclonic circulation was observed over the southeast Bay of Bengal. In the mid-upper troposphere, at 500 hPa level & 200 hPa level, anomalous trough in westerlies was observed over the northern parts of India.

(b) **Large scale features:** Based on the reports of various global climate monitoring centres, it was noted that during October-December 2018, neutral ENSO conditions prevailed over the equatorial Pacific region. Indian Ocean Dipole was normal. Both these major climate indices did not play a major role in NEM 2018. MJO was favourable for NEM activity during the 2nd week of October, first two weeks of November and first two weeks of December (Fig.8d).

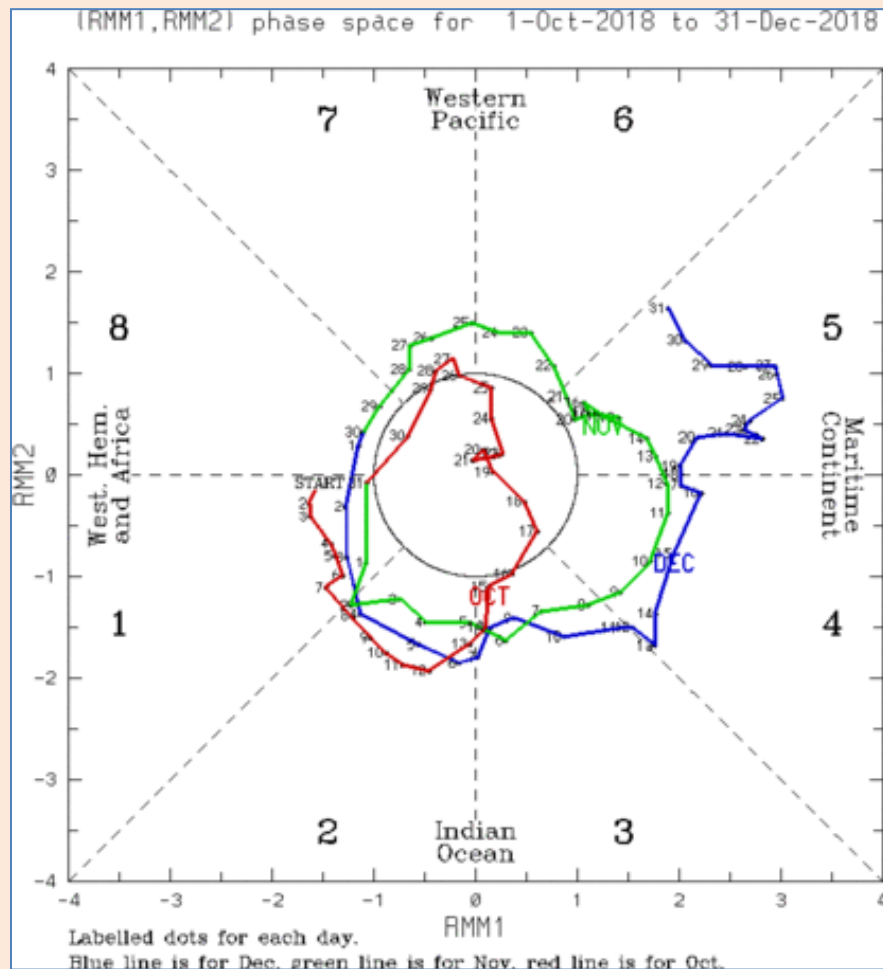


Fig.8d: MJO during Oct-Dec 2018 (Source: Bureau of Meteorology, Australia)

8. Summary

The onset of NEM 2018 over the southeastern parts of peninsular India took place on 1st November [delay of 11 days from the normal date of onset (20 October)]. Only one sub-division, Kerala, received normal rainfall during the season (Oct-Dec 2018). The four sub-divisions

benefitted by the NEM (Tamil Nadu, Kerala, Rayalaseema and South Interior Karnataka) came under deficient to largely deficient categories. Whereas TN and KER received normal rainfall in October and November, the other three subdivisions ended up deficient during these months. In December, excepting CAP that received large excess rainfall, all other sub-divisions became deficient-largely deficient. Four major low pressure systems formed over the North Indian Ocean during the NEM season - VSCS Luban (06-15 Oct) over AS, VSCS Titli (08-13 Oct), VSCS Gaja (10-19 Nov) and SCS Pethai (13-18 Dec) over the BOB. VSCS Titli and SCS Pethai contributed towards seasonal rainfall over CAP. VSCS Gaja contributed towards seasonal rainfall over TN and KER.

Acknowledgements

This report is a compilation of real-time observational data and analytical products generated by various IMD offices including IMD New Delhi, Pune, Hyderabad, Bangalore and Thiruvananthapuram 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

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

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

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

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

DRY: No station of a region reported rainfall

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

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

APPENDIX-(iii): Description of NEM rainfall activity

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

Vigorous: Fairly widespread to widespread sub-divisional rainfall with rainfall more 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.