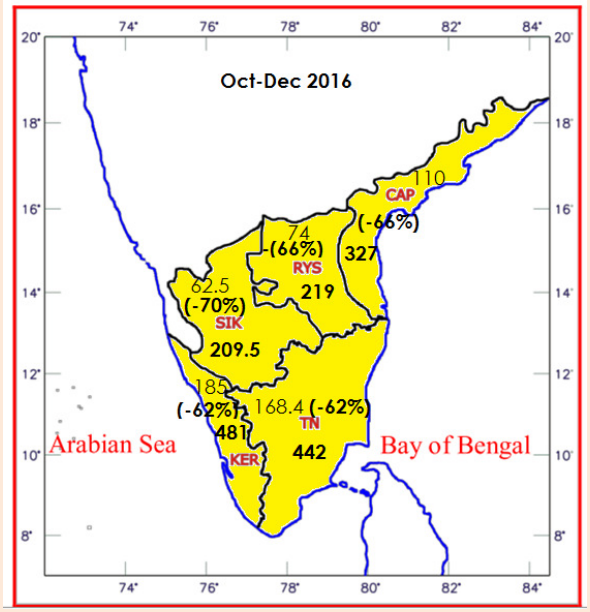
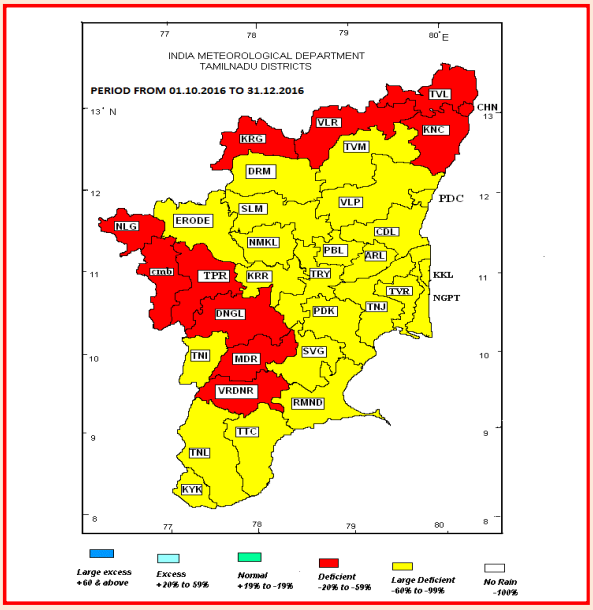
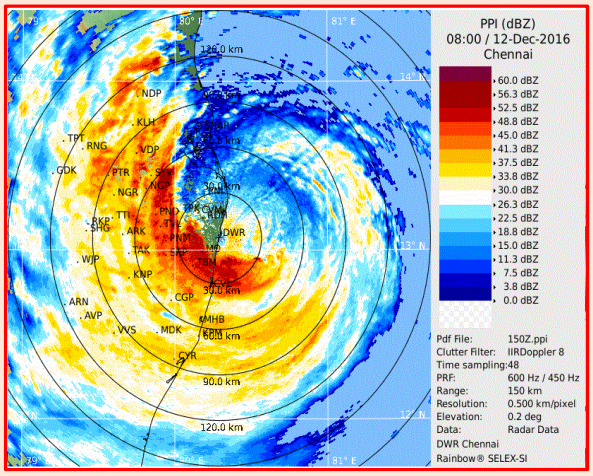
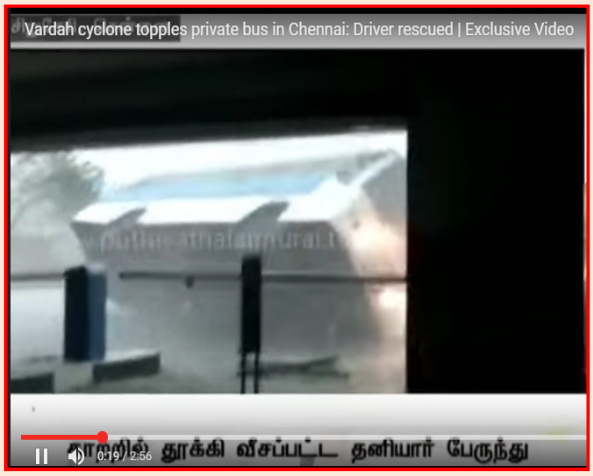
Government of India
Earth System Science Organisation
Ministry of Earth Sciences
India Meteorological Department

REPORT ON NORTHEAST MONSOON – 2016









(Prepared by: S.Balachandran, B.Geetha, R.Rajamohan and S.B.Thampi)

Regional Weather Forecasting Centre

Office of the Deputy Director General of Meteorology

Regional Meteorological Centre, Chennai

1. Background

The Indian southwest monsoon (SWM) season of June to September is the chief rainy season for India and 75% of the country's annual rainfall is realised during this season. However, for the extreme southeastern state of Tamil Nadu and the Union Territory of Puducherry (PDC) which together are considered as the meteorological subdivision of Tamil Nadu (TN), 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 theSWM. 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 the TN subdivision and also contribute significantly to NEM rainfall. As such, the NEM season assumes importance from the agricultural as well as cyclone disaster management perspectives. Inland flooding associated with heavy rainfall episodes during the season is also a cause for concern. The NEM 2015 saw some extremely heavy rainfall activity and unprecedented floods over the north coastal districts of Chennai, Kanchipuram and Thiruvallur and the seasonal rainfall for the entire TN sub division was +52% excess. The excess NEM 2015 occurred under strong El Nino and positive-normal Indian Ocean Dipole (IOD) conditions which are generally associated with good NEM performance. However, during OND 2016, the background flow pattern was completely different from the scenario during OND 2015 with the development of weak La Nina over the equatorial Pacific and IOD being negative to near normal.This report presents the salient features of NEM over the meteorological subdivisions of TN, Coastal Andhra Pradesh (CAP), Rayalaseema (RYS), South Interior Karnataka (SIK), Kerala (KER) during October-December 2016.

2. Onset

Normally, the onset of NEM takes place over coastal Tamil Nadu (CTN) by 20th October after the withdrawal of SWM up to about 15°N latitude. Prior to the onset of NEM over CTN, the low level winds reverse from southwesterlies (during the SWM) to northeasterliesalong CTN and south coastal Andhra Pradesh (SCAP). During the year 2016, the withdrawal of SWM up to 15°N latitude took place around 17th October. Subsequently, an upper air cyclonic circulation formed in the westerlies in the lower latitudes around 18th October. Under its influence, a low pressure area formed over central BOB on 19th which concentrated into adepression over central and adjoining southeast BOB on 21st. The depression moved initially northeastwards towards Myanmar coast, intensified into cyclonic storm (CS) ***Kyant*** and then recurved west-southwestwards towards westcentral BOB. It then weakened into depression off SCAP on 27th. On 28th and 29th, the depression further weakened gradually, and its remnant moved south /

southwestwards resulting in favourable conditions for the onset of NEM over CTN on 30th October.Subsequently, the rainfall activity covered the interior parts of TN and Kerala on 31st October. As such, the extended SWM into the second half of October and the formation of CS ***Kyant*** over the BOB led to a late onset of NEM over CTN by about 10 days. However, such a late onset is not unprecedented as climatologically, during the last 115 years of 1901-2015, onset of NEM has occurred on or after 25th October on 28 occasions with 8 occurrences going into November. The most delayed onset has been in 1915 on 11th November.

850 hPa wind flow pattern over the BOB and southern peninsular India during October 2016 from 1st to 28th October 2016 and on 29th and 30th October (Fig.1a&b) indicate setting in of easterlies over the southeastern coastal region of peninsular India occurred simultaneously with the NEM onset, i.e., on 30th October. The onset occurred over the SCAP and extreme northern parts of CTN first (29-30 Oct) and then advanced southwards and to the interior parts and Kerala on 31st October. This is evident from the INSAT-3D infra-red imageries depicting the cloud pattern (Fig.1c), the Doppler Weather Radar (DWR) Chennai reflectivity and 24-hr accumulated precipitation products [Fig.d(i-ii)], andthe spatial rainfall distribution over the southern peninsular India as depicted by IMD-NCMRWF GPM satellite+Gauge merged 24-hr rainfall (Fig.1e) for the period 28th-31st October 2016. This pattern of NEM onset is in contrast to the normal onset feature wherein the NEM rainfall first occurs over the southern parts of CTN and subsequently, the rainfall belt spreads to the northern and interior parts of TN and Kerala. Further, the onset phase rainfall spell did not sustain long with the Madden-Julian Oscillation (MJO) in an unfavourable phase (7-6) during the period 24th-31st October 2016. Rainfall activity over TN subdivision during the onset phase of NEM 2016, (29-31 October 2016) is presented in Table-1.

Table-1 Rainfall activity over Tamil Nadu during 29-31 October 2016

Date	Sub region	Spatial distribution	NEM Activity
29-Oct-2016	CTN	ISOL	---
30-Oct-2016	CTN	SCT	---
31-Oct-2016	CTN	SCT	---
31-Oct-2016	NCTN	FWS	**Active**
31-Oct-2016	STN	FWS	**Active**
31-Oct-2016	SITN	FWS	**Vigorous**

***WD**: Widespread; **FWD**: Fairly Widespread; **SCT**: Scattered; **ISOL**: Isolated;*
(Note:Kindly refer Appendix(i) for explanations on terminologies used for categorization of spatial rainfall distribution and Appendix (iii) for description of NEM activity)

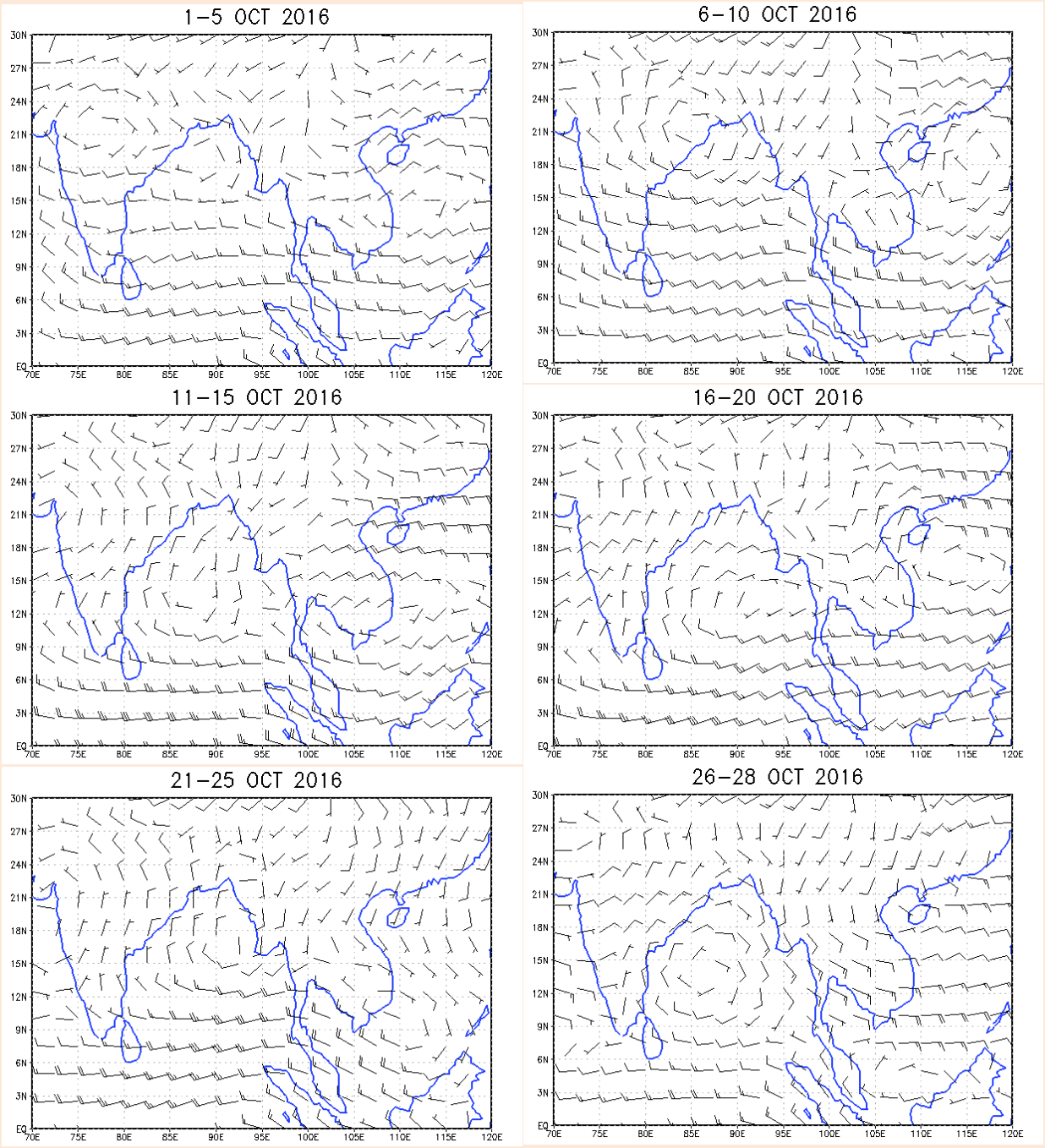


Fig.1a NCEP reanalysis 850 hPa pentad mean wind during 01-25 and mean wind during 26-28 October 2016 prior to onset of NEM southern peninsular India

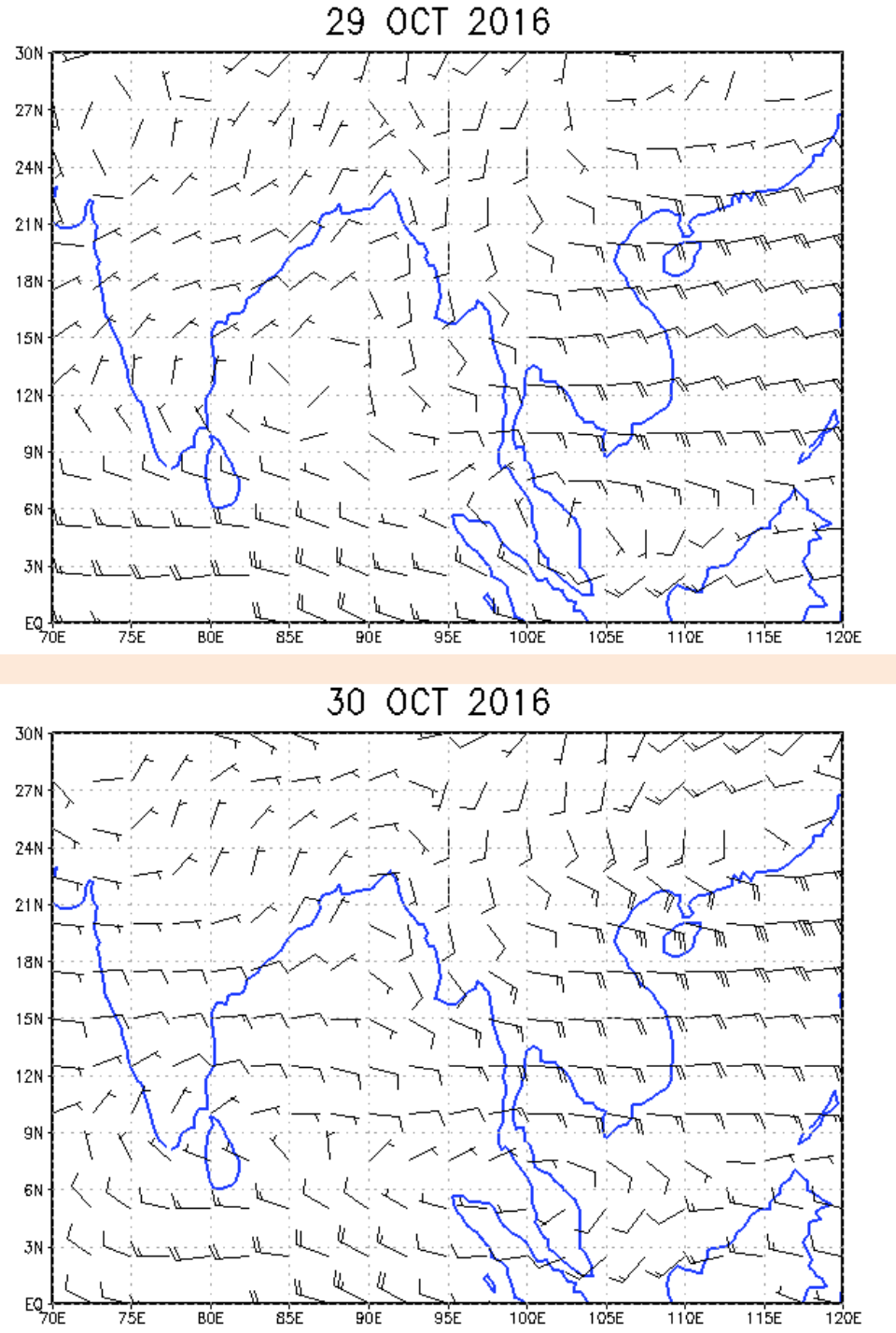


Fig.1b NCEP reanalysis 850 hPa mean wind during the onset phase of NEM 2016 (29th& 30th October)

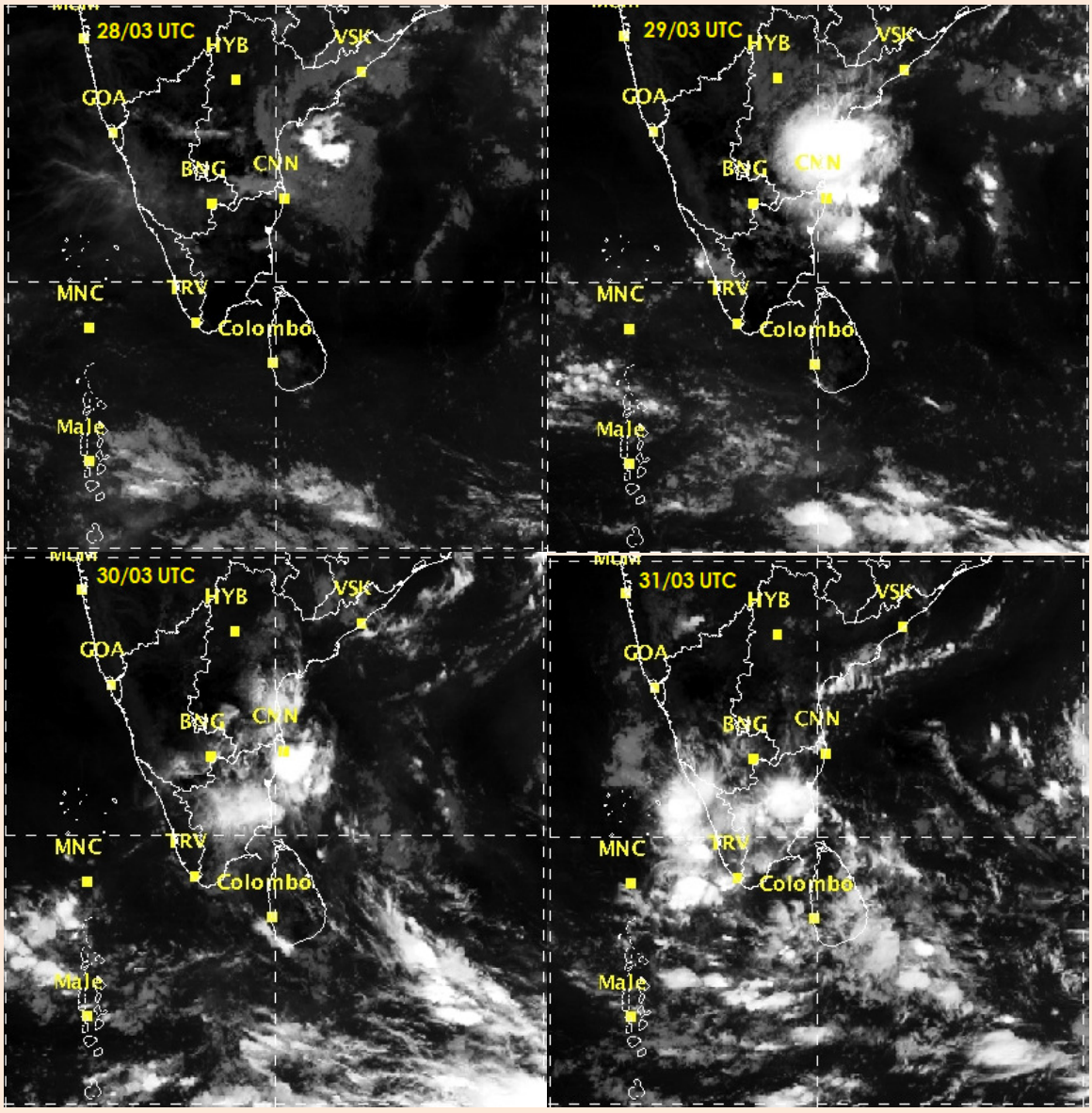


Fig.1c INSAT-3D infra-red imageries as on 28th-31st October 2016/ 0300 UTC

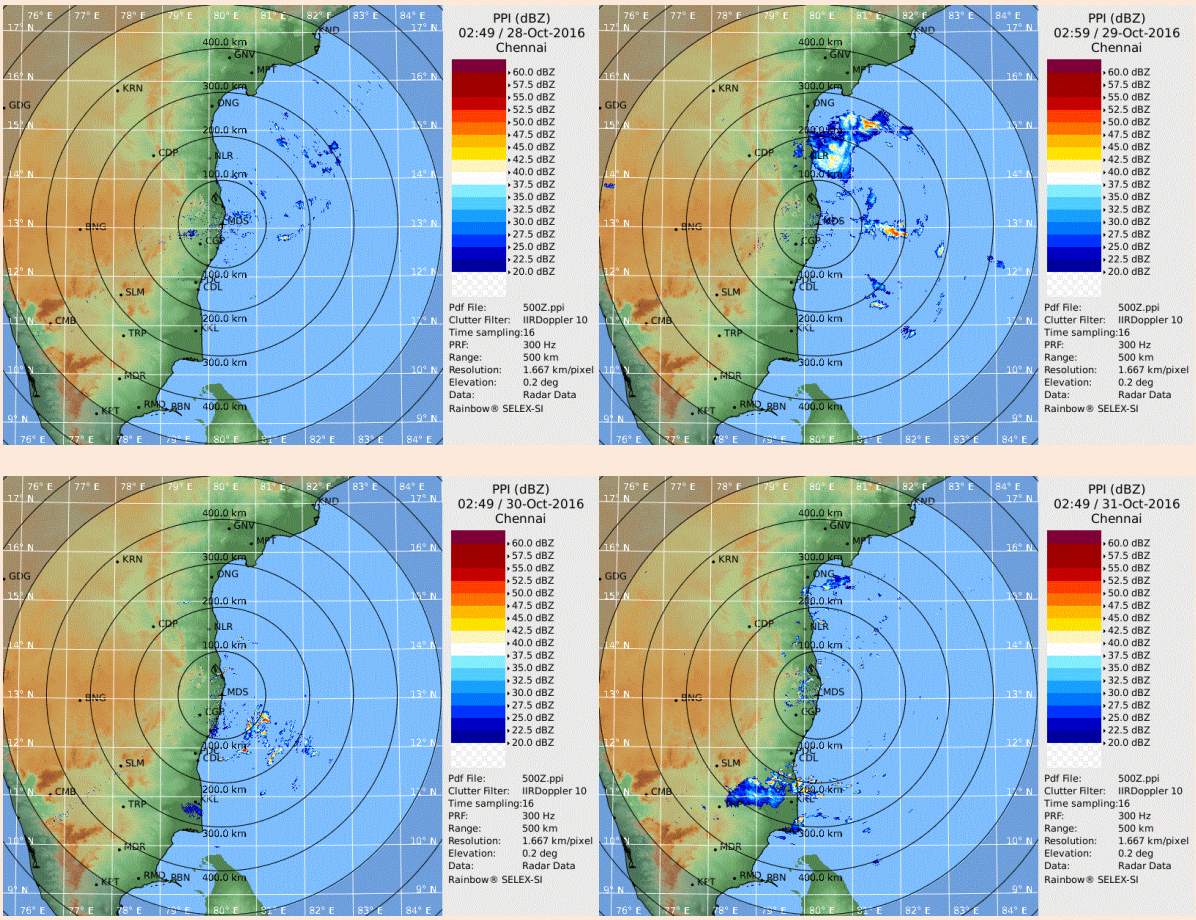


Fig.1d(i) Doppler Weather Radar, Chennai reflectivity product during the period 28th-31st October 2016/ 0300 UTC

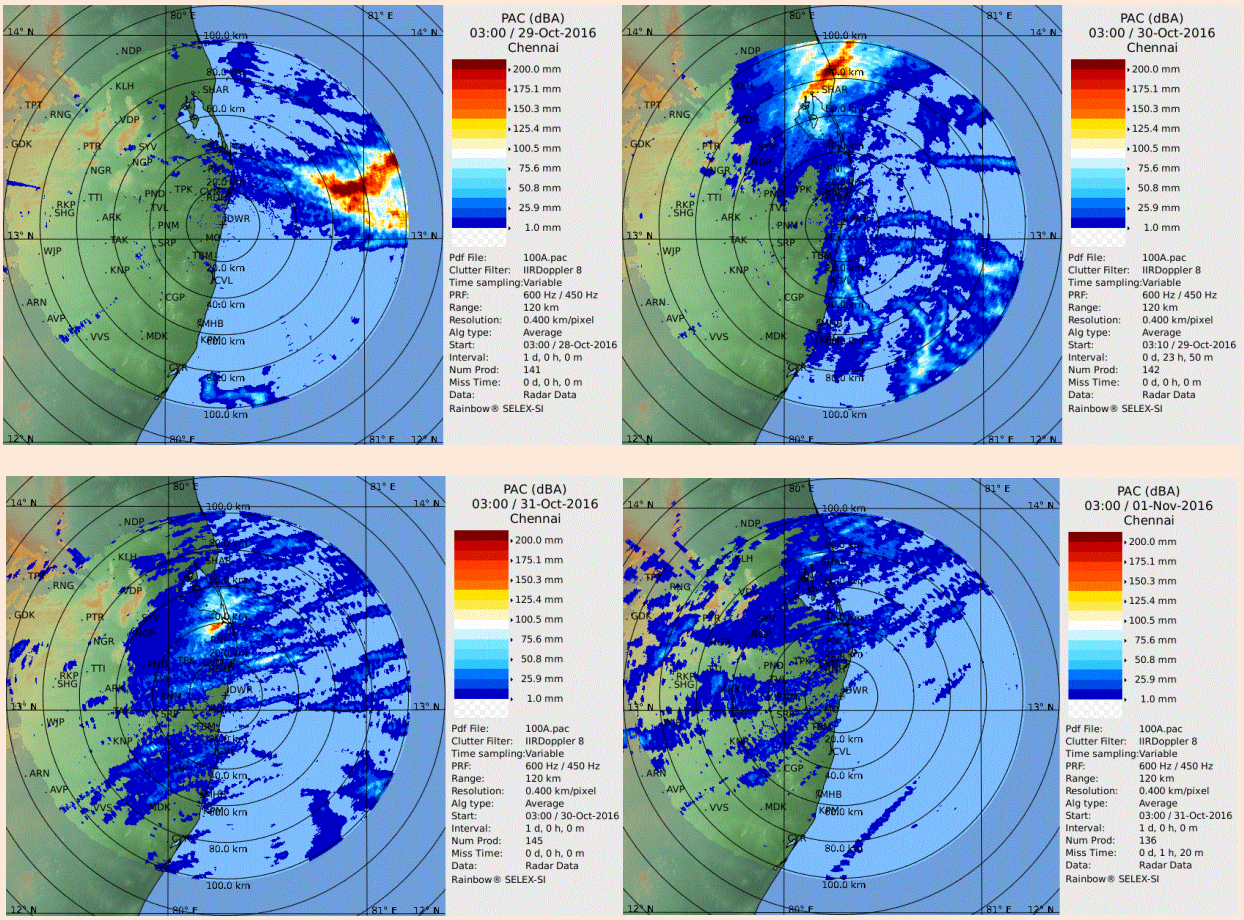


Fig.1d(ii) Doppler Weather Radar, Chennai precipitation accumulation product for 24-hr ending 0300 UTC of 29thOct -1st Nov 2016.

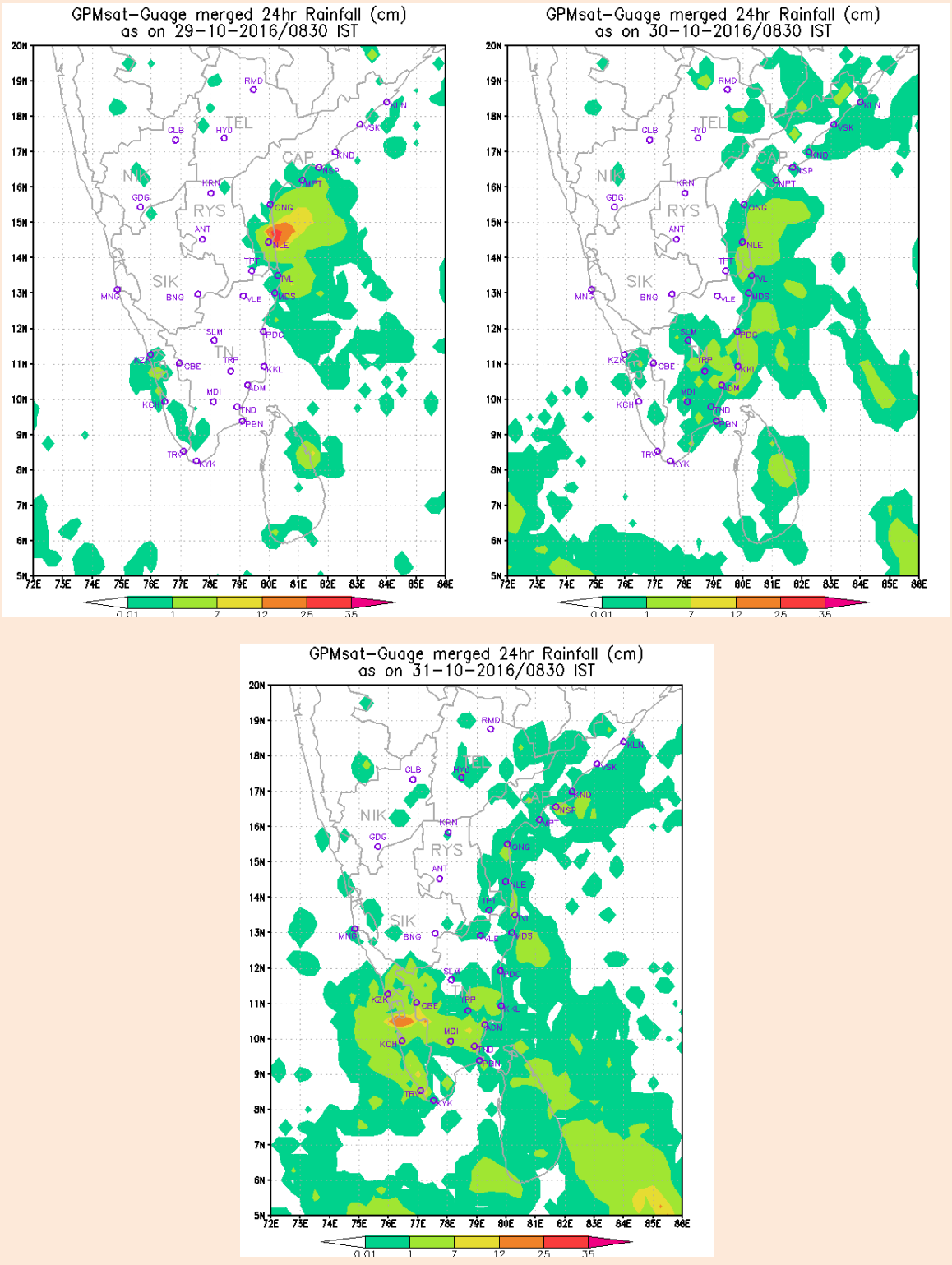


Fig.1e: GPM satellite+Gauge merged 24-hr rainfall (≥ 0.01 cm) as on 29th, 30th and 31st October 2016, 0300 UTC

3. Chief synoptic scale weather systems during NEM 2016

During October-December 2016, 4 low pressure systems formed over the BOB and 1 over AS as listed below:

a. ***Cyclonic storm 'KYANT' over the Bay of Bengal during Oct 21st /0000 -27th /1800***
b. ***Depression over the Bay of Bengal during Nov 2nd /1500 – 6th /1200***
c. ***Cyclonic Storm "Nada" over the Bay of Bengal during Nov 29th /1200 – Dec 2nd /0300***
d. ***Very Severe* Cyclonic *Storm 'VARDAH' over the Bay of Bengal (6th /0900 -13th/0000 Dec 2016)***
e. ***Depression over the Arabian Sea (17th/0300 -18th /0300 December 2016)***

The tracks of low pressure systems (a-d) that affected the NEM activity over southeast India are shown in Fig.2(a-d).

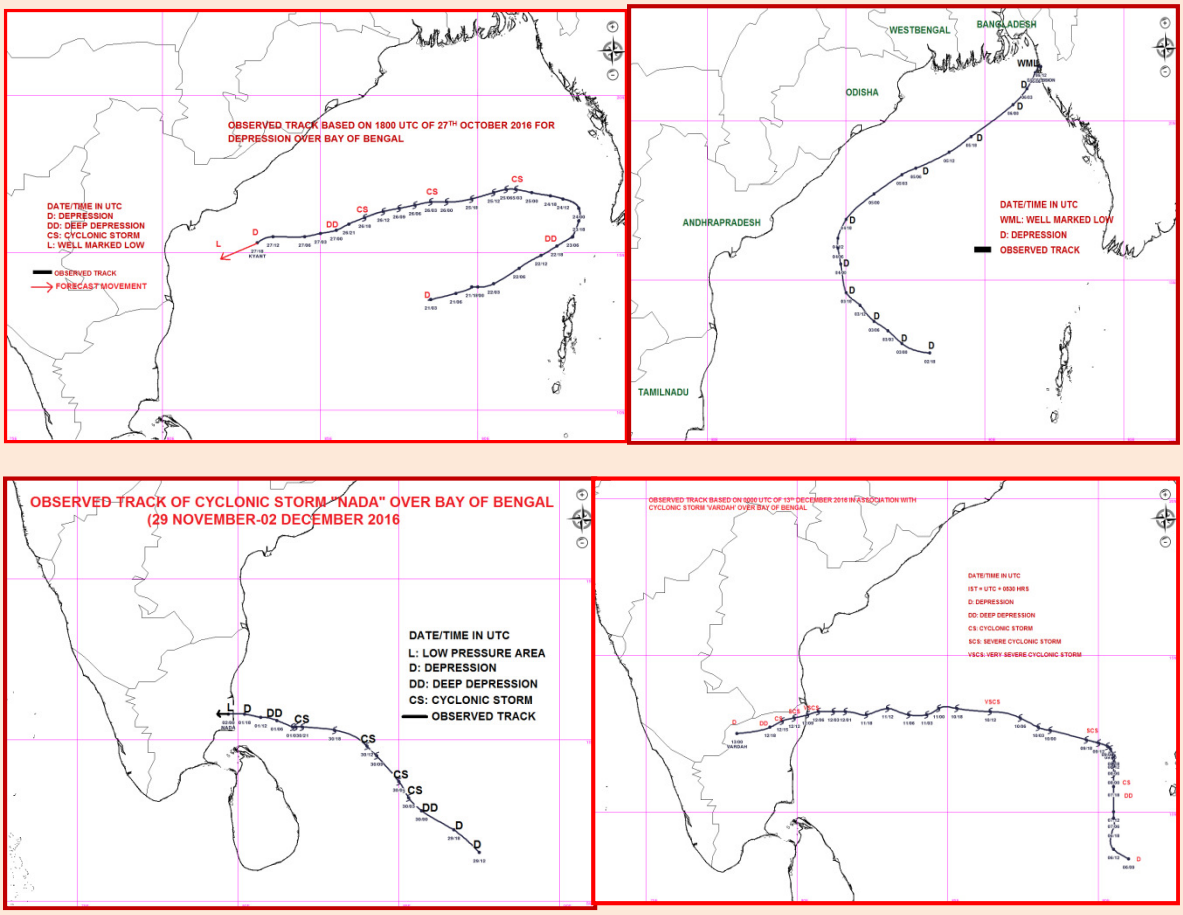


Fig.2 Observed tracks of (a) CS Kyant, 21-27 Oct; (b) Depression, 2-6 Nov; (c) CS Nada (29 Nov- 3 Dec) and (d) VSCS Vardah, 06-13 Dec 2016 over Bay of Bengal. (Source: Bulletins / reports of RSMC, IMD New Delhi).

Further,a few transient easterly wave troughs also passed through the southern parts of BOB during the 2nd-4th weeks of November. Contributions from these synoptic systems to the NEM 2016 is detailed below.

(i) CS KYANT (21-27 OCT 2016)

Formation of the first system, **CS *KYANT*** over BOB on 21st October and its further movement over the BOB until its weakening off south Coastal Andhra Pradesh (SCAP) coast on 27thdelayed the onset of NEM over CTN. However, its remnant was associated with the onset of NEM over CTN on 30th October and active NEM conditions over TN on 31st October. *Isolated heavy* to *very heavy* rainfall occurred over TN on 31st October and *isolated heavy* rainfall occurred over Kerala during 31st October-2nd November.

(ii) Depression over BOB (02-06 NOV 2016)

The second system, a ***Depression*** during 2nd-6thNov 2016 which moved initially towards north Coastal Andhra Pradesh (NCAP) and then re-curved towards Bangladesh coast. Associated with the passage of this system, there was *isolated heavy* rainfall activity over NCAP on 04th November. However, it led to sweeping away of available moisture along and off Tamil Nadu coast and penetration of dry and cold wind from the north which caused weak NEM conditions over the southern peninsular India during the first week of November even though isolated *heavy* to *very heavy* rainfall was reported over TN during 01st-05th November.

(iii) Upper air trough in easterlies & troughs of low at meal sea level

Subsequently, a series of transient low intensity weather systems (upper air trough / trough of low pressure at mean sea level) prevailed over the extreme southern parts of BOB during the rest of November. However, due to penetration of dry and cold winds from the north, the easterlies over the southeast BOB did not traverse upto the southeastern peninsular coast of India as the winds became northeasterlies over the western parts of southwest BOB and turned towards Sri Lanka and adjoining region skipping major part of the southern peninsular India (Fig.3).

As such, during this period, the Indian NEM region could not benefit much from associated rainfall activity. Associated with an upper air trough in easterlies over southwest BOB on 12th November which moved westwards (off Sri Lanka-Tamil Nadu coast on 13th and 14th, comorin area to south Konkan coast on 15th) led to *scattered* rainfall activity on 14thwith *isolated heavy* to *very heavy* rainfall occurrences during 13th-15thover TN and *isolated heavy* rainfall over Kerala on 14th. A trough of low pressure at mean sea level over equatorial Indian ocean and adjoining southwest BOB during 16th-20th November caused *scattered* rainfall activity over TN on 18th and *isolated* rainfall activity during 19th-23rd November.

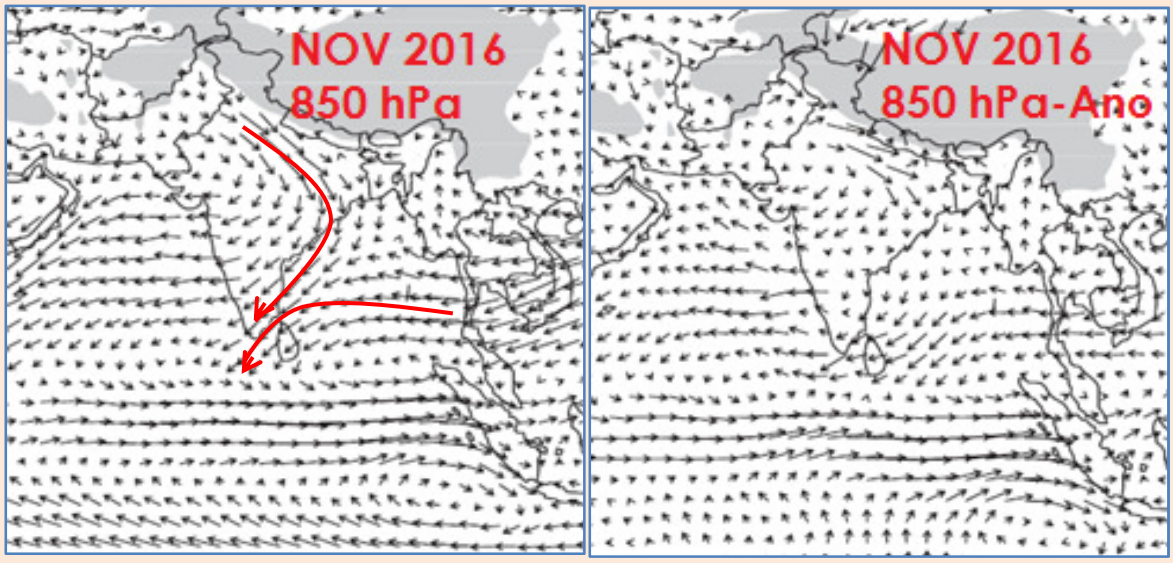


Fig.3 850 hPa mean wind and wind anomaly during the month of November 2016 over the Indian region (Source: Climate diagnostic bulletin of India - Nov 2016, IMD Pune)

(iv) CS NADA (29th November – 02nd December)

During the last week of November, a trough of low at meal sea level over southeast BOB on 24th-25th, moved westward over southwest BOB and adjoining equatorial Indian ocean on 26th and 27th. It became a ***low pressure area (LOPAR)*** on 28thand concentrated into a ***Depression*** on 29th/1200 UTC near 6.5°N/87.5°E. It moved westnorthwest-northwestward and intensified into ***CS NADA*** on 30th/0300 UTC. Subsequently in moved westwards and weakened into Depression and crossed north Tamil Nadu coast near Nagapattinam (about 20 km south of Karaikal) between 0400 and 0500 hrs IST on 02nd December. It then moved further westwards and weakened into a well marked low pressure area and lay over interior Tamil Nadu and neighbourhood 02nd /0300 UTC. It further weakened intoa LOPAR at 12 UTC of 02nd and moving westwards it emerged into Arabian sea and lay as a low pressure area over Lakshadweep and neighbourhood on 3rd December. Associated with the landfall and further westward movement of ***NADA***, *active* NEM conditions with *isolated heavy* rainfall activity prevailed over TN on 2nd and 3rd December.

(v) VSCS VARDAH (6th -13th December)

On 4th December, another***LOPAR*** formed over South Andaman sea and neighbourhood which became well marked on 05thconcentrated into a ***Depression***on 06th/0900 UTC over southeast BOB near 8.5°N/91.0°E. Moving north-northwest wards, it intensified into ***CS VARDAH*** on 08th/0000 UTC. Subsequently, moving westnorthwest-westwards, it intensified into severe cyclonic storm (***SCS***) and very severe cyclonic storm (***VSCS***)***VARDAH*** on 09th/1800 UTC and 10th/1200 UTC respectively. Moving west-westsouthwestwards, it then crossed north Tamil Nadu coast close to Chennai between 0930-1130 UTC of 12thDecember with maximum

sustained surface wind speed of 100-110 kmph gusting to 120 kmph. INSAT-3D enhanced IR imagery and DWR Chennai reflectivity product depicting the cloud and precipitation patterns during the landfall of VSCS VARDAH are presented in Fig.4.

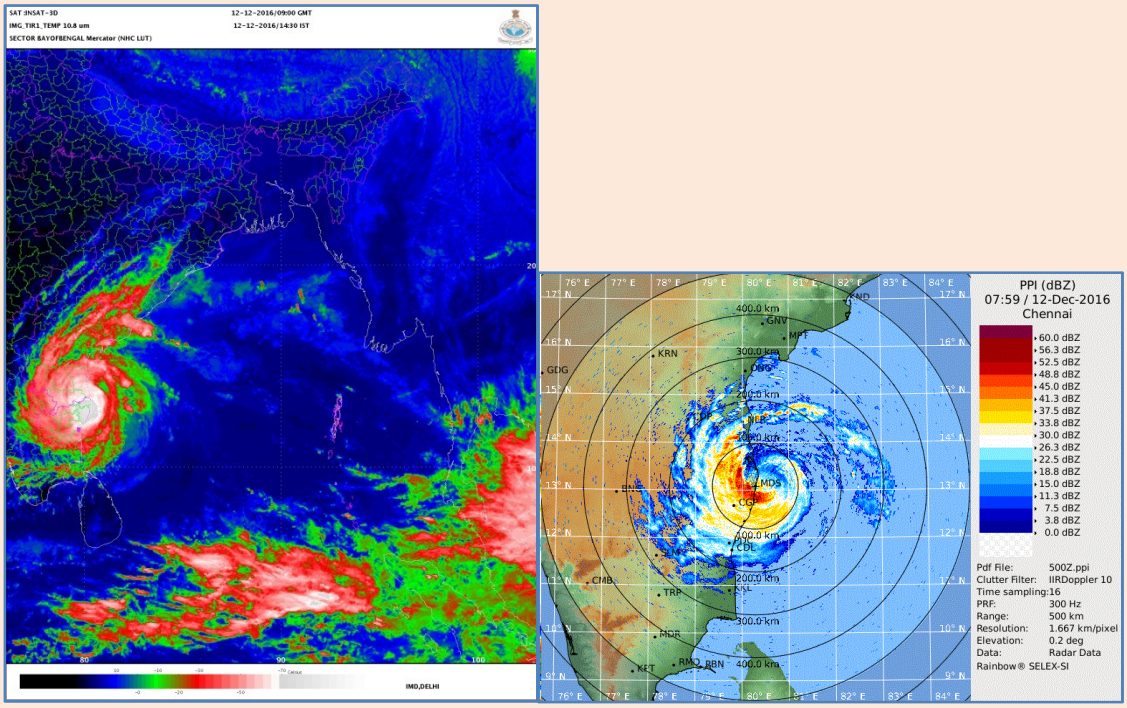


Fig.4 INSAT-3D enhanced IR imagery as on 0900 UTC and Doppler Weather Radar, Chennai reflectivity product as on 0800 UTC of 12th December 2016.

During the landfall, adverse weather conditions due to gale force winds, heavy to extremely heavy rainfall and storm surge prevailed over extreme north CTN districts. Gale force winds of the order of 100-110 kmph prevailed over north Tamil Nadu and south Andhra Pradesh coasts during 03-15 UTC of 12th December 2016. Storm Surge of height 1metre above the astronomical tide occurred near Pulicatlake at 1200 hours IST of 12thDecember. Heavy rainfall occurred at many places with very heavy falls at few places and isolated extremely heavy rainfall over Chennai, Kancheepuram, Tiruvallur, and Villupraum districts of Tamil Nadu during the 24-hr ending 0830 IST of 13th December. Heavy to very heavy rainfall occurred at a few places over Vellore, Krishnagiri, Tiruvannamalai districts of Tamil Nadu, Nellore district of Coastal Andhra Pradesh and Chittoor, Anantapur&Cuddapah districts of Rayalaseema on the same day. Highest rainfall amount of 38 cm has been reported by Satyabama University in Kancheepuram district.

Reported heavy rainfallamounts in cm (24 hr accumulated rainfall ≥7cm ending at 0830 hrs IST of 13th December 2016) in association with the cyclone are listed below station-wise (corresponding district name is indicated in brackets).

Tamil Nadu:

Extremely heavy rainfall (≥ 20 cm/day):Satyabama University (Kancheepuram)-**38**, Kattukuppam (Kancheepuram)-**34**, Kancheepuram (Kancheepuram)-**28**, Kalavai (Vellore)-**23**, Poonamallee (Tiruvallur)-**22**, Chembarabakkam (Tiruvallur)-**21**, Meenambakkam-**20**

Very heavy rainfall (12-20 cm/day):Sriperumbudur (Kancheepuram)-17, Chembarambakkam (Tiruvallur)-16, Yercaud (Salem)-15, Alangayam (Vellore)-15,Tambaram (Kancheepuram)-14, Nungampakam-12

Heavy rainfall (7-12 cm/day): Vellore-11, Melalathur (Vellore)-9,Tirppattur-8, Poondi (Tiruvallur)-9, Mahabalipuram (Kancheepuram), Uthiramerur(Kancheepuram), Tirupattur (Vellore), Maduranthagam (Kancheepuram), Krishnagiri (Krishnagiri), Shoolagiri (Krishnagiri), Hosur (Krishnagiri), Vandavasi (Tiruvannamalai), Marakkanam (Villupuram), Vaniaymbadi (Vellore), Gudiyatham (Vellore) and Cheyyur(Kancheepuram) -7 each

Coastal Andhra Pradesh:

Very Heavy: Atmakur (Nellore)-13, Vinjamur (Nellore)-12

Heavy: Udayagiri (Nellore)-11, Sullurpeta (Nellore), Kandukur (Prakasam)- 9 each, Kavali (Nellore), Nellore (Nellore), Veligandla (Prakasam) – 8 each, Rapur (Nellore), Gudur (Nellore), Venkatagiri (Nellore) , Shar (Nellore) – 7each

Rayalaseema:

Very Heavy: Tirumalla (Chittoor)-15, Puttur (Chittoor)-14, Nagari (Chittoor)-12

Heavy: Chittoor, Kodur (Cuddapah), Satyavedu (Chittoor)- 10 each, Venkatagiri Kota (Chittoor), Palasamudram (Chittoor)- 9 each, Nambulipulikunta (Anantapuram), Thottambedu (Chittoor), Tirupati Aero (Chittoor), Atlur (Cuddapah), Rajamet (Cuddapah), Mandapalle (Chittoor), Kuppam (Chittoor), Pakala (Chittoor), Sambepalle (Cuddapah), Royachoti (Cuddapah)- 7 each.

24-hr accumulated rainfall as on 0300 UTC (0830 IST) of 13th December 2016 based on (a) DWR Chennai precipitation accumulation product indicated maximum rainfall of 43 cm /day at a distance of about 43 km southwest of the Radar (Fig.5a) and (b) GPM satellite+ gauge merged rainfall depicted heavy to extremely heavy rainfall over Chennai and neighbouring districts of extreme north Tamil Naduand adjoining Rayalaseema and coastal Andhra Pradesh as shown in Fig.5b.

Damage reports

Print and electronic media as well as the general public covered the ground truth from different locations over the landfall area and provided visuals covering the ground truth. As the system made landfall over the thickly populated metro city of Chennai, gale winds prevailed over NTN and south Andhra Pradesh for about 7-8 hours. This caused extensive damages to several structures, uprooted several thousands of trees, snapped telecom links due to falling of electrical poles and damaged agricultural crops. Fig.6 depicts some of the damage snapshots collected from the media/general public.

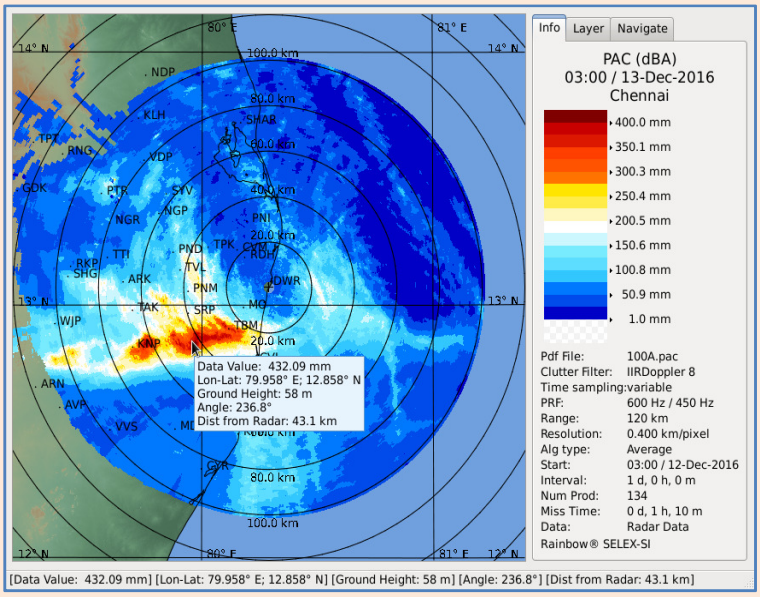


Fig.5a DWR Chennai 24-hr accumulated precipitationproduct(in mm) as on 13-12-2016 /0830 IST

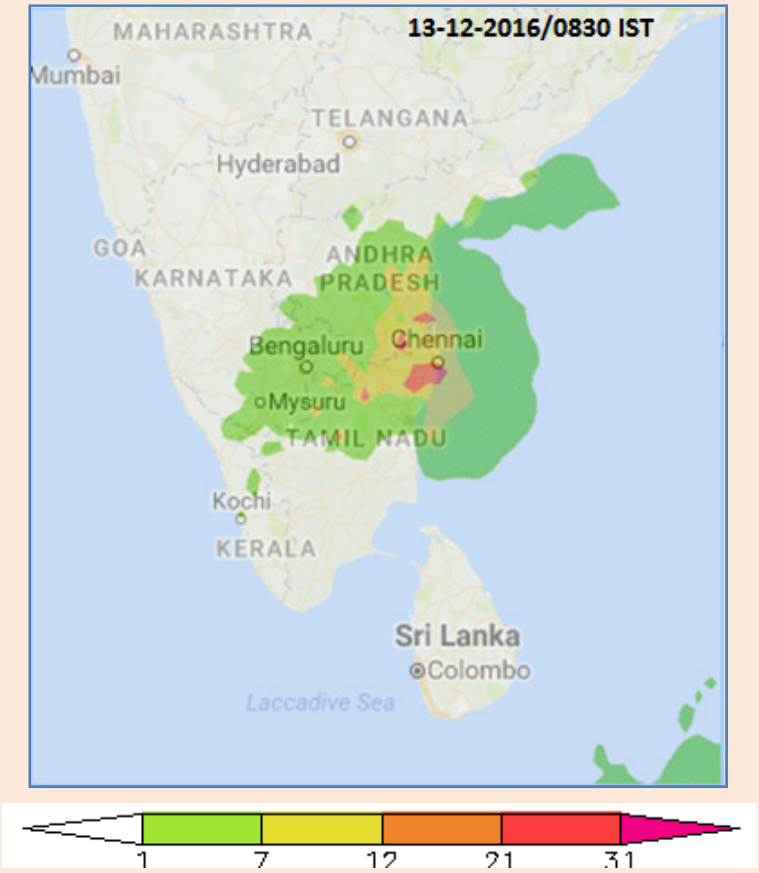
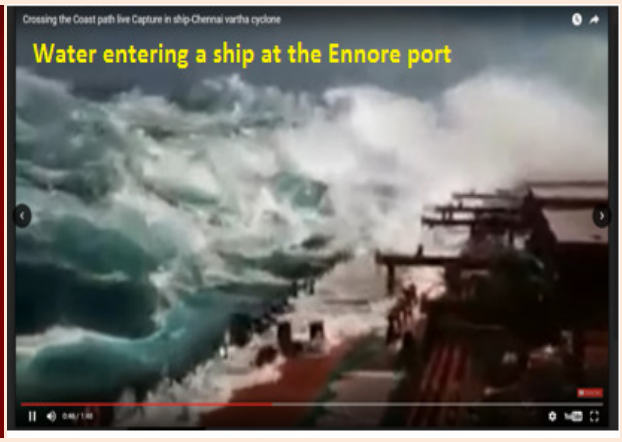


Fig.5b GPM satellite-Gauge merged 24-hr accumulated rainfall (in cm) as on 13-12-2016 /0830 IST



12/14/2016

Home States Tamil Nadu

18 people killed due to Cyclone Vardah related incidents in TN

By PTI | Published: 13th December 2016 10:48 PM |
Last Updated: 14th December 2016 12:12 AM | A+ A A-

Fallen trees in Ambattur as Cyclone Vardah makes landfall. | EPS

CHENNAI: Eighteen people were killed in six districts of Tamil Nadu in rain-related incidents linked to Cyclone Vardah that crossed the coast, as Chief Minister O Panneerselvam held a meeting of top officials today to speed up work to ensure return of normalcy in storm-hit regions.

The government said it is taking all steps to ensure that the jammed mobile phone networks are restored and a meeting of telecom operators and officials was held.

"A total of 18 persons were killed in rain-related incidents linked to Cyclone Vardah," a top Tamil Nadu government official monitoring the situation told PTI.

He said five each were killed in Chennai and Tiruvallur districts. Four persons died in Kancheepuram district, one each in Villupuram and Nagapattinam districts and two in Tiruvannamali district, the officials added.

All these deaths were in the revenue districts.

He said as expected districts like Tiruvannamalai, Vellore and the Western belt of Dharmapuri too witnessed heavy rains that began with the commencement of the cyclone Vardah's landfall.

"Chief Minister Panneerselvam held a meeting of top officials today. Our priority is to restore power supply which has been hit due to fallen trees, clear clogged roads which have fallen trees," the official said.

He said traffic has already been cleared in all arterial roads in all of the affected districts and efforts were now on to clear the roads and restore power in other neighbourhoods.

"TANGEDO (State-run power undertaking) itself has deployed about 4,000 personnel to ensure quick restoration of power supply," he said.

Personnel from multiple government departments including Revenue, Police, Fisheries, Animal Husbandry and other state agencies from Ariyalur, Perambalur, Tiruvallur, Cuddalore, Salem and Thanjavur districts were being deployed to handle the situation in the cyclone-hit regions, he said.

On the number of people now housed in relief centres, he said more than 13,000 people are being sheltered in over 100 centres. All vulnerable areas were identified in advance and teams of officials are on the job, he said.

To a question on clogged mobile phone networks, he said a meeting of telecom officials and operators was being held to address the situation and ensure expeditious return of normalcy.

Related Article

- Vardah: Graves in Madras War Cemetery marooned
- Losing steam, Vardah moves to interior TN and Karnataka
- Winged residents lose homes in Chennai
- Home Minister Rajnath reviews relief operations in TN, AP
- Highway mayhem, cashless truckers stranded for over 24 hrs
- Vardah: TN CM seeks Rs 1,000 crore from Centre

TAGS Tamil Nadu death cyclone Vardah

The New Indian Express – 13 Dec

1/1

Fig.6 Sample damages due to landfall over VSCS VARDAH

After landfall it moved west-southwestwards and weakened into a CS in the evening of 12th and further into a Depression in the early morning of 13thover North Interior Tamil Nadu and into a well marked low at 0300 UTC of 13thand lay over North Interior Tamil Nadu and adjoining South Interior Karnataka. It then emerged into Arabian sea and lay over southeast Arabian sea off Karnataka-Kerala coast on 14th.

4. Seasonal rainfall performance during NEM 2016

Despite two low pressure systems crossing TN coast and easterly wave troughs traversing over the BOB, the NEM rainfall of 2016 ended up *deficient* (-20% to -59%) over all the five subdivisions benefitted by NEMviz., Tamil Nadu &Puducherry, Coastal Andhra Pradesh, Rayalaseema, South Interior Karnataka and Kerala. Fig.6 presents the season ending (01st Oct-31st Dec) rainfall figures over these subdivisions. The entire region came under *large deficient* category (-60% to -99%) with SIK recording -70%, CAP and RYS: -66%, TN and KER: -62% (Fig.7). Such *largely deficient* rainfall of NEM 2016 would have adverse impact on rain-fed agriculture, especially over Tamil Nadu & Puducherry, wherein agricultural activities mainly depend on NEM rains. As per IMD records, the 62% rainfall deficiency of NEM 2016 over TN is second to the worst situation that arose in 1876 when the sub division recorded -63% NEM rainfall.

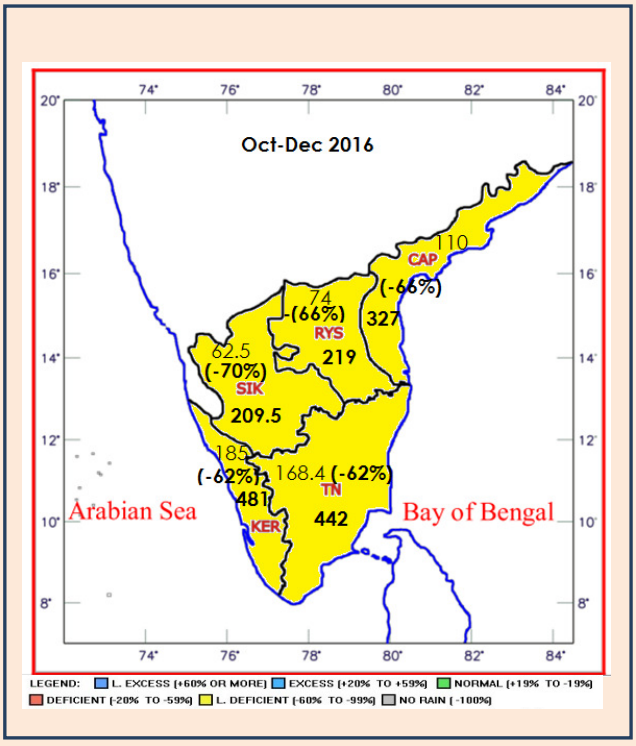


Fig.7 Subdivisional seasonal rainfall during October-December 2016 Plainfigures indicate***Actual* rainfall (mm)**and **bold** figures indicate ***Normal* rainfall (mm). (Figures in brackets indicate *Percentage Departures from Normal).***

In the monthly scale, October and November rainfall over all the subdivisions was *largely deficient*. TN, which depends more on NEM rainfall than the SWM rainfall became *largely deficient* in October due to late onset of NEM on 30th October (Table-2). The other subdivisions generally benefitted by the SWM (KER, SIK, CAP, RYS) also ended up *largely deficient* in October as the SWM activity in October was generally over north of the NEM region. In November, the ***Depression*** over BOB (02nd -06th November) that moved towards Bangladesh coast, penetration of cold and dry air from the north into the southwest BOB and adjoining NEM region and confinement of activity due to troughs in easterlies to south of Indian latitudes led to poor NEM activity and *large deficiency* over the region. Week-by-week rainfall departures (Table-3a) indicate that, but for the lone week ending 19th October when Kerala received normal to excess rainfall (extended SWM), rainfall during all other weeks in October and November was *deficient* to *largely deficient* in all the NEM subdivisions. Time series of area weighted rainfall over southern peninsular India for the month of November during 1951-2016 indicating the large deficiency in November rainfall of 2016 is presented in Fig.8.

Subsequently, due to the passage of **CS *NADA*** and **VSCS *VARDAH*** rainfall over TN, CAP, RYS and SIK was *normal* to *large excess* during the first two weeks of December and this rainfall brought down the cumulative rainfall figures by 10% or more in these subdivisions (Table-3b). During the whole season, there have been 4 days of *active* NEM conditions over KER, 3days of *active* NEM over TN and 1 day each over CAP and RYS (Table-4). There has been a single day of *vigorous* NEM activity over RYS. Regarding *heavy* rainfall occurrences, there has been one day of *isolated very* to *extremely heavy* rainfall over TN, two days of *isolated very heavy* rainfall over CAP and one day of *isolated very heavy* rainfall over RYS during the passage of VSCS VARDAH, 1 day of *isolated very heavy* rainfall over TN during the onset phase of NEM and three days of *isolated very heavy* rainfall over north TN in November in association with the passage of trough in upper air easterlies during 13th-15th November.

Table-2: Subdivisional monthly rainfall during NEM 2016

Subdivision	OCT			NOV			DEC		
	Actual (mm)	Normal (mm)	PDN (%)	Actual (mm)	Normal (mm)	PDN (%)	Actual (mm)	Normal (mm)	PDN (%)
TN	66.1	181.1	-64	34.4	171.7	-80	67.8	89.2	-24
KER	105.1	292.4	-64	57.9	150.9	-62	22.0	37.4	-41
CAP	59.8	193.2	-69	13.0	106.4	-88	36.8	23.7	35
RYS	14.1	129.4	-89	5.4	66.0	-92	54.4	23.7	129
SIK	22.5	147.8	-85	9.0	49.0	-82	31.0	12.6	146

PDN: Percentage Departure from Normal

TN: Tamil Nadu &Puducherry; KER: Kerala; CAP: Coastal Andhra Pradesh;
RYS: Rayalaseema; SIK: South Interior Karnataka.

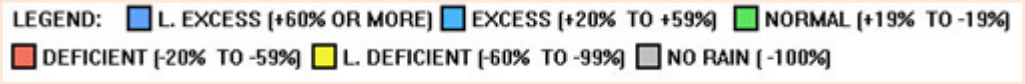


Table-3a: Week by week rainfall departures (%) during NEM 2016

Subdivision	5/10/2016	12/10/2016	19/10/2016	26/10/2016	2/11/2016	9/11/2016	16/11/2016	23/11/2016	30/11/2016	7/12/2016	14/12/2016	21/12/2016	28/12/2016
TN	-42	-76	-51	-69	-50	-75	-80	-82	-99	-3	14	-70	-84
KER	-86	-94	-14	-75	-28	-47	-76	-89	-93	-27	-38	-31	-98
CAP	-30	-44	-99	-100	-68	-86	-91	-93	-100	14	120	-73	-100
RYS	-64	-81	-98	-100	-90	-94	-96	-89	-100	100	322	-15	-100
SIK	-85	-70	-55	-99	-75	-98	-57	-97	-100	66	400	-28	-100

(TN, KER, CAP, RYS, SIK and Legend: same as Table-2)

Table-3b: Week by week cumulative rainfall departures (%) during NEM 2016

Subdivision	5/10/2016	12/10/2016	19/10/2016	26/10/2016	2/11/2016	9/11/2016	16/11/2016	23/11/2016	30/11/2016	7/12/2016	14/12/2016	21/12/2016	28/12/2016
TN	-78	-76	-66	-67	-63	-66	-68	-69	-71	-66	-61	-61	-62
KER	-98	-95	-66	-69	-61	-59	-60	-62	-63	-62	-62	-61	-61
CAP	16	-36	-59	-69	-69	-71	-73	-74	-76	-73	-66	-66	-66
RYS	-2	-79	-84	-88	-88	-89	-90	-90	-90	-81	-66	-66	-66
SIK	-18	-83	-78	-83	-82	-84	-82	-83	-84	-81	-70	-70	-70

(TN, KER, CAP, RYS, SIK and Legend: same as Table-2)

Table-4: Frequency of active and vigorous NEM conditions and Frequency of heavy rainfall occurrences

Subdivision	No. of days				
	NEM Activity		Heavy Rainfall Occurrence		
	Vigorous	Active	Extremely Heavy	Very Heavy	Heavy
TN	NIL	3	1	6	24
KER		4			13
CAP		1		2	10
RYS	1	1		1	3
SIK					

Active, Vigorous: Kindly refer Appendix (iii)

Heavy, Very heavy, Extremely heavy: Kindly refer Appendix(ii)

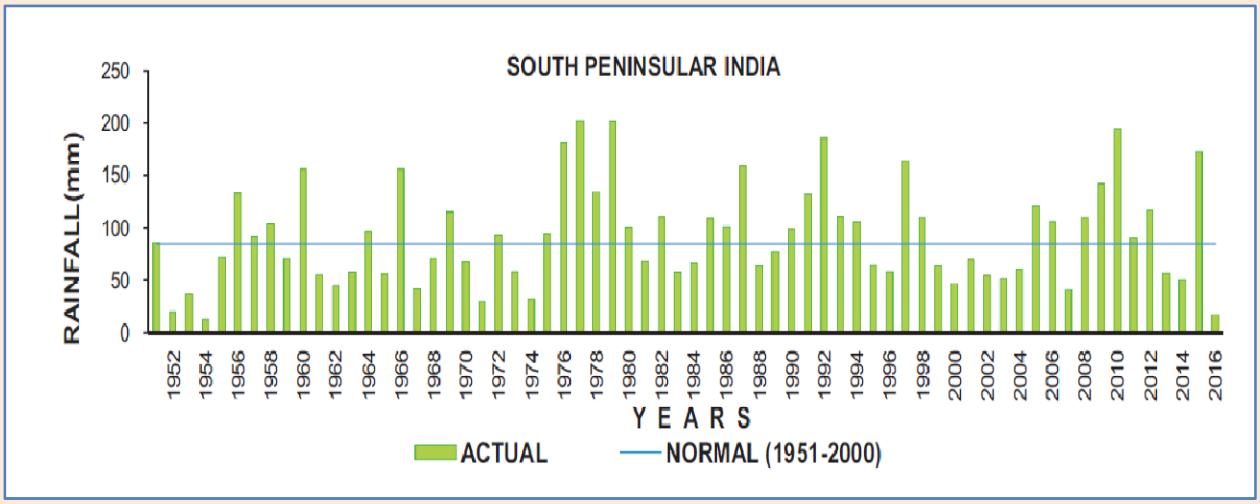


Fig.8 Time series of area weighted November rainfall over southern peninsular India during 1951-2016 (Source: Climate Diagnostic Bulletin of India- Nov 2016, IMD Pune)

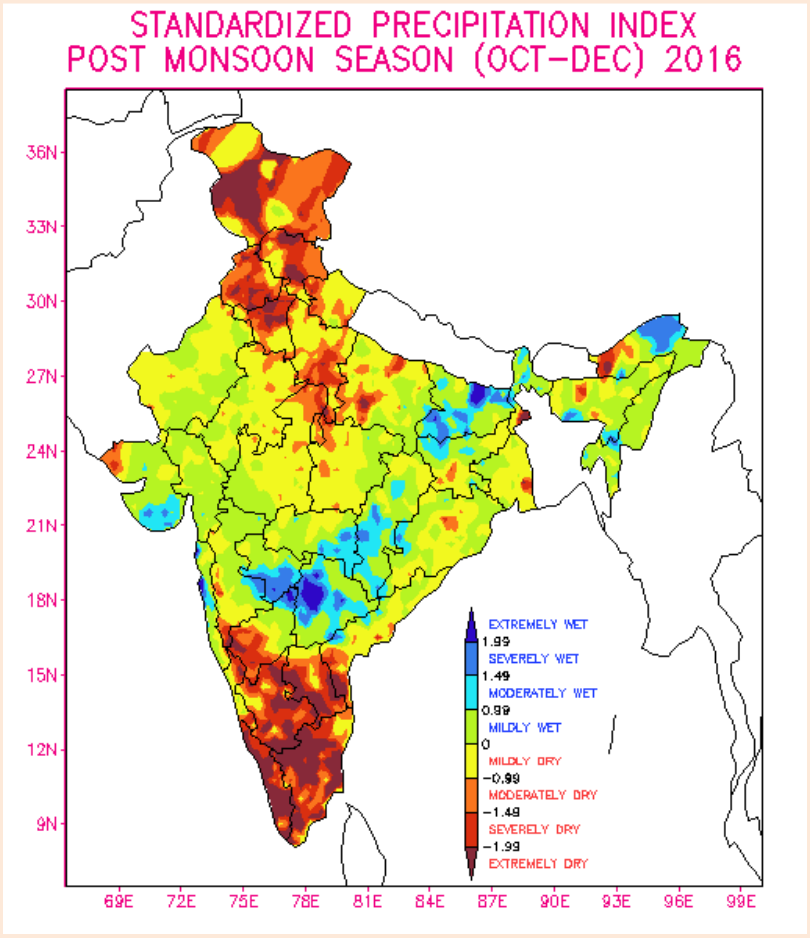


Fig.9 Standardised Precipitation Index (SPI) for Oct-Dec 2016
(Source: www.imdpune.gov.in)

At the end of the season the Standardized Precipitation Index (SPI) which is a measure of wetness/ dryness of a region based on rainfall, indicated moderately dry to extremely dry situation over most of the NEM region during October-December 2016 (Fig.9).

5. Performance of NEM 2016 over Tamil Nadu and Puducherry

Spatial and temporal rainfall distributions over the TN subdivision during Oct-Dec 2016 are depicted by means of district-wise rainfall distribution and area averaged daily rainfall distribution over TN. Fig.10 presents the daily rainfall distribution over the TN subdivision (including the state of Tamil Nadu and UT of Puducherry) during Oct-Dec 2016. It is noted that only on 6 days (2 days during the pre-onset phase), the TN subdivisional rainfall was greater than the normal rainfall. On all 30 days in November, the daily rainfall was lower than the normal.

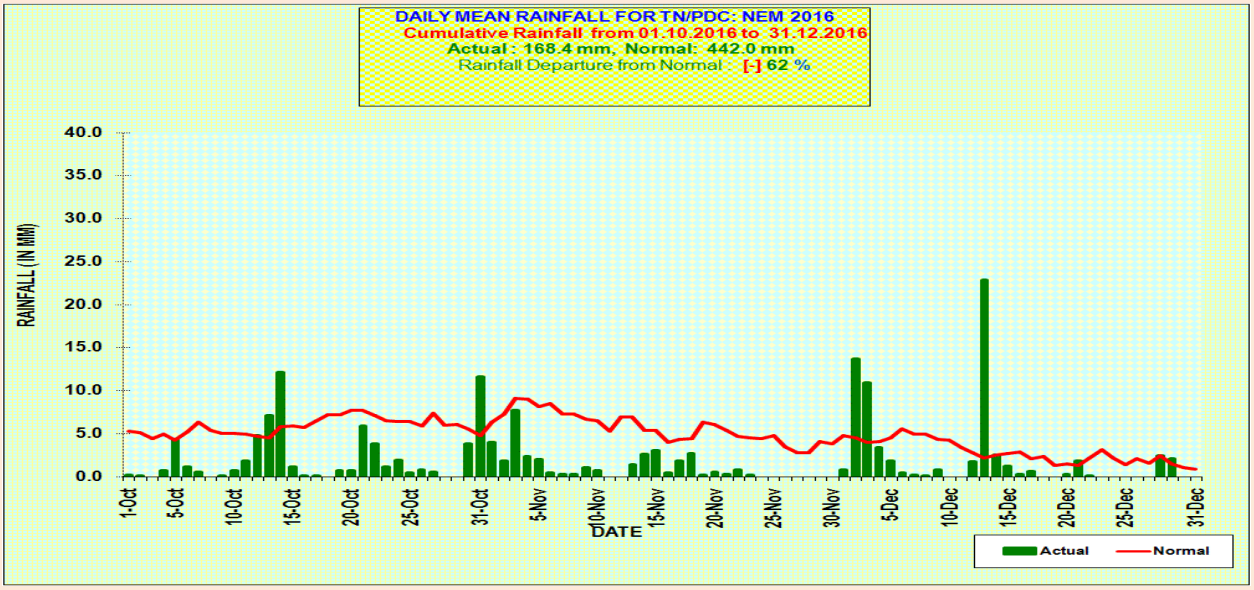


Fig.10 Area averaged daily rainfall over TN subdivision during Oct-Dec 2016

District-wise rainfall realised is presented in Table-5 and Fig.11. As seen, all 32 districts in Tamil Nadu and both Karaikal and Puducherry in UT of Puducherry ended up *deficient* to *large deficient* at the end of the season. Whereas 21 districts in Tamil Nadu and both Karaikal and Puducherry in UT of Puducherry came under *large deficient* category, 11 districts in Tamil Nadu fell under *deficient* category. Cuddalore and Puducherry recorded maximum deficiency (-81%) and Tiruppur recorded the least (-35%).

Table-5: District-wise rainfall figures of Tamil Nadu and Puducherry during Oct-Dec 2016

State/District/Subdivision	Actual rainfall (mm)	Normal rainfall (mm)	Percentage departure from normal
STATES			
Puducherry (UT)	**191.8**	**915.6**	**-79**
Tamil Nadu	**168.3**	**440.4**	**-62**
DISTRICTS			
Ariyalur	**128.5**	**545.5**	**-76**
Chennai	**342.1**	**789.9**	**-57**
Coimbatore	**142**	**328.9**	**-57**
Cuddalore	**130.5**	**697.8**	**-81**
Dharmapuri	**99.4**	**330.1**	**-70**
Dindigul	**227.7**	**436.4**	**-48**
Erode	**74.9**	**314.6**	**-76**
Kancheepuram	**334.8**	**641.8**	**-48**
Kanyakumari	**154.5**	**496.4**	**-69**
Karaikal	**245.2**	**1048.5**	**-77**
Karur	**69.4**	**314.7**	**-78**
Krishnagiri	**120**	**289.4**	**-59**
Madurai	**228.2**	**419.1**	**-46**
Nagapattinam	**248.7**	**941**	**-74**
Namakkal	**57.5**	**291.6**	**-80**
Nilgiris	**243.2**	**478.2**	**-49**
Perambalur	**127.1**	**440.9**	**-71**
Puducherry	**162.6**	**843.1**	**-81**
Pudukottai	**159.4**	**406.2**	**-61**
Ramanathapuram	**191.3**	**491.7**	**-61**
Salem	**100.3**	**370.5**	**-73**
Sivaganga	**159.1**	**422.7**	**-62**
Thanjavur	**210.3**	**550.3**	**-62**
Theni	**140.3**	**357.9**	**-61**
Tirunelveli	**186.4**	**467.2**	**-60**
Tiruppur	**205.2**	**314.3**	**-35**
Tiruvallur	**247.8**	**589.3**	**-58**
Tiruvannamalai	**172.6**	**446.5**	**-61**
Tiruvarur	**250**	**719.1**	**-65**
Toothukudi	**158.9**	**427**	**-63**
Tiruchirapalli	**132.7**	**391.5**	**-66**
Vellore	**178.1**	**348.7**	**-49**
Villupuram	**175.3**	**499.1**	**-65**
Virudhunagar	**173.2**	**419**	**-59**
TN Subdivision	**168.4**	**442**	**-62**

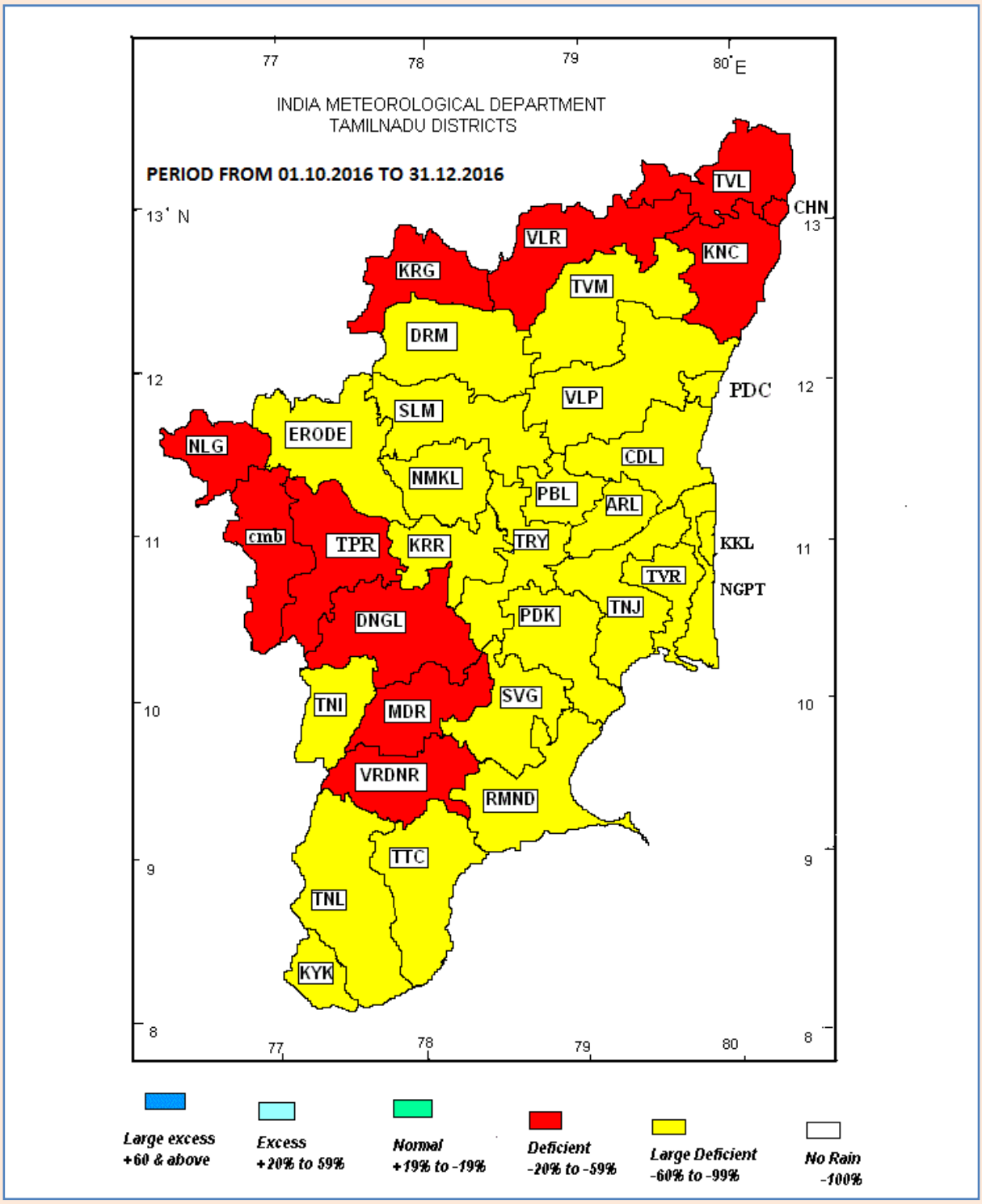


Fig.11 District-wise rainfall distribution over the TN subdivision during Oct-Dec 2016

6. Summary

During the year 2016, the onset of NEM took place on 30th October, a delay of about 10 days from the normal date of onset (20th October). Subsequently, formation and movement of a Depression over Bay of Bengal towards Bangladesh during the first week of November led to sweeping away of moisture from the southern BOB to northern latitudes causing dry NEM conditions over the southern India. Thereafter, when the mean easterly flow revived, penetration of cold and dry westerly winds from the northern latitudes weakened the easterly flow over south Indian region and the equatorial trough shifted southwards, south of the Indian latitudes. As such, the NEM activity was confined to south and east of the Indian NEM region in November leading to largely deficient NEM rainfall during the month. Subsequently, rainfall associated with two cyclones, CS NADA that crossed north TN coast near Nagapattinam on 02nd December and VSCS VARDAH that crossed coast over Chennai on 12th December improved the rainfall figures slightly over the north coastal districts. Associated with the landfall over VSCS VARDAH, lowest MSLP of 975-974 hPa and maximum sustained wind speeds of about 60 knots were observed over Chennai. Extremely heavy rainfall of 38 cm/day was recorded in Kancheepuram district during the 24-hr rainfall ending 0830 IST of 13th December. However, at the end of the season, all the five subdivisions in the region came under *large deficient* category (-60% to -99%) with SIK recording -70%, CAP and RYS: -66%, TN and KER: -62%.

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 Thirvananthapuram 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.

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 subdivisional 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 subdivisional 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.