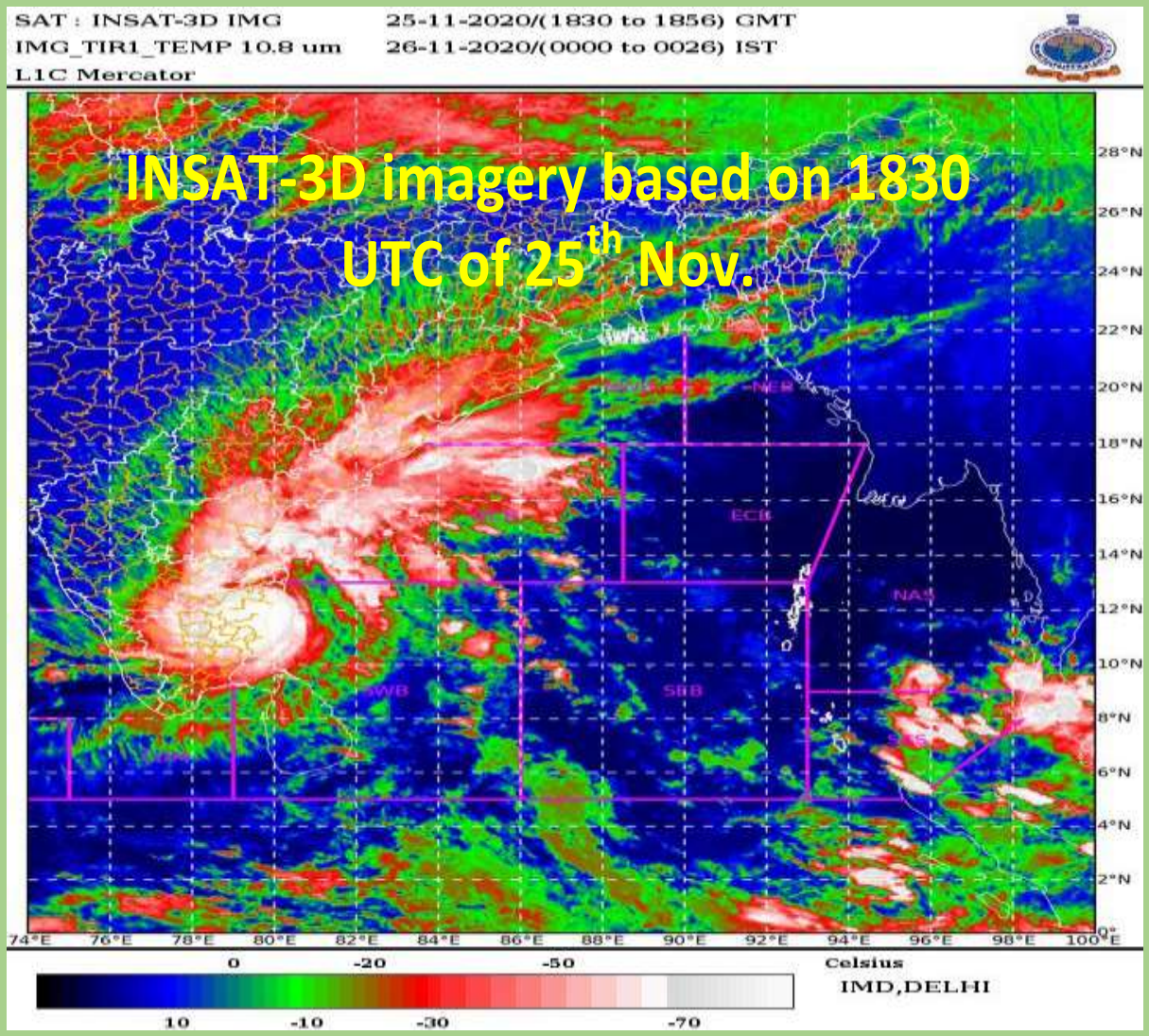
GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
INDIA METEOROLOGICAL DEPARTMENT

Very Severe Cyclonic Storm, 'NIVAR' over the Bay of Bengal (22nd -27th November 2020): A Report



INSAT-3D enhanced colored IR imagery of 1830 Hrs IST, 25th November, 2020

Cyclone Warning Division

India Meteorological Department

New Delhi

December, 2020

Very Severe Cyclonic Storm "NIVAR" over the Bay of Bengal (22nd -27th November 2020)

1. Introduction

- A Low Pressure Area (LPA) formed over Equatorial Indian Ocean (EIO) and adjoining central parts of south Bay of Bengal (BoB) on 21st November.
- It lay as a Well Marked Low Pressure Area (WML) over southwest & adjoining southeast Bay of Bengal on 22nd November.
- It concentrated into a depression over the same region in the early hours (0230 hrs IST / 2100 UTC of 22nd) of 23rd November.
- Moving west-northwestwards, it intensified into a deep depression in the evening of 23rd and further into the cyclonic storm **"NIVAR"** in the early morning (0530 hrs IST / 0000 UTC) of 24th over southwest BoB.
- Continuing to move west-northwestwards, it further intensified into a severe cyclonic storm in the midnight (2330 hrs IST / 1800 UTC) of 24th and into a very severe cyclonic storm in the afternoon (1430 hrs IST / 0900 UTC) of 25th.
- Moving further northwestwards, it crossed Tamilnadu & Puducherry coasts near Puducherry (near lat. 12.1°N and long. 79.9°E) during 2330 IST of 25th to 0230 IST of 26th as a very severe cyclonic storm with estimated wind speed of 120 kmph gusting to 135 kmph.
- Continuing to move northwestwards, it weakened into a severe cyclonic storm in the early morning hours (0230 hrs IST) of 26th.
- Thereafter, it moved north-northwestwards and weakened into a cyclonic storm in the morning (0830 hrs IST / 0300 UTC) of 26th November, 2020 over north coastal Tamilnadu.
- Thereafter, it started recurving north-northeastwards and weakened into a deep depression in the afternoon (1430 hrs IST) of 26th over south Rayalaseema, into a depression in the same midnight (2330 hrs IST) over south coastal Andhra Pradesh.
- Thereafter, it weakened into a well marked low pressure area over south coastal Andhra Pradesh and adjoining westcentral BoB in the early morning (0000 UTC)of 27th November.
- Under the influence of this system, intense rainfall activity occurred over north Tamil Nadu & Puducherry, Rayalseema and south coastal Andhra Pradesh. Heavy to very heavy rainfall occurred at a few places and isolated extremely heavy rainfall (≥ 20 cm) occurred over north Tamilnadu, Puducherry on 24th, 25th & 26th and over Rayalaseema & south coastal AP on 25th and 26th.
- The observed track of the system during 22nd to 27th November is presented in Fig. 1.

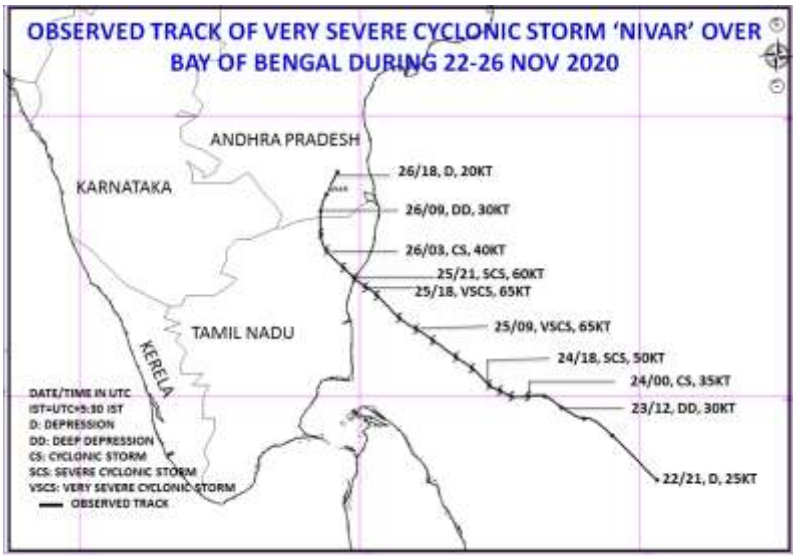


Fig.1: Observed track of very severe cyclonic storm "NIVAR" over Bay of Bengal

2. Monitoring of "NIVAR"

India Meteorological Department (IMD) maintained round the clock watch over the north Indian Ocean and the cyclone was monitored since 5th November, about 16 days prior to the formation of low pressure area over equatorial Indian Ocean and adjoining central parts of south BoB on 21st November and 18 days prior to the formation of depression over central parts of south BoB on 23rd. The cyclone was monitored with the help of available satellite observations from INSAT 3D and 3DR, SCAT SAT, polar orbiting satellites and available ships & buoy observations in the region. The system was also monitored by Doppler Weather RADARs (DWR) Chennai, Karaikal and Sriharikota. Various numerical weather prediction models run by Ministry of Earth Sciences (MoES) institutions (IMD, IITM, NCMRWF, INCOIS), global models and dynamical-statistical models were utilized to predict the genesis, track, landfall and intensity of the cyclone. A digitized forecasting system of IMD was utilized for analysis and comparison of various models' guidance, decision making process and warning products generation. Typical satellite and radar imageries are presented in Fig. 2.

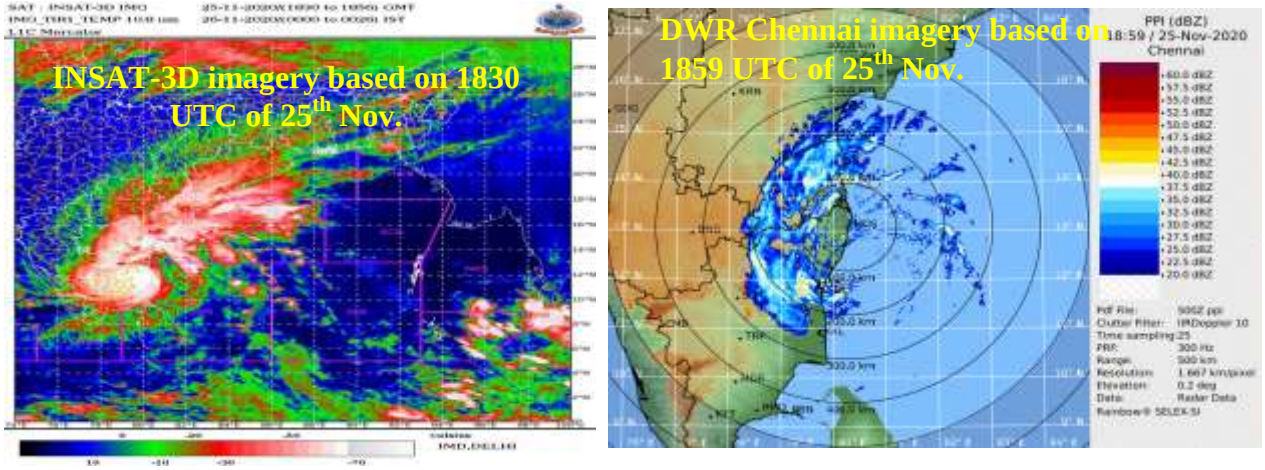


Fig.2: Typical satellite and radar imageries from DWR Chennai of VSCS "NIVAR"

Table 1: Best track positions and other parameters of the Very Super Cyclonic Storm, 'NIVAR' over the Arabian Sea during 22 Nov- 26 Nov, 2020

Date	Time (UTC)	Centre lat.^{0} N/ long.^{0} E		C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimated Pressure drop at the Centre (hPa)	Grade
22/11/2020	2100	8.5	85.3	1.5	1002	25	3	D
23/11/2020	0000	9.3	84.5	1.5	1002	25	3	D
	0300	9.5	84.2	1.5	1002	25	3	D
	0600	9.6	84.0	1.5	1001	25	4	D
	1200	9.8	83.6	2.0	999	30	5	DD
	1800	10.0	83.3	2.0	998	30	6	DD
24/11/2020	0000	10.0	83.0	2.5	997	35	7	CS
	0300	10.0	83.0	2.5	997	35	7	CS
	0600	10.0	82.7	2.5	994	40	8	CS
	0900	10.0	82.6	3.0	994	45	10	CS
	1200	10.1	82.5	3.0	994	45	10	CS
	1500	10.1	82.4	3.0	994	45	10	CS
	1800	10.2	82.3	3.5	992	50	12	SCS
	2100	10.3	82.2	3.5	988	55	16	SCS
25/11/2020	0000	10.5	82.0	3.5	986	60	18	SCS
	0300	10.7	81.7	3.5	986	60	18	SCS
	0600	11.0	81.3	3.5	986	60	18	SCS
	0900	11.2	81.0	4.0	982	65	22	VSCS
	1200	11.4	80.7	4.0	982	65	22	VSCS
	1500	11.7	80.4	4.0	982	65	22	VSCS
	1800	12.0	80.1	4.0	982	65	22	VSCS
		Crossed Tamilnadu and Puducherry coasts near Puducherry (near Lat 12.1^{0}N and Log 79.9^0 E) during 1800 – 2100 UTC of 25th .						
	2100	12.1	79.9	-	986	60	18	SCS
26/11/2020	0000	12.3	79.7	-	992	50	12	SCS
	0300	12.6	79.4	-	996	40	8	CS
	0600	12.9	79.3	-	998	30	6	CS
	0900	13.3	79.3	-	999	30	5	DD
	1200	13.6	79.4	-	1000	30	5	DD
	1800	14.0	79.6	-	1002	20	3	D
27/11/2020	0000	Weakened into a Well-Marked Low Pressure Area over south coastal Andhra Pradesh and adjoining westcentral Bay of Bengal.						

3.1 Genesis, intensification and movement

A Low Pressure Area (LPA) formed over Equatorial Indian Ocean (EIO) and adjoining central parts of south Bay of Bengal (BoB) on 21st November. On 21st, the Madden Julian Oscillation (MJO) index lay in phase 3 with amplitude equal to 1. SST was around 29-30°C over most parts of Bay of Bengal (BOB). High tropical cyclone heat potential (TCHP) (120-140 KJ/cm^2) prevailed in the near equatorial belt of and adjoining south BOB & Sumatra coast. Higher TCHP (120-140 KJ/cm^2) also prevailed off Myanmar coast and north Andhra Pradesh coast (India). TCHP was 60-80 KJ/cm^2 over remaining

parts of BOB and Andaman Sea. Considering the environmental conditions **over BOB**, positive relative vorticity (20-50x$10^{-6}s^{-1}$) prevailed over equatorial Indian Ocean & adjoining central parts of south BOB with vertical extension upto 500 hPa level. Area of positive divergence (30x$10^{-5}s^{-1}$) prevailed over equatorial Indian Ocean & adjoining central parts of south BOB. Area of positive convergence zone (05-10 x $10^{-5}s^{-1}$) prevailed over the same region. The vertical wind shear (VWS) was moderate (10-20 kts) over south and adjoining central BOB. The upper tropospheric ridge at 200 hPa ran along 11.5°N over the BOB.

It lay as a Well Marked Low Pressure Area (WML) over southwest & adjoining southeast Bay of Bengal on 22nd November. At 0300 UTC of 22nd November , similar sea conditions prevailed. Considering the environmental conditions over BOB, positive relative vorticity (25-50x$10^{-6}s^{-1}$) prevails over the system area over central parts of south BOB with vertical extension upto 500 hPa level. Area of positive divergence (40x$10^{-5}s^{-1}$) prevailed over southwest of the system area over central parts of south BOB. Area of positive convergence zone (10-20 x $20^{-5}s^{-1}$) prevailed over the same area. The vertical wind shear (VWS) was low (05-10 kts) over south and adjoining central BOB. The upper tropospheric ridge at 200 HPA ran along 11.5°N over the BOB.

At 2100 UTC of 22nd November, the system intensified into a depression. Similar sea conditions prevailed. Positive relative vorticity (150x$10^{-6}s^{-1}$) prevailed over the south of the system area over central parts of south BOB with vertical extension upto 500 hPa level. Area of positive divergence (40x$10^{-5}s^{-1}$) prevailed over the system area over southwest BOB. Area of positive convergence zone (30 x $20^{-5}s^{-1}$) prevailed over the same area. The vertical wind shear (VWS) was low (05-10 kts) over south and adjoining central BOB. The upper tropospheric ridge at 200 hPa ran along 11.5°N over the BOB.

At 1200 UTC of 23rd November, it further intensified into a deep depression. Similar sea conditions prevailed. Positive relative vorticity (150x$10^{-6}s^{-1}$) prevailed over the south of the system area over central parts of south BOB with vertical extension upto 300 hPa level. Area of positive divergence (30x$10^{-5}s^{-1}$) prevailed over the system area over southwest BOB. Area of positive convergence zone (20 x $20^{-5}s^{-1}$) prevailed over the same area. The vertical wind shear (VWS) was low (05-15 kts) over south and adjoining central BOB. The upper tropospheric ridge at 200 hPa ran along 13.5°N over the BOB.

At 0000 UTC of 24th November, it intensified into the cyclonic storm “NIVAR”. Similar sea and MJO conditions prevailed. Lower level positive relative vorticity (200x$10^{-6}s^{-1}$) prevailed around system centre. Upper level positive divergence of 40x$10^{-5}s^{-1}$ prevailed around the system centre. The lower level positive convergence was 30 x $20^{-5}s^{-1}$ around system centre. The vertical wind shear (VWS) was low (05-15 kts) over the region. The upper tropospheric ridge at upper and middle tropospheric levels ran along 13.0°N over the BOB in association with the anticyclonic circulation to the northeast of system centre the system lay in the southern peripherry of the above ridge. As a result, it was moving west northwestwards. It was expected to be steered by the above ridge resulting in west-northwestward movement for next 12 hrs and then northwestward movement . The above environmental conditions were favouring further intensification of the system during next 24 hrs into a severe cyclonic storm.

At 1800 UTC of 24th November, the system intensified into a severe cyclonic storm. SST was around 29-30°C over southwest Bay of Bengal (BOB). The tropical

cyclone heat potential was about 80-100 KJ/cm^2 over southwest BOB. Lower level positive relative vorticity (200x10^{-6}s^{-1}) prevailed southwest of system centre. Upper level positive divergence of 40x10^{-5}s^{-1} prevailed southwest of the system centre. The lower level positive convergence was 20 x 20^{-5}s^{-1} around southwest sector of the system. The vertical wind shear (VWS) was low (05-15 kts) over the region. The upper tropospheric ridge at upper and middle tropospheric levels ran along 13.0°N over the BOB in association with an anticyclonic circulation to the northeast of system centre the system lay in the southern periphery of the above ridge. As a result, the system was moving initially west northwestwards. It was expected to be steered by the above ridge resulting in northwestward movement thereafter. The above environmental conditions were favourable for further intensification of the system into a very severe cyclonic storm during next 12 hours.

At 0900 UTC of 25th November , the system intensified into a very severe cyclonic storm. SST was around 29-30°C over southwest Bay of Bengal (BOB). The tropical cyclone heat potential was about 80-100 KJ/cm^2 over southwest BOB. Lower level positive relative vorticity (250x10^{-6}s^{-1}) prevailed around the system centre. Upper level positive divergence of 40x10^{-5}s^{-1} prevailed to the northwest of the system centre. The lower level positive convergence was 20 x 20^{-5}s^{-1} to the south of system center. The vertical wind shear (VWS) was low (10-15 kts) over the region. The upper tropospheric ridge at upper and middle tropospheric levels shifted north and ran along 14.0°N over the BOB in association with an anticyclonic circulation to the northeast of system centre. The system lay in the southern peripherry of the above ridge. As a result, the system was moving likely move northwestward hereafter towards the Tamilnadu coast. The above environmental conditions was favourable for the system to remain as a very severe cyclonic storm during next 12 hours.

The system crossed Tamilnadu & Puducherry coasts near Puducherry (near lat. 12.1°N and long. 79.9°E) during 2330 IST of 25th to 0230 IST of 26th as a very severe cyclonic storm with estimated wind speed of 120 kmph gusting to 135 kmph.

At 2100 UTC of 25th November, it weakened into a severe cyclonic storm. Lower level positive relative vorticity (250x10^{-6}s^{-1}) prevailed around the system centre. Upper level positive divergence of 40x10^{-5}s^{-1} prevailed to the north of the system centre. The lower level positive convergence was 40 x 20^{-5}s^{-1} to the south of system center. The vertical wind shear (VWS) was low (10-15 kts) over the region.

At 0300 UTC of 26th November, it further weakened into a cyclonic storm. Lower level positive relative vorticity decreased and was about 200x10^{-6}s^{-1} to the southeast of the system centre. Upper level positive divergence of 40x10^{-5}s^{-1} prevailed to the northeast of the system centre. The lower level positive convergence 40 x 10^{-5}s^{-1} prevailed to the northeast of system center. The vertical wind shear (VWS) was low (10-15 kts) over the southern peninsular region and along the expected track.

At 0900 UTC of 26th November, it weakened into a deep depression. Lower level positive relative vorticity decreased and was about 200x10^{-6}s^{-1} to the southeast of the system centre. Upper level positive divergence of 40x10^{-5}s^{-1} prevailed to the northeast of the system centre. The lower level positive convergence 40 x 10^{-5}s^{-1} prevailed to the northeast of system center. The vertical wind shear (VWS) was low (10-15 kts) over the southern peninsular region and along the expected track.

Similar unfavourable environment continued and the system weakened into a depression at 1800 UTC of 26th and into a well marked low pressure area at 0000 UTC of 27th November. Typical total precipitable water vapour imagery during lif e cycle of NIVAR are presented in Fig.3.

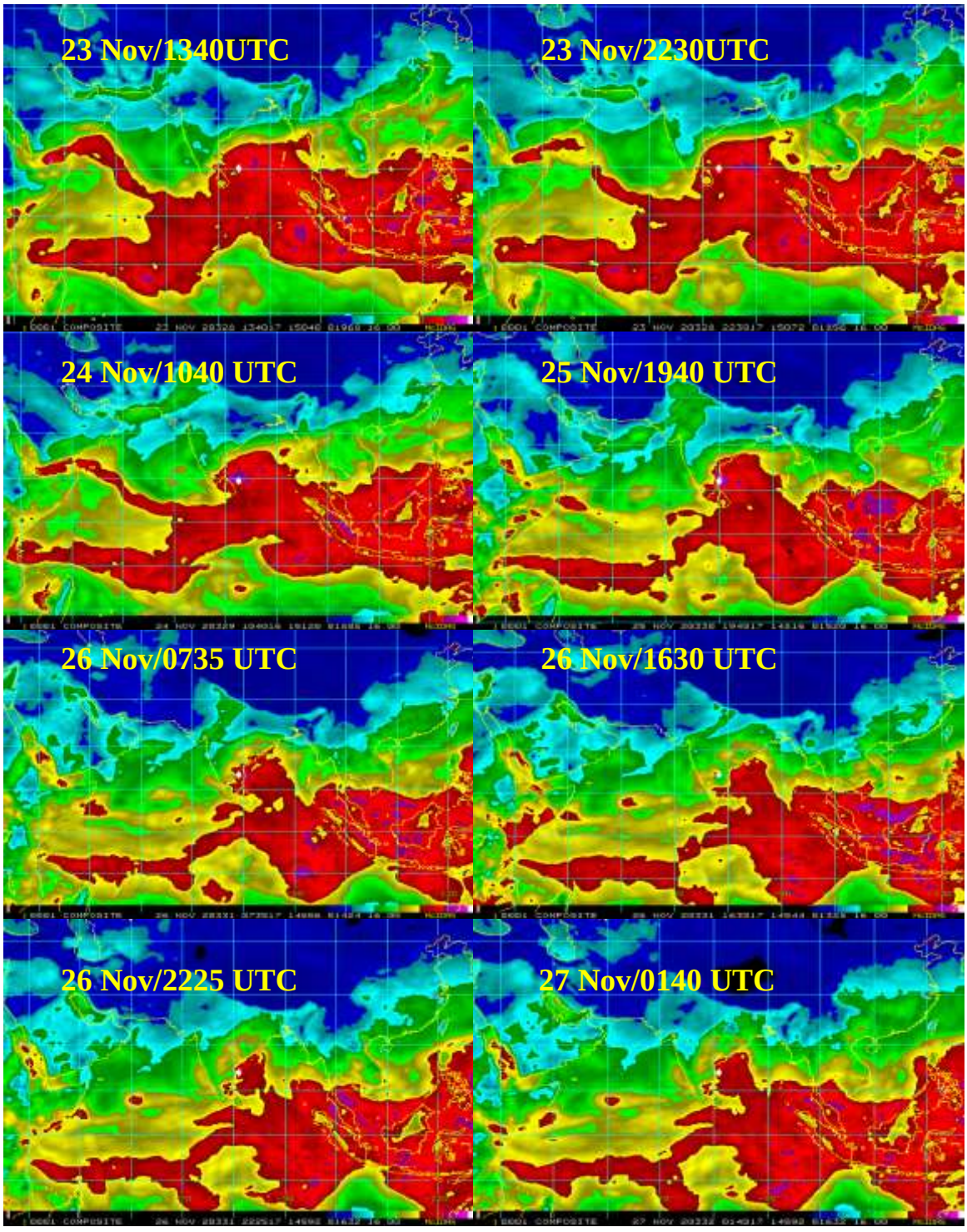


Fig. 3: Total Precipitable Water (TPW) imageries during VSCS NIVAR during 22nd - 27th November 2020

The wind speed in middle and deep layer around the system centre is presented in Fig.4. The wind shear around the system between 200 & 850 hPa levels remained low till 26th November and thereafter, it became moderate. The mean wind speed in the deep layer was low (05 kts) till 26th and thereafter, it increased becoming 10 kts.

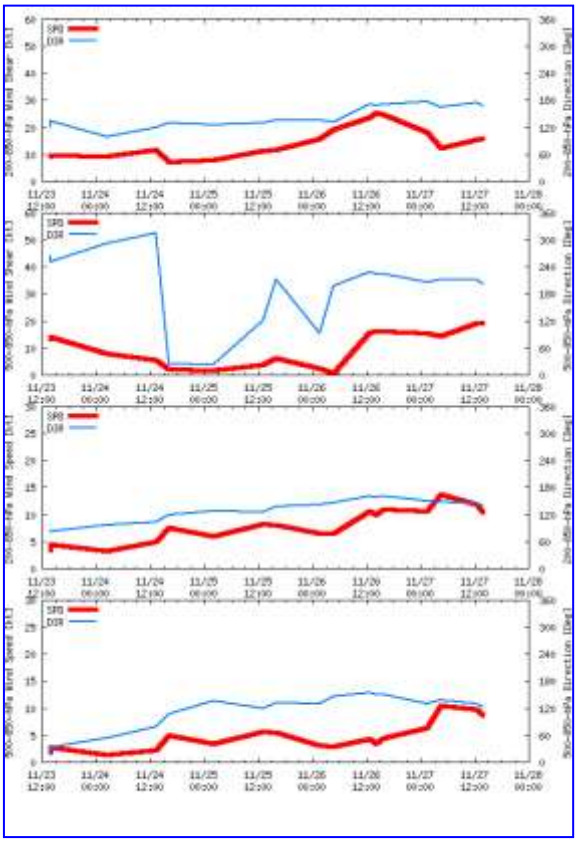


Fig.4: Mean wind speed and shear in deep (850-200 hPa) and middle (500-850 hPa) layers

3.2. Maximum Sustained Surface Wind speed and estimated central pressure

There was gradual increase in intensity during the period 0000 UTC of 23rd November to 1200 UTC of 25th November. The system reached it's peak intensity of 65 knots at 1200 UTC of till 1800 UTC of 25th November. Thereafter, it weakened rapidly. The minimum estimated central pressure of 982 hPa was observed during 1200 UTC to 1800 UTC of 25th November. The lowest estimated central pressure and the maximum sustained wind speed are presented in Fig.5a.

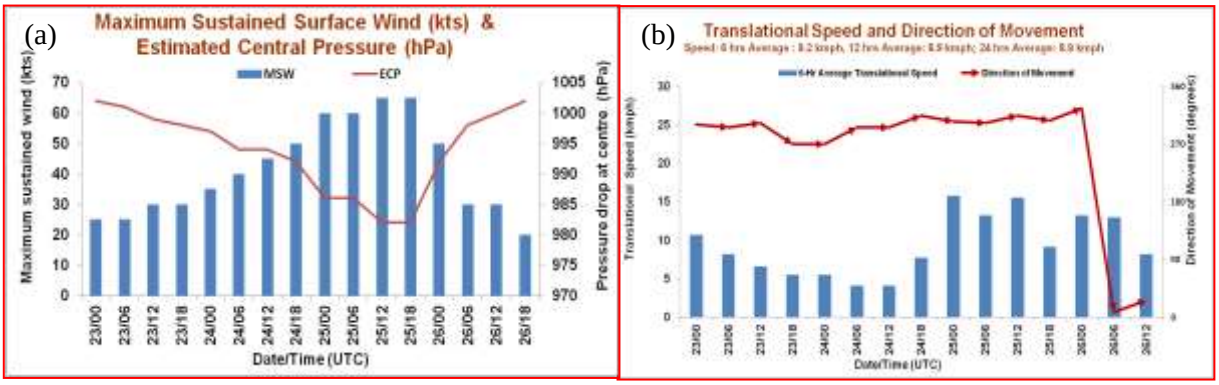


Fig.5. (a) Maximum sustained surface winds (kts) & Estimated Central Pressure

3.2. Translational speed & direction of movement

The six hourly movement of VSCS NIVAR is presented in **Fig.5b**. The 12 hourly average translational speed of VSCS NIVAR was about 8.9 kmph against the normal speed of 15.0 kmph for VSCS category over BoB during post monsoon season. The system moved nearly northwestwards till 0000 UTC of 26th November. Thereafter, it recurved north-northeastwards. The mean wind speed and direction in the deep layer between 850-200 hPa level and the middle layer between 850-500 hPa level is presented in Fig. 4.

4. Monitoring

4.1 Features observed through satellite

Satellite monitoring of the system was mainly done by using half hourly INSAT-3D and 3DR imageries. Satellite imageries of international geostationary satellites Meteosat-8 & MTSAT and microwave & high resolution images of polar orbiting satellites DMSP, NOAA series, Metops were also considered. Typical INSAT-3D visible/IR imageries, enhanced colored imageries and cloud top brightness temperature imageries are presented in Fig.6.

At 2100 UTC of 22nd November, the vortex associated with this system lay over central parts of south Bay of Bengal centered 8.6^{0}N/85.2^{0}E. And intensity is increase T1.5/1.5. Broken low and medium clouds with embedded intense to very intense convection lay over south Bay of Bengal, between latitude 8.0^{0}N & 12.0^{0}N and longitude 82.0^{0}E & 89.0^{0}E in association with the system. Minimum cloud top temperature is -93.0^{0}C.

At 1200 UTC of 23rd November, the vortex associated with this system lay over central parts of south Bay of Bengal centered 9.7^{0}N/83.7^{0}E. And intensity was T2.0/2.0. Shear pattern. Broken low and medium clouds with embedded intense to very intense convection lay over south Bay of Bengal, between latitude 9.0^{0}N & 12.5^{0}N and longitude 80.0^{0}E & 84.0^{0}E in association with the system. Minimum cloud top temperature is -80.0^{0}C.

At 0000 UTC of 24th November, the intensity was T2.5. Associated scattered to broken low and medium clouds with embedded intense to very intense convection lay over south and adjoining central Bay of Bengal, between latitude 8.0^{0}N & 14.0^{0}N and longitude 79.0^{0}E & 84.0^{0}E in association with the system. Minimum cloud top temperature is -93.0^{0}C.

At 1800 UTC of 24th November, the intensity was T3.5 associated scattered to broken low and medium clouds with embedded intense to very intense convection lay over south west and adjoining west central Bay of Bengal, between latitude 8.5^{0}N & 14.0^{0}N and longitude 80.0^{0}E & 86.0^{0}E in association with the system. Minimum cloud top temperature is -93.0^{0}C.

At 0900 UTC of 25th November the intensity was T4.0 with CDO pattern. Associated broken low and medium clouds with embedded intense to very intense convection lay over southwest and adjoining westcentral Bay of Bengal, between latitude 9.0^{0}N & 15.0^{0}N and longitude 80.0^{0}E & 85.0^{0}E in association with the system. Minimum cloud top temperature is -93.0^{0}C.

At 2100 UTC of 25th November the intensity was T4.0 with CDO pattern. Associated broken low and medium clouds with embedded intense to very intense convection lay over southwest and adjoining westcentral Bay of Bengal, between latitude 11.0^{0}N & 13.0^{0}N and longitude 79.0^{0}E & 80.5^{0}E in association with the system. Minimum cloud top temperature is -93.0^{0}C.

At 0300 UTC of 26th November broken low and medium clouds with embedded

intense to very intense convection lay over Tamilnadu, south coastal Andhra Pradesh, Rayalseema, south interior Karnataka and over westcentral southwest Bay of Bengal between latitude 10.0^{0}N & 16.0^{0}N and longitude 80.0^{0}E & 82.5^{0}E in association with the system. Minimum cloud top temperature is -87.0^{0}C.

At 0900 UTC of 26th November broken low and medium clouds with embedded intense to very intense convection lay over north Tamilnadu, south coastal Andhra Pradesh, Rayalseema, south interior Karnataka and over westcentral southwest Bay of Bengal between latitude 11.0^{0}N & 16.0^{0}N and longitude 80.0^{0}E & 83.0^{0}E in association with the system. Minimum cloud top temperature is -87.0^{0}C.

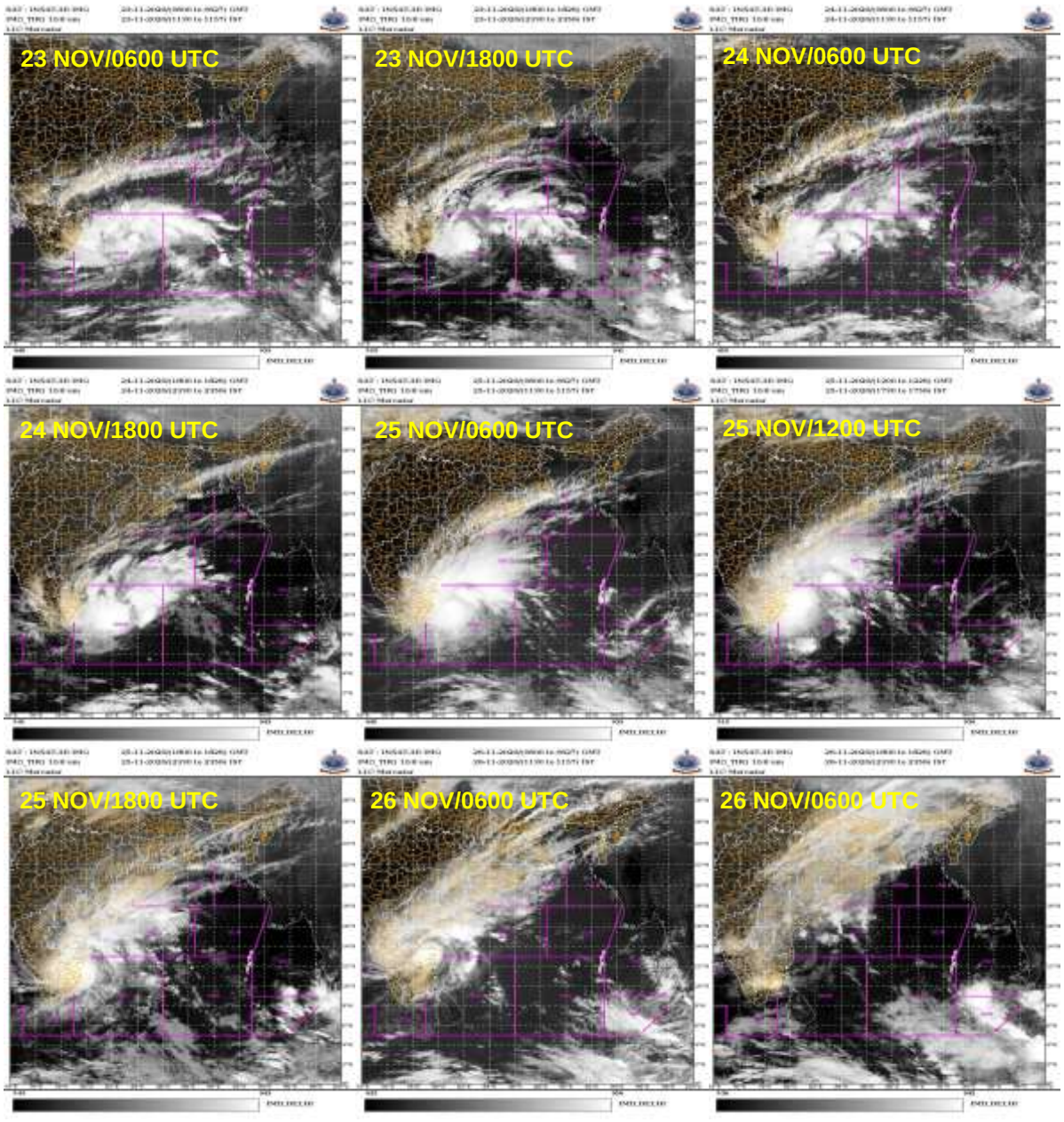


Fig. 6(a): INSAT-3D IR imageries during life cycle of VSCS NIVAR (22 Nov-27 Nov), 2020

At 1800 UTC of 26th November broken low and medium clouds with embedded intense to very intense convection lay over north Tamilnadu, south coastal Andhra Pradesh, Rayalseema, south interior Karnataka and over westcentral southwest Bay of

Bengal. Minimum cloud top temperature is -59.0^{0}C.

At 0000 UTC of 27th November, the system was over south castal Andhra Pradesh and neighbourhood centered within half a degree of 14.0N/80.0E. Center not clearly defined in IR imagery. Broken low and medium clouds with embedded weak to moderate convection lay over north-east Tamilnadu, south coastal Andhra Pradesh, Rayalseema, and over westcentral southwest Bay of Bengal.

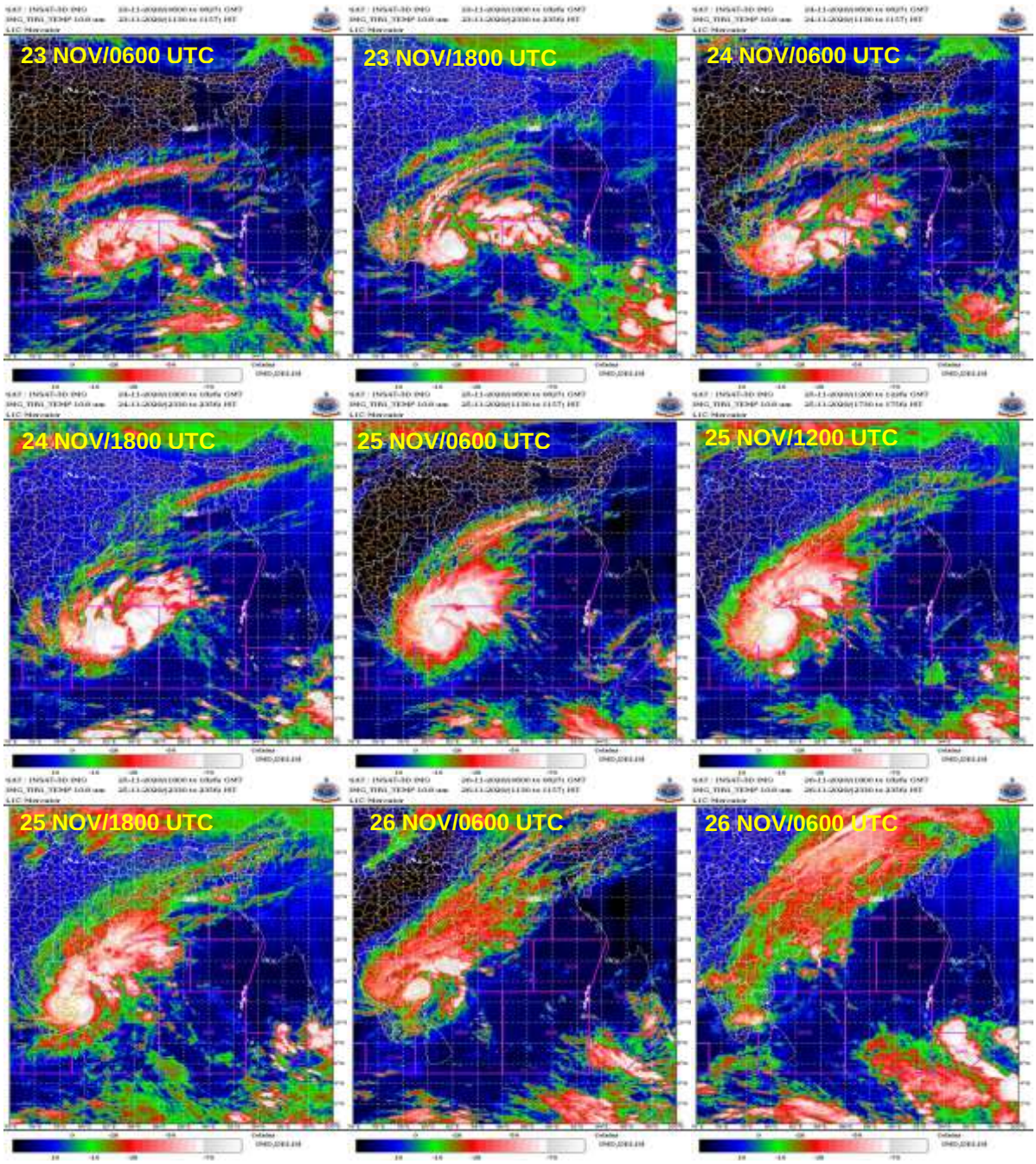


Fig. 6(b): INSAT-3D enhanced colored imageries during life cycle VSCS NIVAR (22 Nov-27 Nov), 2020

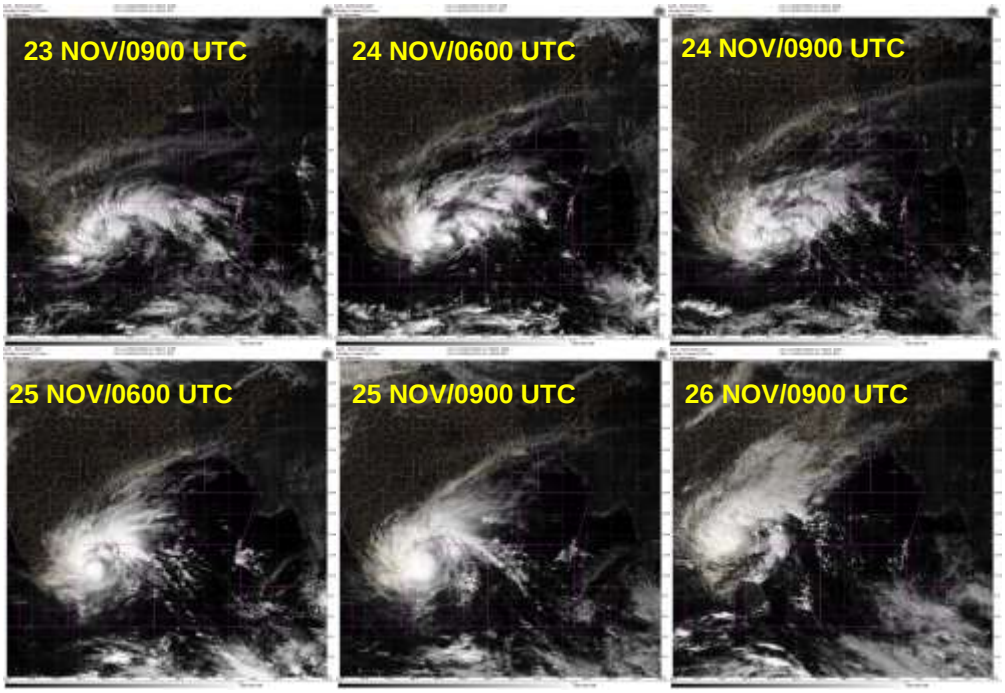


Fig. 6(d): INSAT-3D Visible imageries during life cycle of VSCS NIVAR (22 Nov-27 Nov), 2020

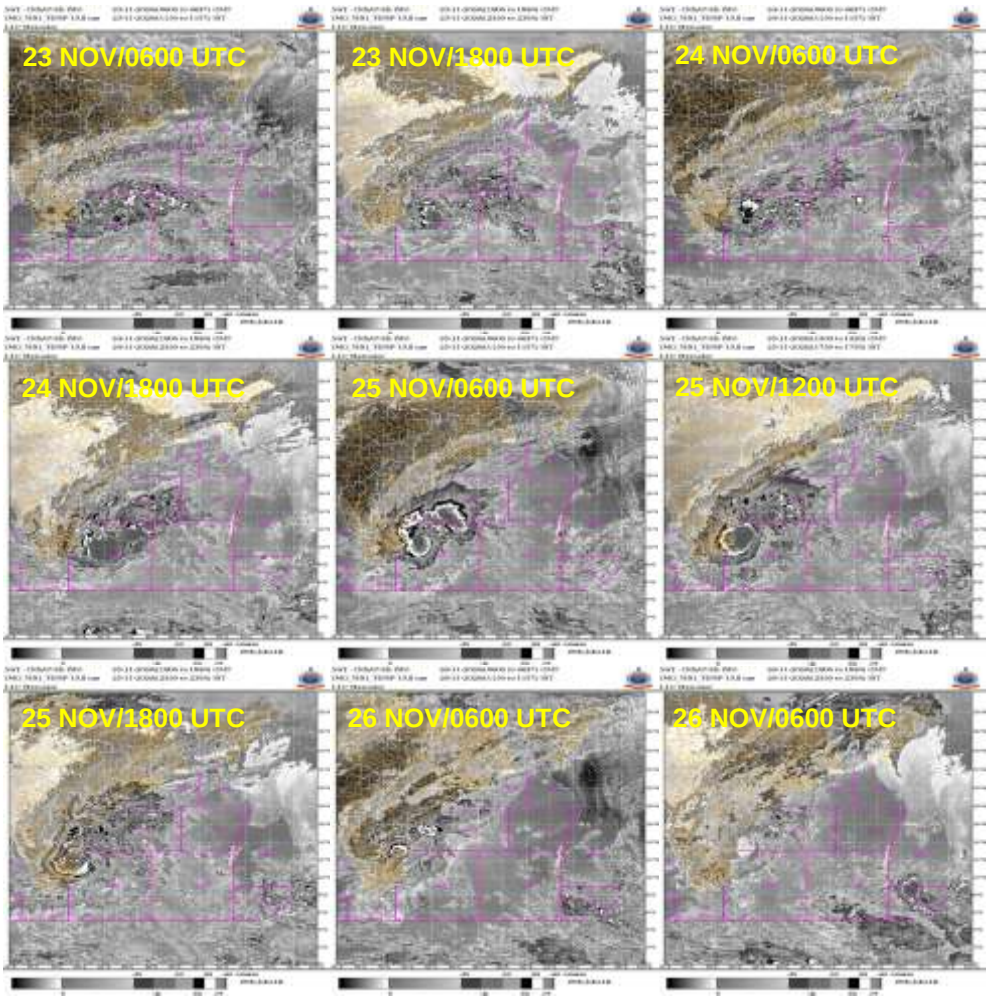


Fig. 6(e): INSAT-3D Water Vapor imageries during life cycle of VSCS NIVAR (22 Nov-27 Nov), 2020

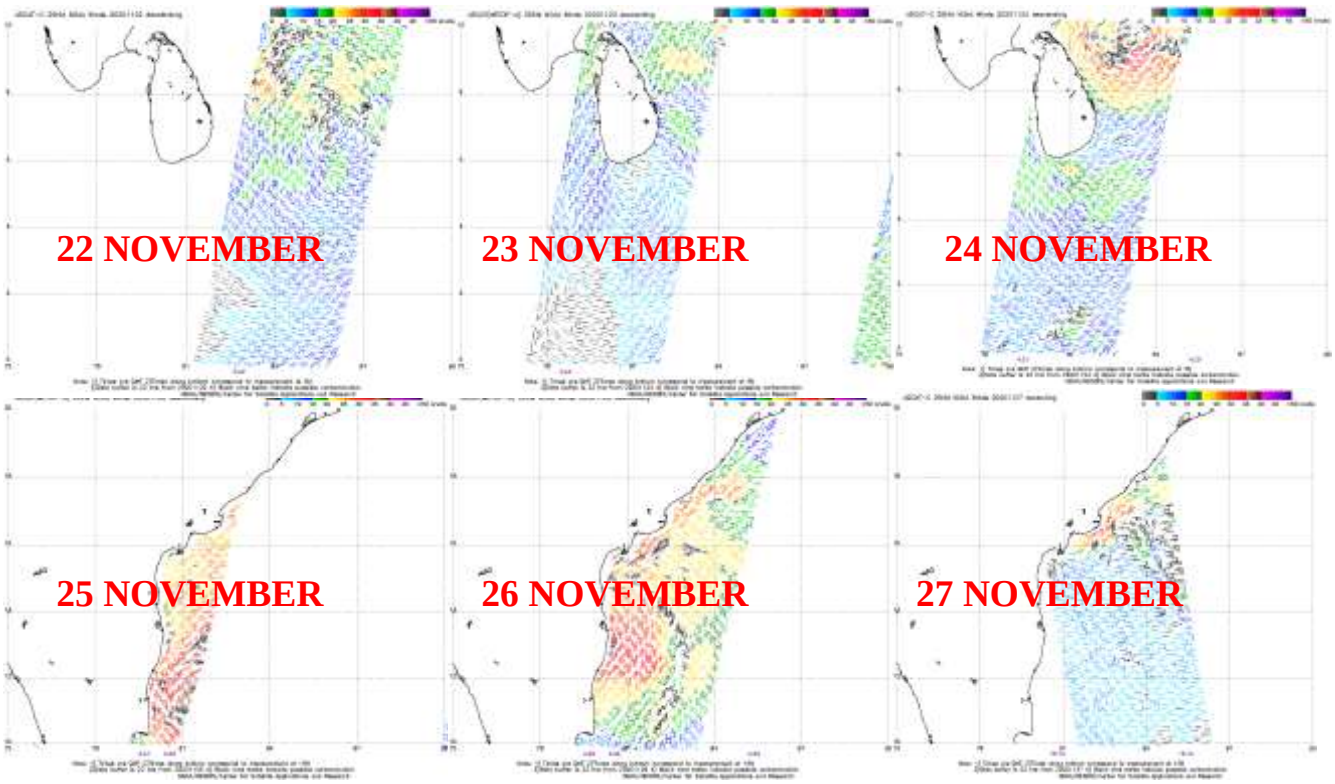


Fig. 6(f): ASCAT imageries during life cycle of VSCS NIVAR (22-27 November, 2020)

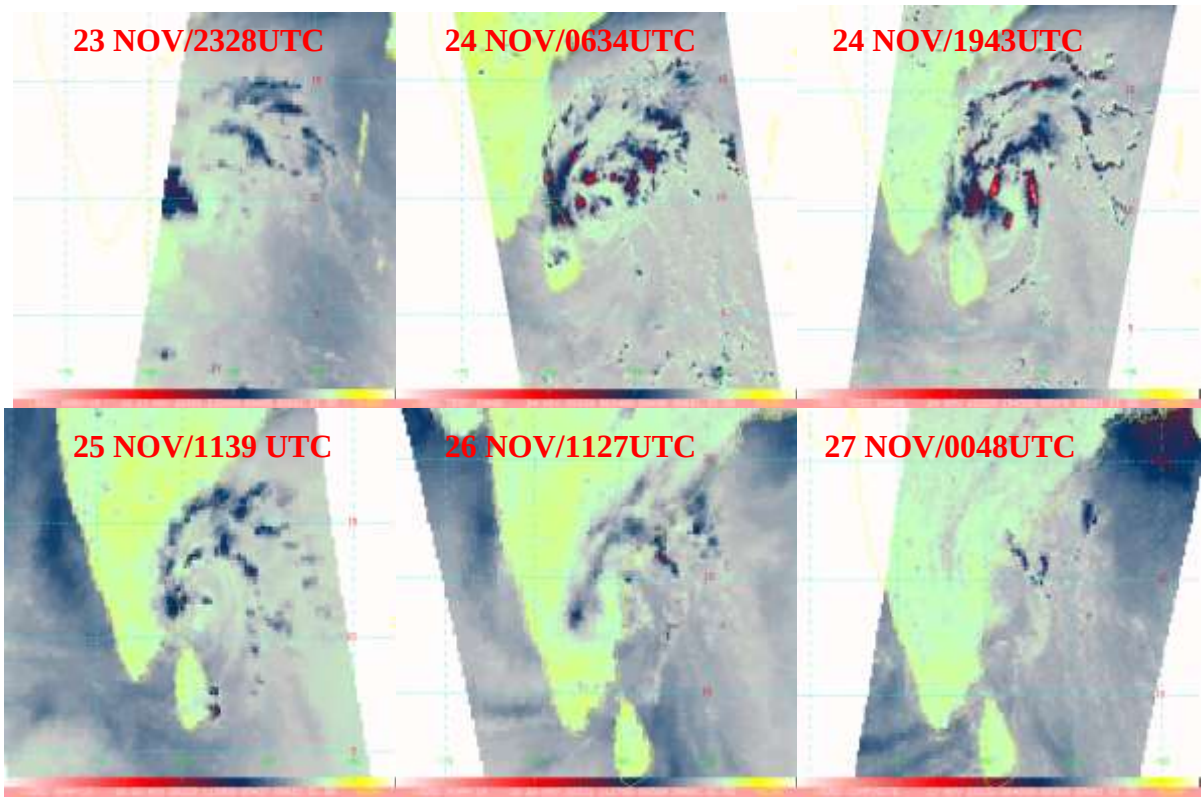


Fig. 6g: Microwave imageries during life cycle of VSCS NIVAR (23-27 Nov), 2020

4.2 Features observed through Radar

The VSCS NIVAR was tracked by DWRs Shriharikota, Karaikal, Chennai. Typical DWR imageries from these radars are presented in Fig. 7.

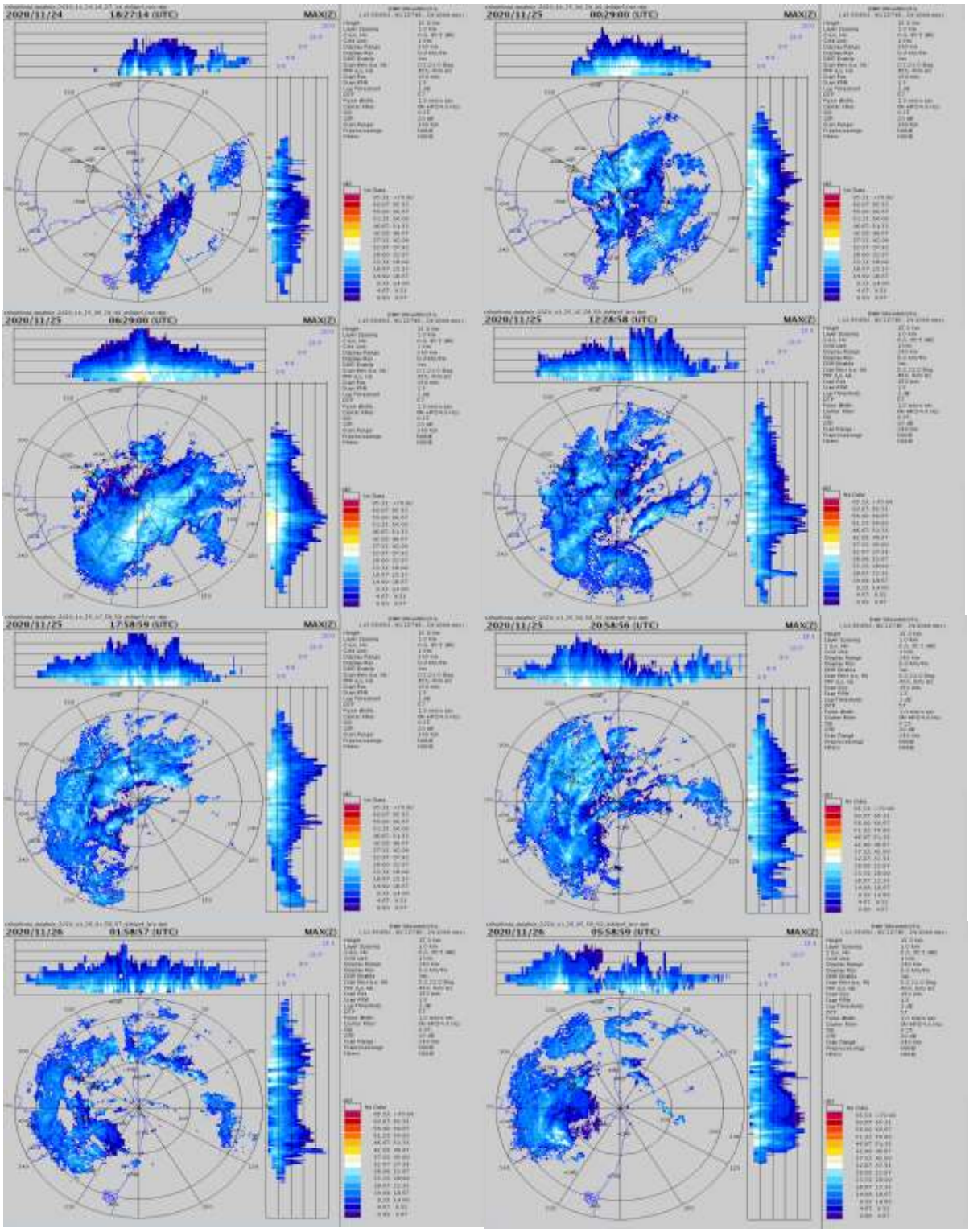


Fig.7 (a):Typical Radar imagery MAX-Z from DWR Shriharikota during 24-26 November

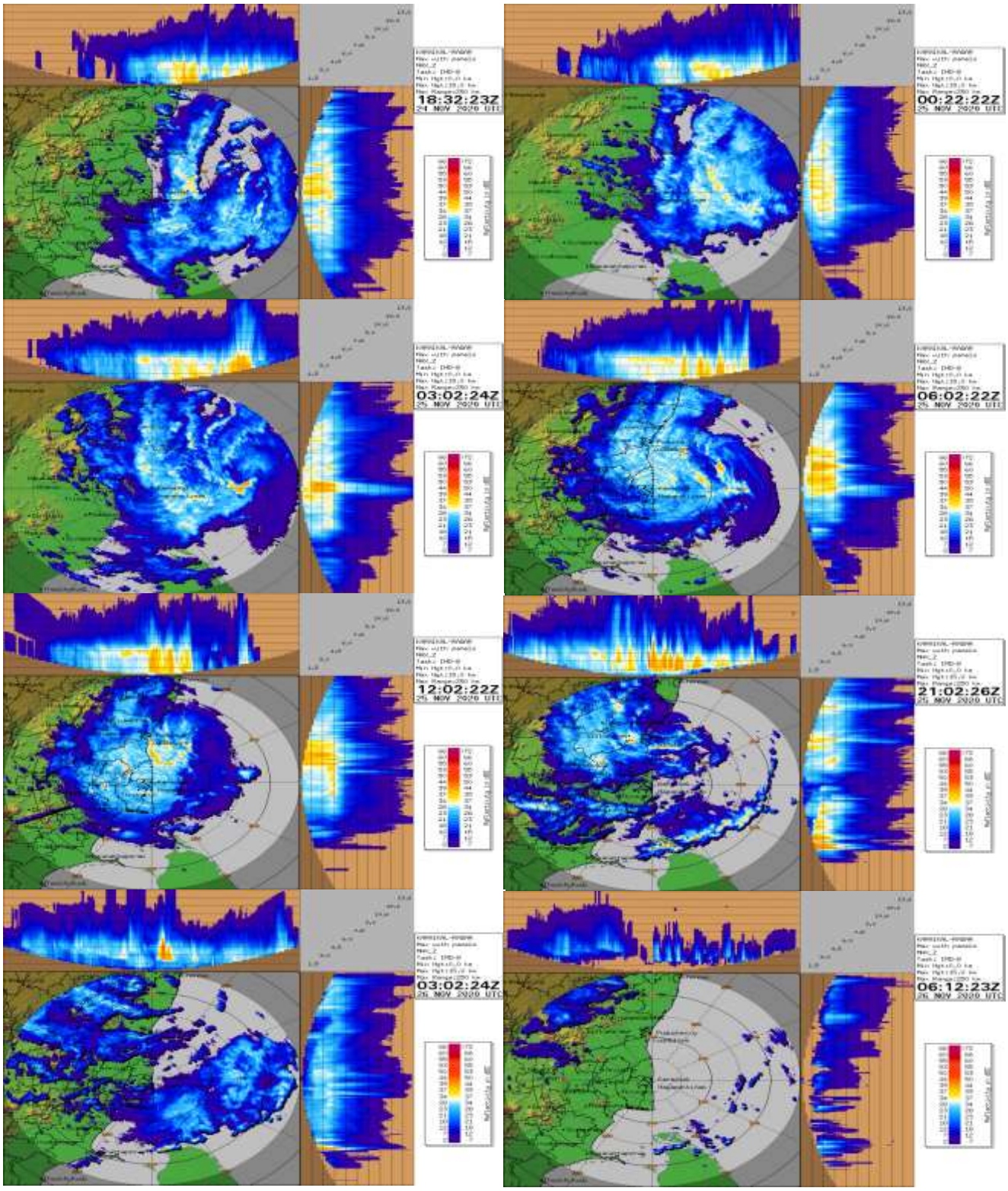


Fig.7(b):Typical Radar imagery MAX-Z from DWR Karaikal during 24-26 November

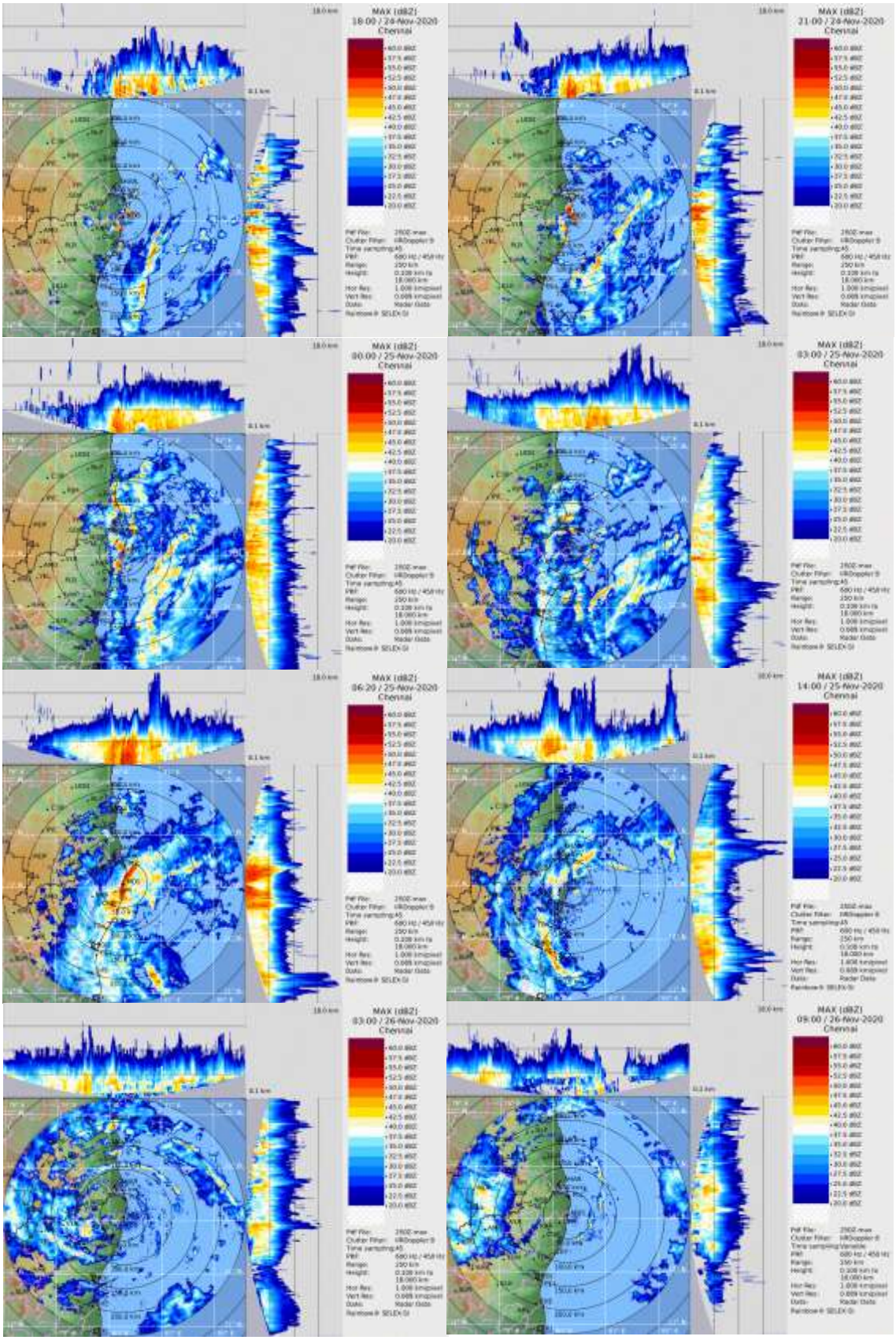


Fig.7(c):Typical Radar imagery MAX-Z from DWR Chennai during 24-26 November

5. Dynamical features

IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels during 22nd - 27th November are presented in **Fig. 8.** The analysis of IMD-GFS T-1534 model based on 0000 UTC of 22nd, is indicating presence of an LPA over central parts of south BoB on 22nd with vertical extension upto 500 hPa level.

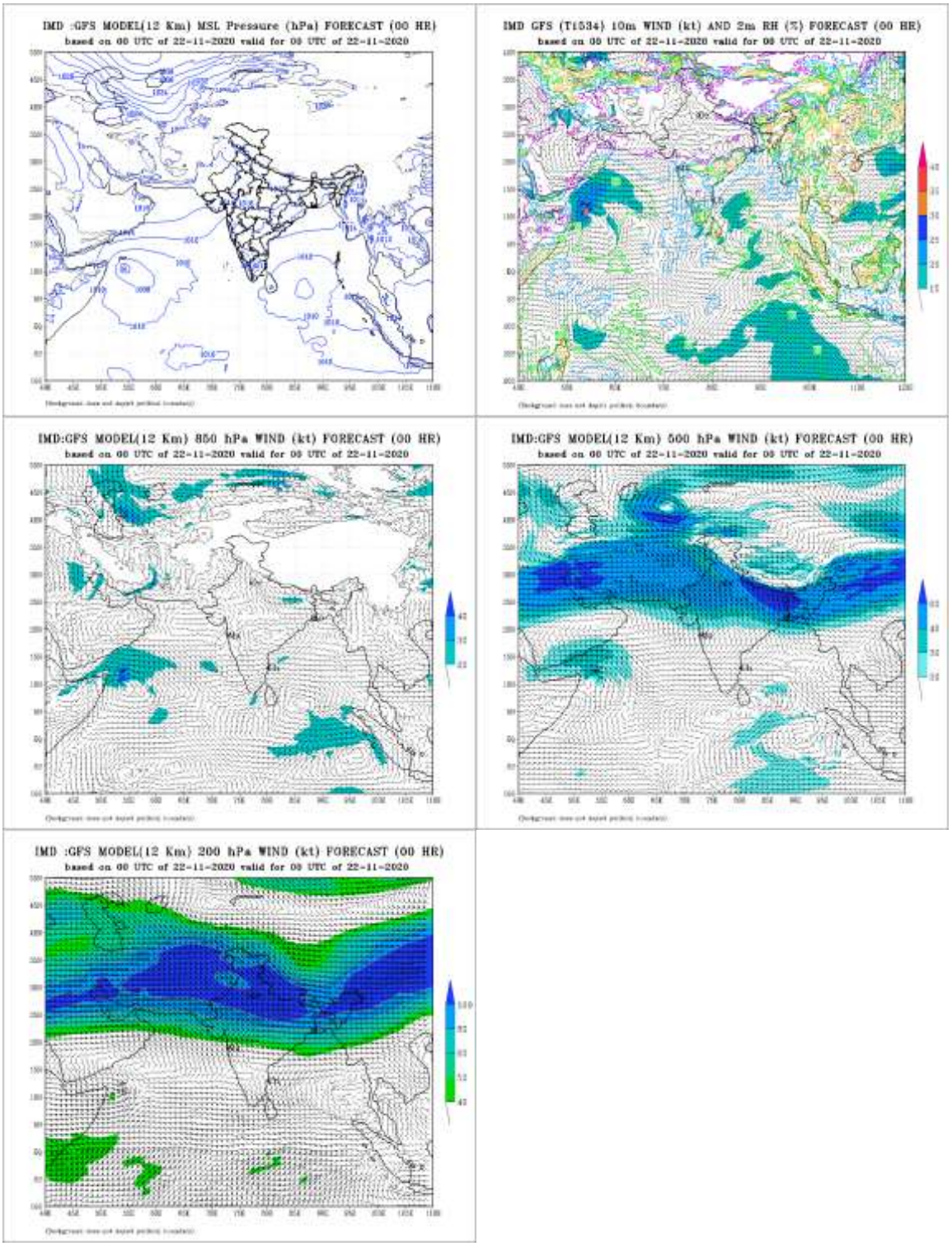


Fig. 8 (a): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 22nd November 2020

The analysis of IMD-GFS T-1534 model based on 0000 UTC of 23rd, IMD GFS was indicating presence of a cyclonic storm over southwest BoB with vertical extension upto 500 hPa level. At tis time, the model over estimated the intensity of the system.

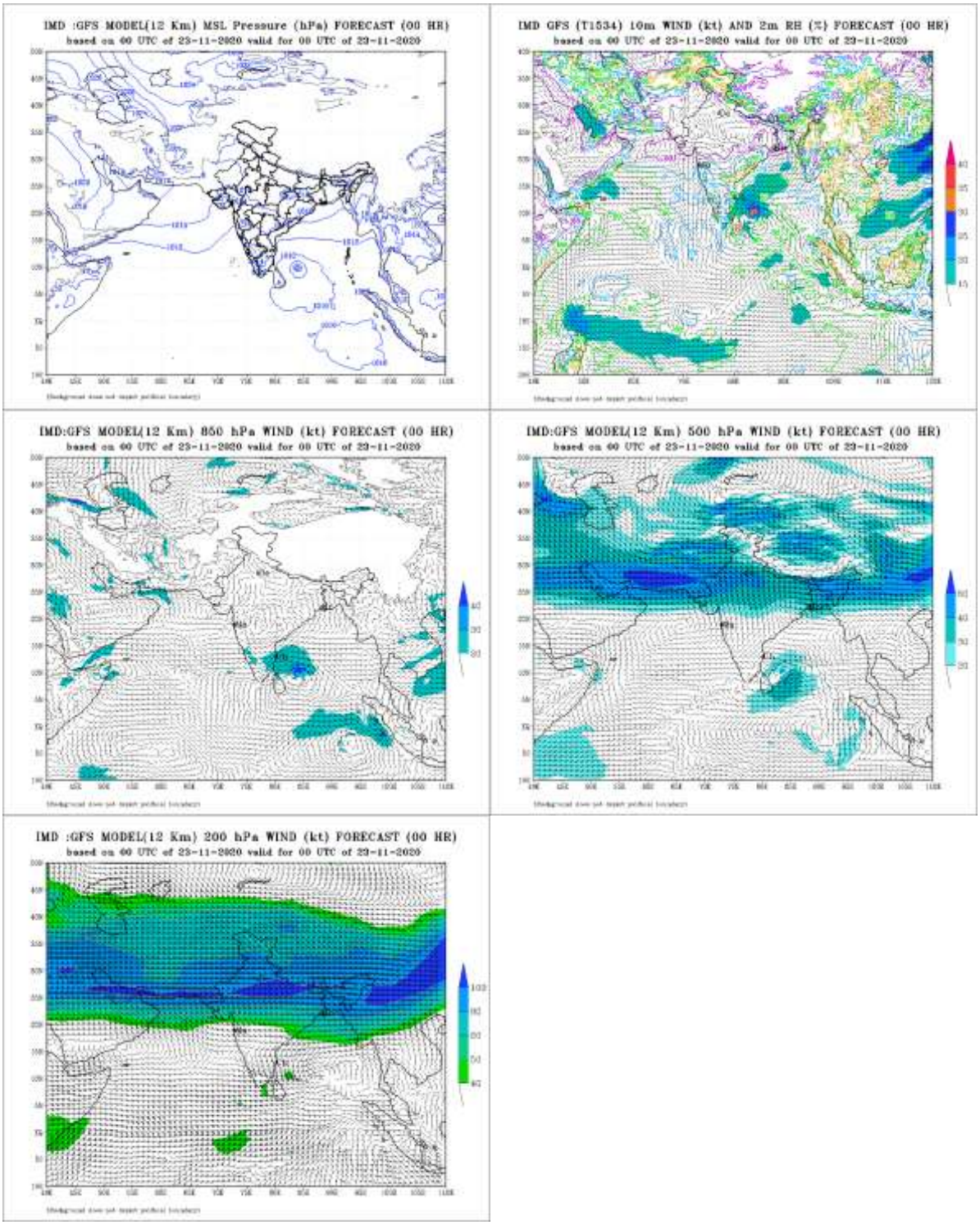


Fig. 8(b): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 23rd November 2020

The analysis of IMD-GFS T-1534 model based on 0000 UTC of 24th, IMD GFS was indicating presence of a cyclonic storm over southwest BoB with west-northwestwards movement towards Tamil Nadu coast with vertical extension upto 500 hPa level.

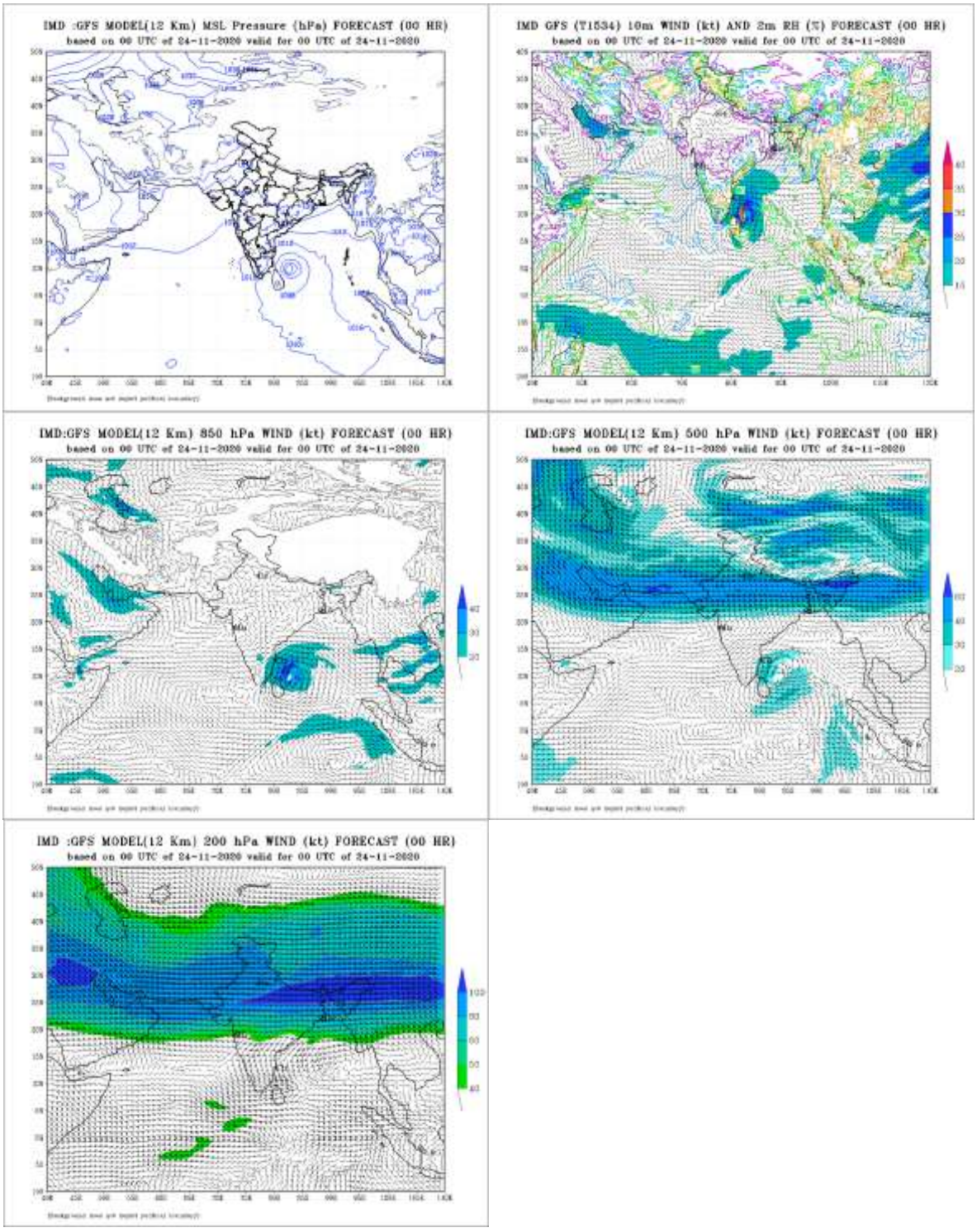


Fig. 8 (c): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 24th November 2020

The analysis of IMD-GFS T-1534 model based on 0000 UTC of 25th, IMD GFS was indicating presence of an Extremely Severe Cyclonic Storm (ESCS) over southwest BoB off Tamil Nadu coast on 25th with vertical extension upto 200 hPa level.

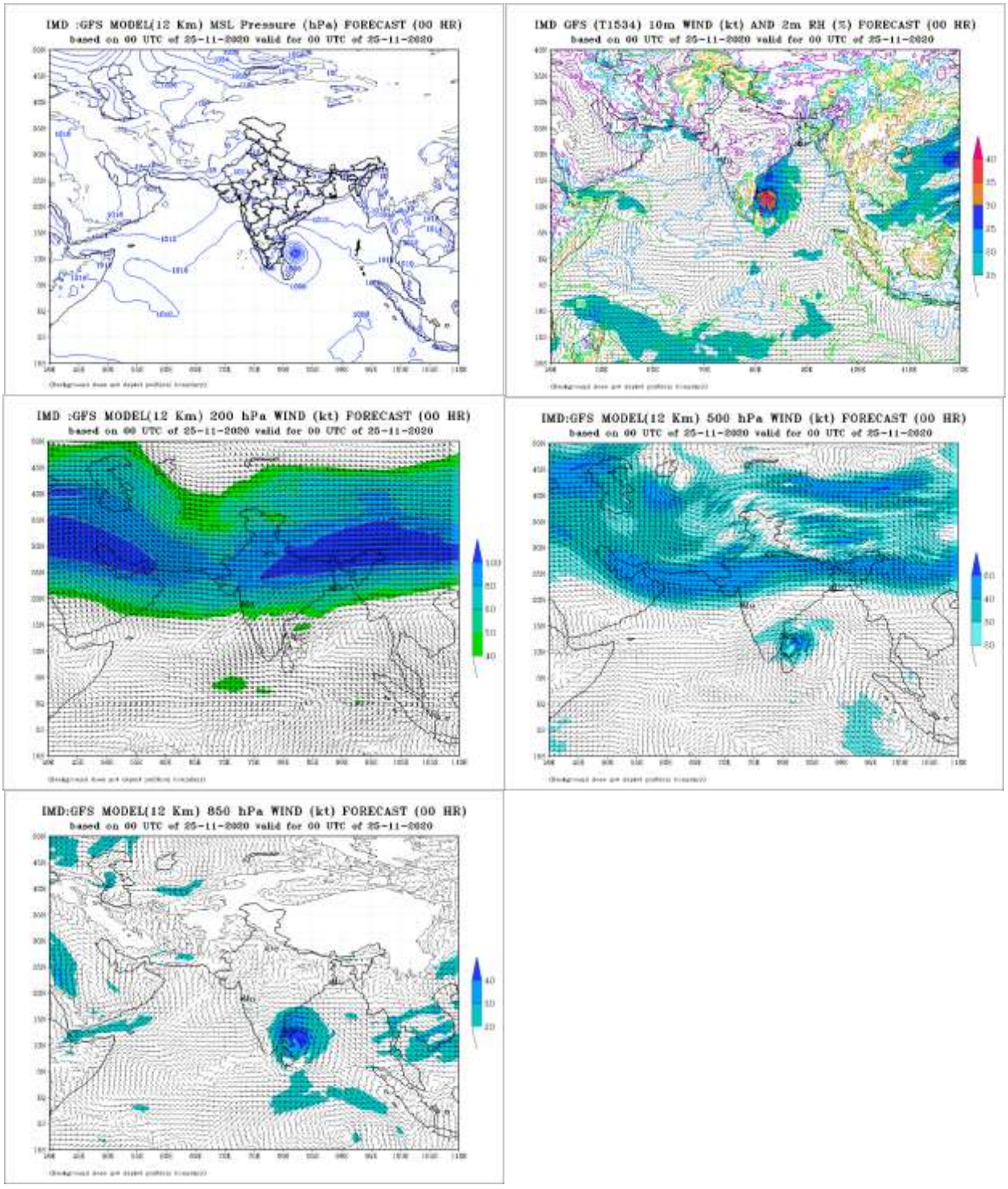


Fig. 8 (d): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 25th November 2020

The analysis of IMD-GFS T-1534 model forecasts based on 0000 UTC of 26th November, 2020 indicated presence of a Very Severe Cyclonic Storm (VSCS) over north coastal Tamil Nadu on 26th with vertical extension upto 200 hPa level.

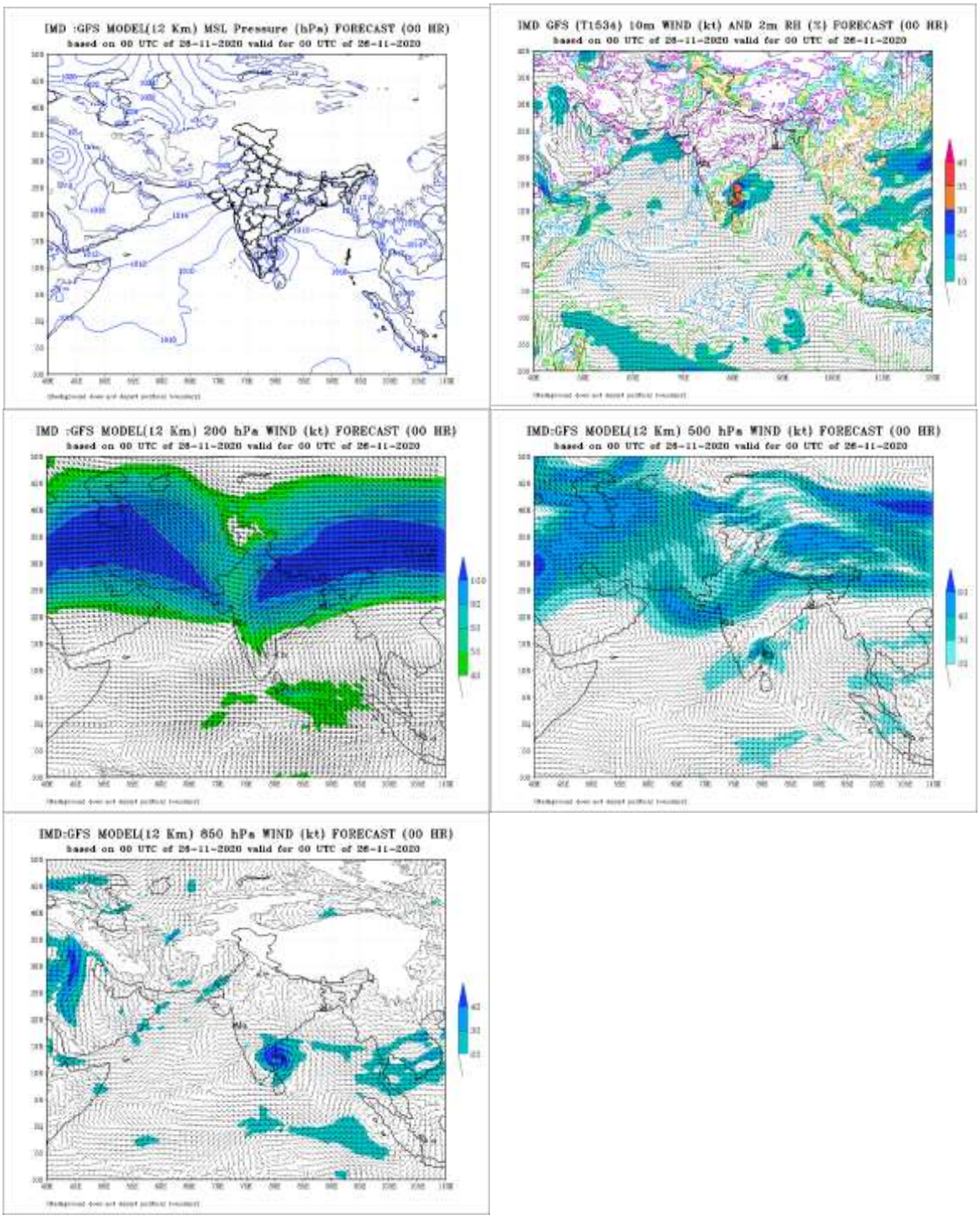


Fig. 8 (e): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 26th November 2020

The analysis of IMD-GFS T-1534 model forecasts based on 0000 UTC of 27th November, 2020 indicated presence of the remnant of the Very Severe Cyclonic Storm (VSCS - NIVAR) as a Depression (D) over south coastal Andhra Pradesh on 27th. The model over estimated the intensity of the system at 0000 UTC of 27th.

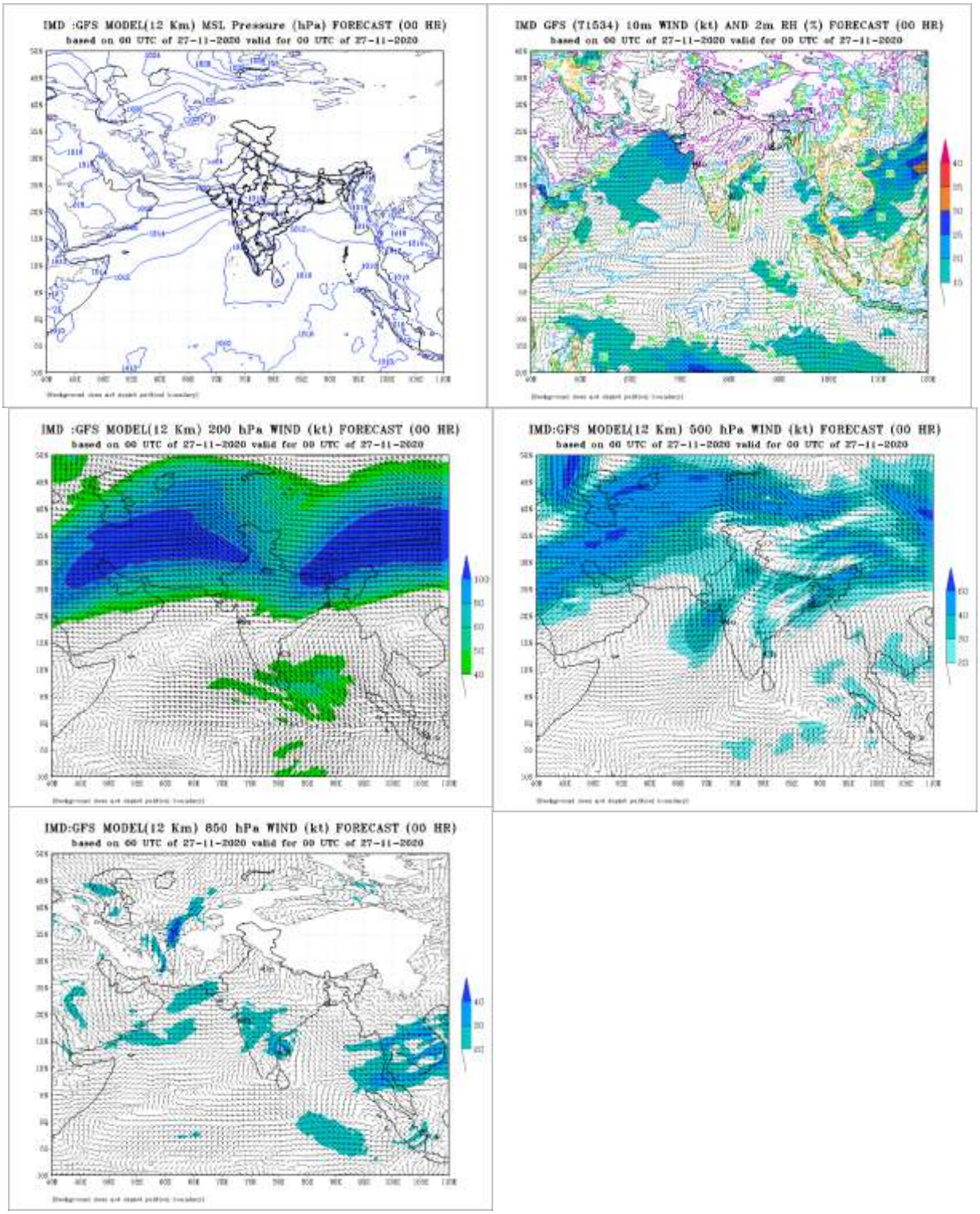


Fig. 8 (f): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 27th November 2020

7. Realized Weather

7.1 Realised rainfall

Rainfall associated with VSCS NIVAR based on IMD-NCMRWF GPM merged gauge rainfall data is depicted in Fig 9. It indicates heavy rainfall (7-12 cm) over coastal Tamilnadu on 24th, heavy to very rainfall at few places over coastal Tamilnadu on 25th, heavy to very heavy rainfall at many places over coastal Tamilnadu and south Andhra Pradesh on 26th and 27th with extremely heavy falls at isolated places.

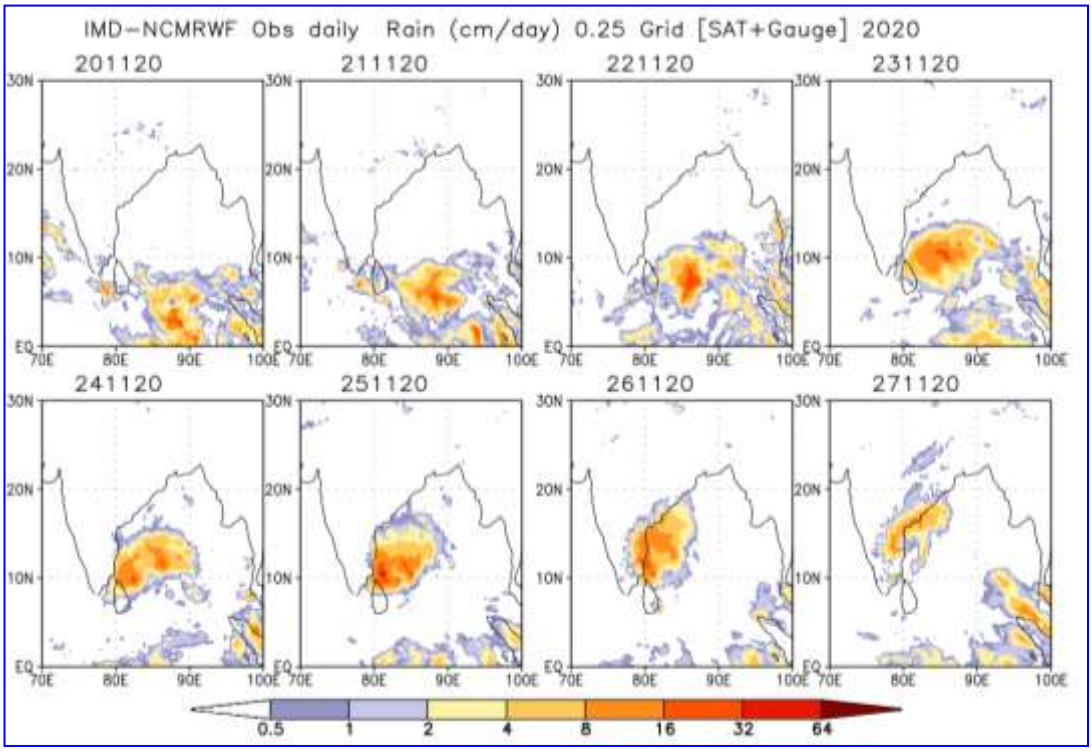


Fig.9: IMD-NCMRWF GPM merged gauge rainfall during 20th -27th Nov and 7 days average rainfall (cm/day)

Realized 24 hrs accumulated rainfall (≥7cm) ending at 0830 hrs IST of date during the life cycle of the system is presented below:

24 November 2020

Tamilnadu, Puducherry & Karaikal: Tambaram-9, MGR Nagar, Chennai-8 each, Alandur-7.

25 November 2020

Tamilnadu, Puducherry & Karaikal: Chennai (Nungambakkam)-16, Anna University, Chennai (Meenambakkam), Sholinganallur-15 each, Taramani, Anna University, DGP Office, MGR Nagar-14 each, Mahabalipuram, Alandur, Hindusthan University, Puzhal, Chembarambakkam-12 each, Tambaram, Ambathur-11 each, Perambur, Red Hills, Kolapakkam, Poonamallee-10 each, Ennore, Thirupporur, Cholavaram- 9 each, Maduranthagam, Kelambakkam-8 each, Sriperumbudur-7.

26 November 2020

Andhra Pradesh: Kodur-25, Venkatagiri-24, Gudur-19, Rapur-16, Atmakur, Sullurpeta-15 each, Nellore, Kavali, Satyavedu, Sambepalle-14 each, Nagari, Rajampet, Tirupati-13 each, Thottambedu, Puttur-12 each, Palamaner, Srikalahasti, Tada-11 each, Penagaluru, Kalakada-10 each, Palasamudram, Royachoti, Amalapuram-9 each, Vinjamur, Udayagiri, Pullampeta, Pakala-8 each, Chittoor, Chinnamandem, Cuddapah, Madanapalle-7 each.

Tamilnadu, Puducherry & Karaikal: Tambaram-31, Puducherry-30, Vilupuram-28, Cuddalore-27, DGP Office, Chennai-26, Sholinganallur-22, Thamaraipakkam-19, Parangipettai-18, Pallipattu-17, Cholavaram-16, Gingee, Poonamallee, Ambathur, Tiruvallur, Mahabalipuram, Gummidipoondi-15 each, Tindivanam, Maduranthagam, Chembarabakkam, Anna University, Vanur, Kollidam, Bhuvanagiri-14 each, MGR Nagar, Kancheepuram, Kurinjipadi, Alandur, Chidambaram, Red Hills, Marakkanam, Chengalpattu, Tiruttani, Chidambaram-13 each, Ulundurpet, Poondi, Keelpennathur, Vadapudupattu, Koratur, Sirkali-12 each, Chennai Airport, Vandavasi, Sethiyathope, Vembakkam, Poonamalle-11, Arakonam, Thirukalukundram, Sriperumbudur, Panruti-11 each, Ponneri, Arcot, Taramani, Perambur, Uthiramerur, Sholingur, Cheyyur-10 each, Anna University, Chembarambakkam, Thiruvalangadu, Tirukoilur, Polur, Mayiladuthurai, Thirupporur, Kelambakkam, Karaikal, Manalmedu, Puzhal-9 each, Arani, Chennai (Nungambakkam), Vridhachalam, Vepur, Hindusthan University, Ammundi, Vellore, R.K.Pet, Kodavasal, Manjalaru-8 each, Uthukottai, Ambur, Kaveripakkam, Agaram Seegoor, Tiruttani, Tozhudur, Tarangambadi, Pelandurai, Tiruvannamalai, Srimushnam, Ennore, Needamangalam, Sendurai, Katpadi, Cheyyar, Aduthurai-7 each.

27 November 2020

Andhra Pradesh: Kavali-27, Nambulipulikunta-25, Gurramkonda-21, Sambepalle-20, Royachoti, Madanapalle, Chinnamandem, Kalakada-18 each, Punganur, Udayagiri, Vinjamur- 17 each, Atmakur, Pullampeta, Thambalapalle, Palamaner-16 each, Chapad, Chittoor, Proddutur, Arogyavaram, Avanigada, Ongole, Amalapuram-15 each, Yanam, Marripudi, Podili, Veligandla, Kandukur, Utukuru(A), Vempalle, Kamalapuram-14 each, Atlur-13, Kakinada, Palakoderu, Cuddapah -12 each, Bheemavaram, Bapatla, Vijayawada Airport, Gudivada, Narsapuram, Chimakurthi, Duvvur-11, Raju Palem, Pakala, Palasamudram-11 each, Vallur, Kodur, Rajampet, Karamchedu, Repalle, Seetharamapuram, Tanuku-10 each, Mundlamuru, Addanki, Mangalagiri, Tadepalligudem, Masulipatnam, Peddapuram, Kaikalur, Jammalamadugu, Badvel, Porumamilla, Puttur-9 each, Pulivendla, Muddanur, Lakkireddipalle, Konakanamitla, Cumbum, Bestavaripeta, Markapur, Nellore, Darsi-8 each, Vijayawada, Tuni, Anakapalle, Rapur, Santhamaguluru, Guntur, Bhimadole, Racherla, Prathipadu, Visakhapatnam, Eluru, Penagaluru, Kadiri, Tanakal, Venkatagiri Kota-7 each.

Tamilnadu, Puducherry & Karaikal: Sholingur-23, Vadapudupattu-16, Vellore, Ponnai Dam, Ammundi-14 each, Ambur, R.K.Pet-13 each, Alangayam, Katpadi-12 each, Vaniyambadi, Tirupuvanam, Kaveripakkam-9 each, Wallajah, Gudiyatham, Virinjipuram-8 each, Devakottai, Vembakkam, Melalathur-7 each.

7.2. Realised wind:

The system crossed Tamil nadu and Puducherry coasts as a very severe cyclonic storm with an estimated wind speed of 120 kmph gusting to 135 kmph.

7.3. Realised storm surge:

No significant storm surge was reported.

8. Damage due to VSCS NIVAR

The Cyclone brought heavy to very heavy rains over North coastal Tamilnadu starting 23rd November 2020.Chennai received continuous downpours on 23,24,25 November 2020 with IMD Chennai recording 163mm ending 25th November 8:30 AM IST. Chennai and other parts of North TN saw gusty winds touching 60-70kmph on 24th, 25th November. Several roads were closed in the area of the Greater Chennai Corporation were closed due to water logging. Due to intense rainfall,

Chembarambakkam lake have released water for the first time after five years. Many areas including Madipakkam, Velachery, Adambakkam and suburbs around Tambaram and low lying regions along the river Adyar were flooded. Rainwater entering houses was also seen in some places in the western suburbs. The Greater Chennai Corporation removed uprooted trees from 223 roads. The estimates of Chennai civic officials reported that flood water entered around 40,000 homes within the borders of the Corporation. Five people were reported dead in Tamil Nadu.

In Puducherry, trees were uprooted, electric poles were damaged and several areas were flooded as of November 26. The Chief Minister of Puducherry V. Narayanasamy reported that the initial loss in agriculture and other sectors was estimated at ₹4 billion.

Eight people were reported dead in Andhra Pradesh. The rainfalls made significant impact on the districts of Chittoor, Prakasam, Kadapa and Nellore, 112000 people were affected, 2,294 houses/huts were damaged, 6,133 homes were left stranded, 2,618 small animals, 88 large animals and 8,130 poultry birds were reported dead based on a preliminary evaluation. In Nellore district, Paddy seedlings in 2500 hectares drowned and in Prakasam district, standing crops in 34,000 hectares were damaged. Loss of APSPDCL amounted to be ₹50.7 million.

Fig.9(a): Damaged houses Bommayarpalayam on the East Coast Road (source:thehindu.com), (b) A man pushes his bicycle through a water-logged road (source: science.thewire.in), (c) Uprooted trees, damaging electric poles (source: https://www.newindianexpress.com/) and (d) Flooded railway station in Puducherry (source: https://www.newindianexpress.com/)

9. Performance of operational NWP models

IMD operationally runs a regional models, WRF for short-range prediction and one Global model T1534 for medium range prediction (10 days). The WRF-VAR model is run at the horizontal resolution of 9 km and 3 km with 38 Eta levels in the vertical and the integration is carried up to 72 hours over three domains covering the area between lat. 25^0S to 45^0 N long 40^0 E to 120^0 E. Initial and boundary conditions are obtained from the IMD Global Forecast System (IMD-GFS) at the resolution of 12 km. The boundary conditions are updated at every six hours interval.

Global models are also run at NCMRWF. These include GFS and unified model adapted from UK Meteorological Office. In addition to the above NWP models, IMD also run operationally dynamical statistical models. The dynamical statistical models have

been developed for (a) Cyclone Genesis Potential Parameter (GPP), (b) Multi-Model Ensemble (MME) technique for cyclone track prediction, (c) Cyclone intensity prediction, (d) Rapid intensification and (e) Predicting decay in intensity after the landfall. Genesis potential parameter (GPP) is used for predicting potential of cyclogenesis (T3.0) and forecast for potential cyclogenesis zone. The multi-model ensemble (MME) for predicting the track (at 12h interval up to 120h) of tropical cyclones for the Indian Seas is developed applying multiple linear regression technique using the member models IMD-GFS, IMD-WRF, GFS (NCEP), ECMWF and JMA. In this report performance of the individual models, MME forecasts, SCIP, GPP, RII for very severe cyclonic storm NIVAR are presented and discussed.

9.1 Prediction of Cyclogenesis (Genesis Potential Parameter (GPP) for NIVAR

Grid point analysis and forecast of GPP is used to identify potential zone of cyclogenesis. Fig. 10 (a-g) below shows the predicted zone of cyclogenesis. Grid point analysis and forecasts of GPP predicted the cyclogenesis zone over the Bay of Bengal 120 hrs before its formation since 17th November.

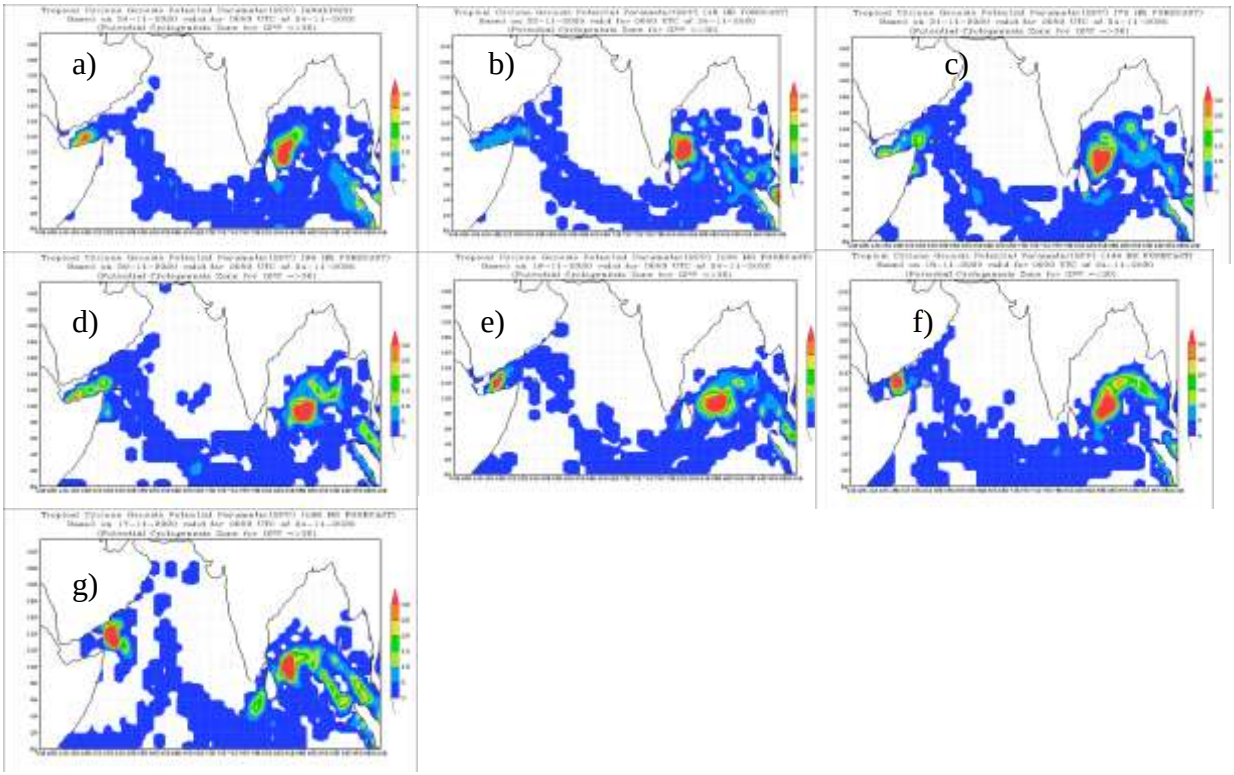


Fig.10 (a-g): Predicted zone of Cyclogenesis based on 0000 UTC from 24-27 Nov.,

The Area average analysis of GPP is presented in Fig.11. Since all low pressure systems do not intensify into cyclones, it is important to identify the potential of intensification (into cyclone) of a low pressure system at the early stages (T No. 1.0, 1.5, 2.0) of development. For developed system, threshold value of GPP is ≥ 8.0 and for non-developed system, threshold value of GPP is < 8.0. It is seen that since 21st/0000 UTC, the GPP area average analysis was indicating the system to intensify into a cyclonic storm. However, it was indicating the system to intensify into a cyclonic storm from 0000 UTC of 21st itself. At that time, even genesis had not occurred.

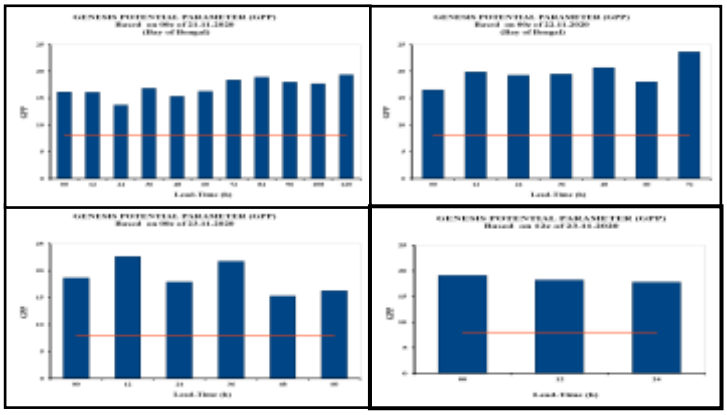


Fig.11: Area average analysis and forecasts of GPP based on (a) 0000 UTC of 21st (b) 0000 UTC of 22nd (c) 0000 UTC of 23rd (d) 1200 UTC of 23rd

9.2 Track prediction by NWP models

Track prediction by various NWP models is presented in **Fig.12**. Based on initial conditions of 0000 UTC of 23rd November, most of the models indicated movement towards north Tamilnadu - south Andhra Pradesh coasts. There was large divergence among the models wrt point and time of landfall. MME predicted peak intensity of 52 kts. The landfall point and time was correctly predicted, but intensity at the time of landfall was underestimated by the MME.

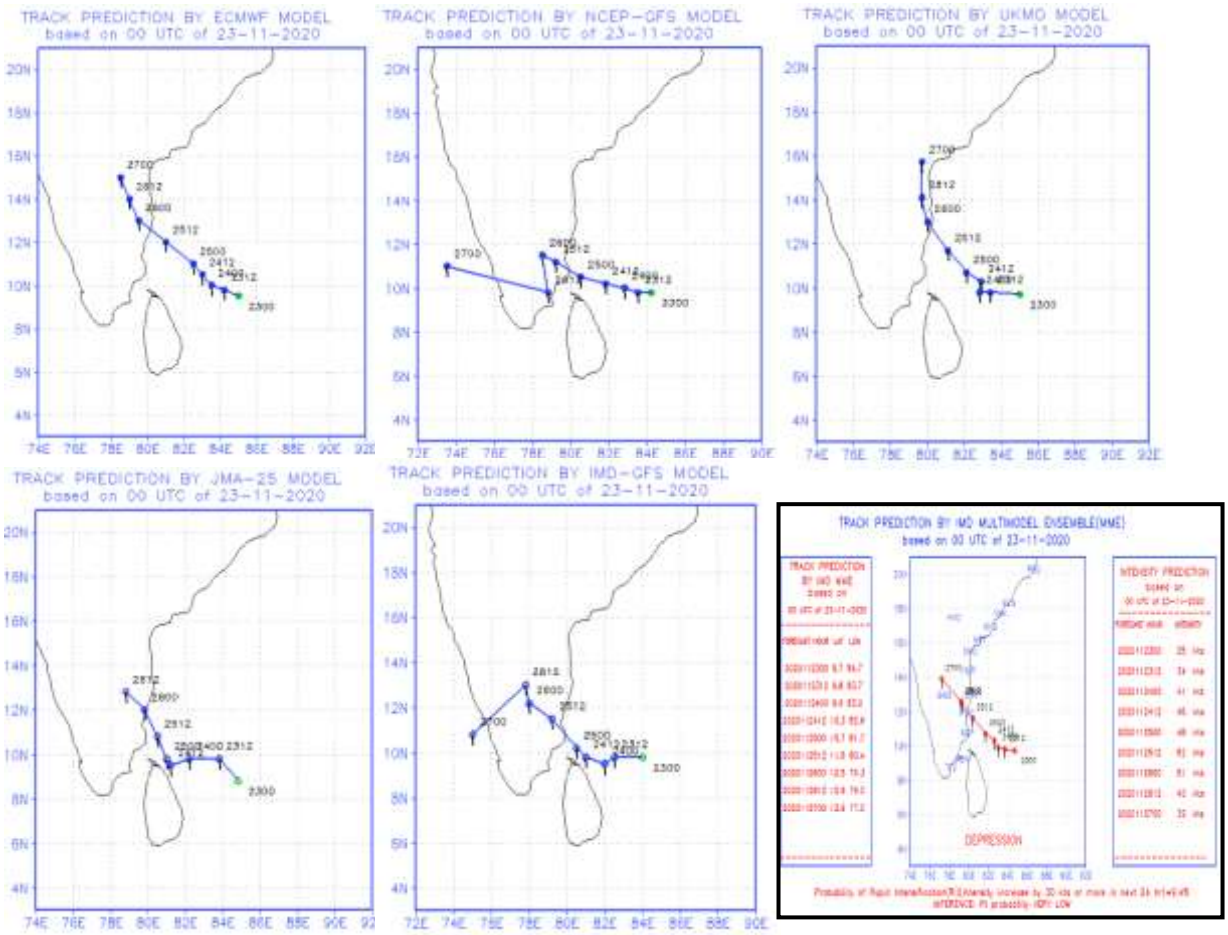


Fig. 12 (a): NWP model track forecast based on 0000 UTC of 23.11.2020

Based on initial conditions of 0000 UTC of 24th November, there was again large divergence wrt landfall point. UKMO and MME captured the northeastwards recurvature of the system. NCEP GFS and HWRF predicted it's re-emergence into Arabian Sea.

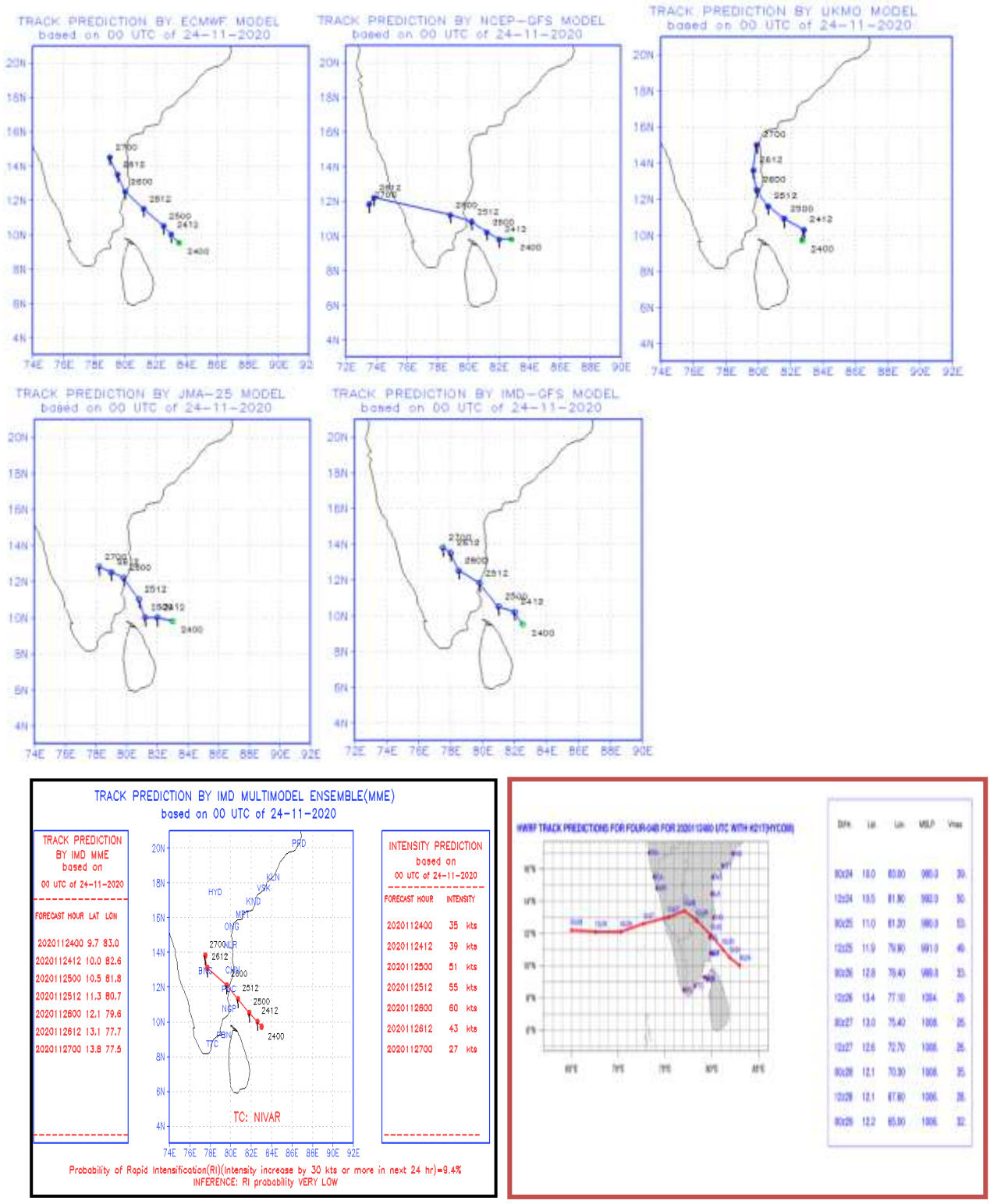


Fig. 12 (b): NWP model track forecast based on 0000 UTC of 24.11.2020

Based on initial conditions of 0000 UTC of 25th November, models were predicting landfall near 12^0N. UKMO, MME, ECMWF, IMD GFS captured the northeastwards recurvature of the system. HWRF predicted it's westwards recurvature.

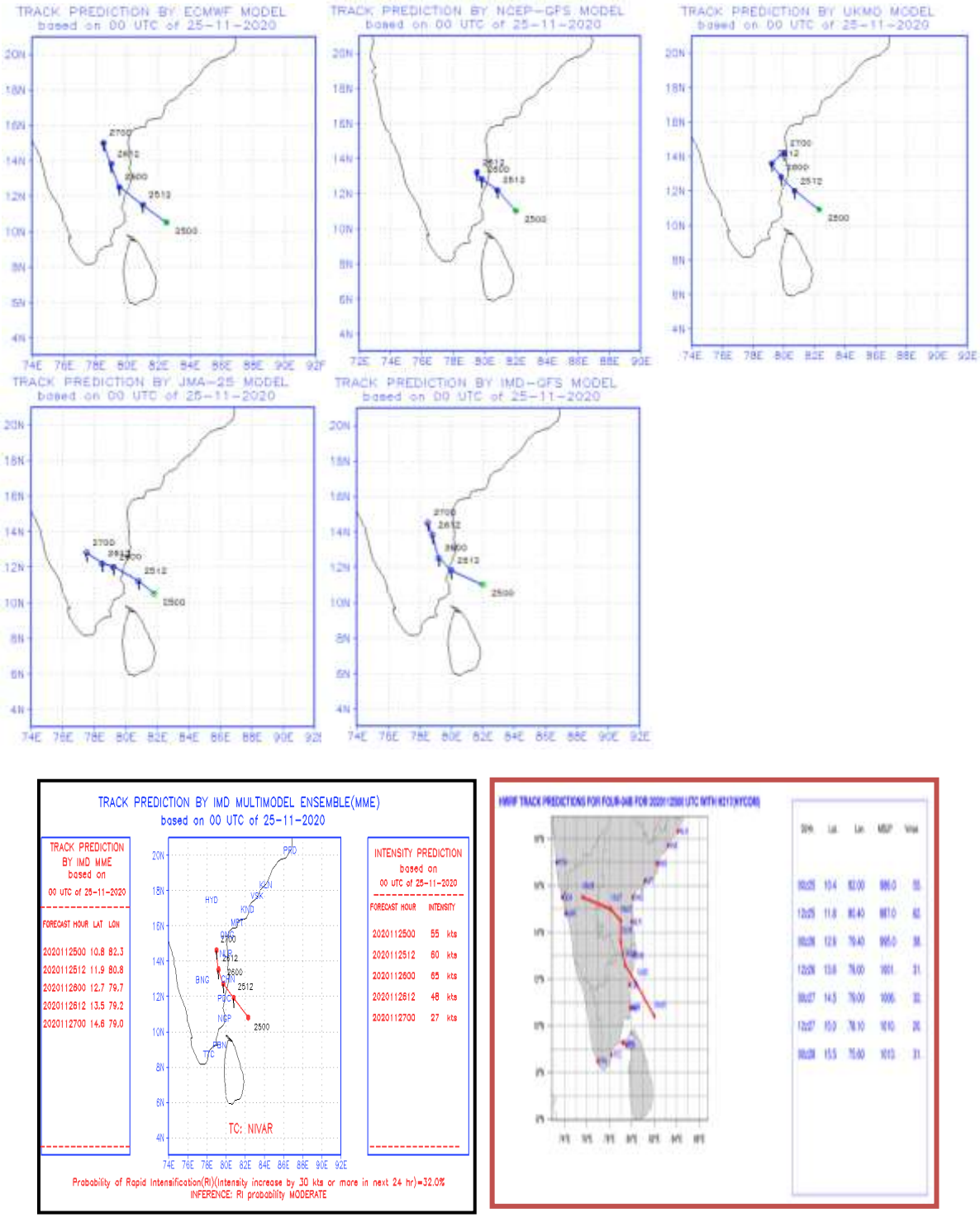


Fig. 12 (c): NWP model track forecast based on 0000 UTC of 25.11.2020

9.3 Track forecast errors

Average track forecast errors by various NWP models is presented in Table 2. For 24 hrs lead period track forecast error was the least i.r.o. MME followed by UKMO, ECMWF, NCEP GFS, JMA and HWRF. For 48 hrs lead period, the track forecast error was the least i.r.o. UKMO followed by ECMWF and MME. For 72 hours lead period, the error was the least i.r.o. ECMWF followed by UKMO and MME.

Table-2. Average track forecast errors (Direct Position Error (DPE)) in km (Number of forecasts verified is given in the parentheses)

Lead time →	**12h**	**24h**	**36h**	**48h**	**60h**	**72h**	**84h**
IMD-MME	26(5)	26(5)	29(5)	91(4)	105(3)	133(2)	113(1)
ECMWF	49(5)	61(5)	46(5)	54(4)	43(3)	52(2)	62(1)
NCEP-GFS	50(5)	67(5)	95(5)	294(4)	360(3)	401(2)	427(1)
UKMO	36(5)	46(5)	38(5)	40(4)	59(3)	67(2)	64(1)
JMA	38(5)	86(5)	126(5)	102(4)	94(3)	115(2)	110(1)
IMD-GFS	102(5)	121(5)	140(5)	184(4)	180(3)	290(2)	185(1)
HWRF	70 (11)	86 (11)	115 (9)	210 (7)	309 (5)	380 (3)	-

9.4. Landfall forecast errors

The landfall point and time forecast errors by IMD MME are presented in Fig. 13. The landfall point error varied from 30-60 km for various lead period ranging from 18 hrs to 66 hrs.

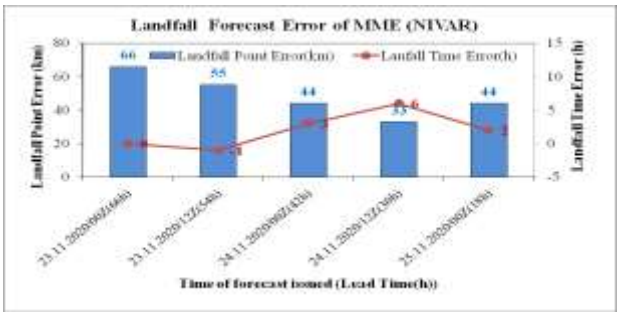


Fig. 13: MME Landfall Point and Time Forecast Error (NIVAR)

The landfall point and time errors by IMD HWRF are presented in Table 3. The landfall point errors varied from 15 to 75 km for various lead periods between 12 and 60 hrs. For 12 and 24 hrs lead period, the landfall time error was zero hrs.

Table-3. Landfall Point (in km) and time (in hrs) of IMD-HWRF Model (Number of forecasts verified is given in the parentheses)

Lead Time	12 Hr	24 Hr	36 Hr	48 Hr	60 Hr
Landfall Point	16	77	46	34	55
Landfall Time	0	0	-6	-6	-12

9.5. Intensity forecast errors by various NWP Models

Intensity forecast by MME for various lead periods is presented in Fig. 14 (a) and intensity prediction at the time of landfall is presented at Fig. 14 (b). MME throughout underestimated the intensity at the time of landfall. The intensity forecasts of IMD-SCIP model and HWRF model are presented in Table 4**.**

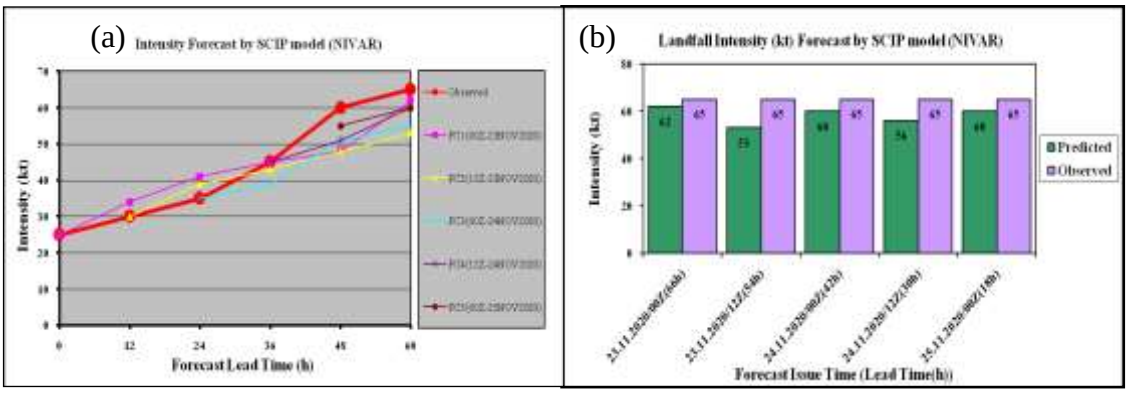


Fig. 14: (a) SCIP Intensity Forecast Error (NIVAR) and (b) SCIP Landfall Intensity Forecast Error (NIVAR)

Table-4 Average absolute errors (AAE) and Root Mean Square (RMSE) errors in knots of SCIP model (Number of forecasts verified is given in the parentheses)

Lead time →	12H	24H	36H	48H	60H	72H
IMD-SCIP (AAE)	5.6(5)	5.5(4)	7.3(3)	12.0(2)	3.0(1)	
IMD-HWRF (AAE)	6.6 (11)	8.4 (11)	10.8 (9)	12.1 (7)	12.6 (5)	7.7 (3)
IMD-SCIP (RMSE)	5.9	6.0	9.0	12.0	3.0	
IMD-HWRF (RMSE)	7.4 (11)	10.1(11)	13.6 (9)	16.6 (7)	18.2 (5)	8.8 (3)

10. Operational Forecast Performance

10.1 Genesis, track, landfall and intensity forecast:

- The extended range outlook issued on 12th November, indicated that a low pressure area would form over BoB during first half of week (20-26 November) and depression would form over south Bay of Bengal later half of the week. Actually, low pressure area formed over EIO and adjoining central parts of south BoB on 21st November and depression formed over central parts south BoB in on 23rd November. Thus, the genesis of “NIVAR” was predicted by IMD about 12 days in advance.
- The daily national bulletin issued at 1210 hrs IST of 20th November indicated that a low pressure area would form over central parts of south Bay of Bengal around 23rd November, 2020. It was also indicated that it would concentrate into a depression over southwest Bay of Bengal and move west-northwestwards towards Tamilnadu coast by 25th. Actually, the system moved northwestwards towards Tamilnadu coast and crossed the coast in the late night of 25th. Thus, track of “NIVAR” was predicted correctly by IMD about 5 days in advance.

- The first special bulletin and press release issued at 1500 hrs IST of 21st November indicated that a depression would form over southwest BoB around 23rd. It was also indicated that, it would intensify further and move west-northwestwards towards Sri Lanka-south Tamil Nadu coast and reach near Tamil Nadu & Puducherry coast on 25th November, 2020 (about 4 days and 8 hours prior to landfall near Puducherry).
- In the bulletin issued at 1130 hrs IST of 22nd November. It was indicated that the cyclone would cross Tamilnadu and Puducherry coasts between Karaikal and Mammalapuram during 25th afternoon (3 days and 12 hours prior to landfall). **For the first time IMD indicated landfall area of the cyclone, when the system was in the stage of low pressure area.**
- First information that the system would cross Tamilnadu coast close to Puducherry in the evening of 25th with a wind speed of 100-110 kmph gusting to 120 kmph was released in the bulletin issued at 0830 hrs IST of 23rd (about 2 days and 18 hours prior to landfall). The cyclone crossed coast near Puducherry during midnight of 25th to early hours of 26th November with a wind speed of about 120 kmph.
- Since 20th November, regular warnings about the heavy rainfall and strong winds were issued for the states of Tamilnadu, Puducherry and Andhra Pradesh.
- The observed and forecast track based on 0530 hrs IST of 23rd about 72 hrs prior to landfall demonstrating accuracy in track, landfall and intensity prediction is presented in Fig. 15. The black and red lines indicate the observed (actual) track and forecast track respectively. The closeness of these two lines indicate very accurate forecast of track (movement) and landfall point of cyclone, NIVAR.

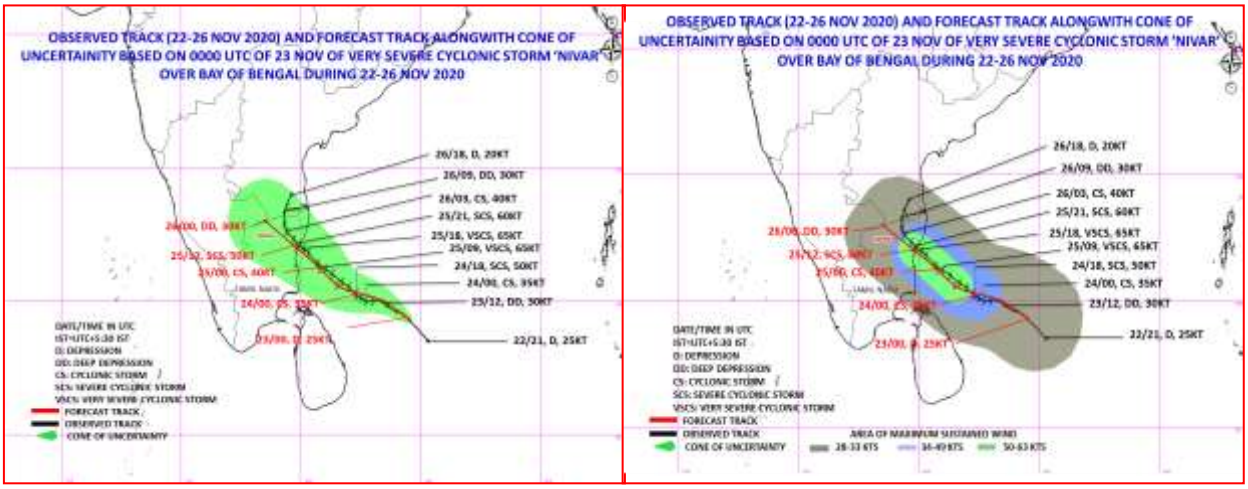


Fig 15: Observed and forecast track of VSCS NIVAR based on 0530 hours IST of 23rd (72hrs in advance of landfall) demonstrating accuracy in track, landfall and intensity forecast

10.2 Landfall forecast error

The landfall point and time Forecast errors compared to long period average (LPA) errors during 2015-19 are presented in Fig. 16 (a-b). The landfall point forecast errors for 24, 48 and 72 hrs lead period were 25, 25 and 16 km respectively against the LPA errors (2015-19) of 44.7, 69.4 and 109.3 km during 2015-19 respectively. The landfall time forecast errors for 24, 48 and 72 hrs lead period were 0.5, 5.0, and 8.5 hours respectively against the LPA errors (2015-19) of 3.0, 5.4 and 8.6 hours during 2015-19

respectively. **For all lead periods, the landfall point errors were exceptionally less than the LPA errors during 2015-19.**

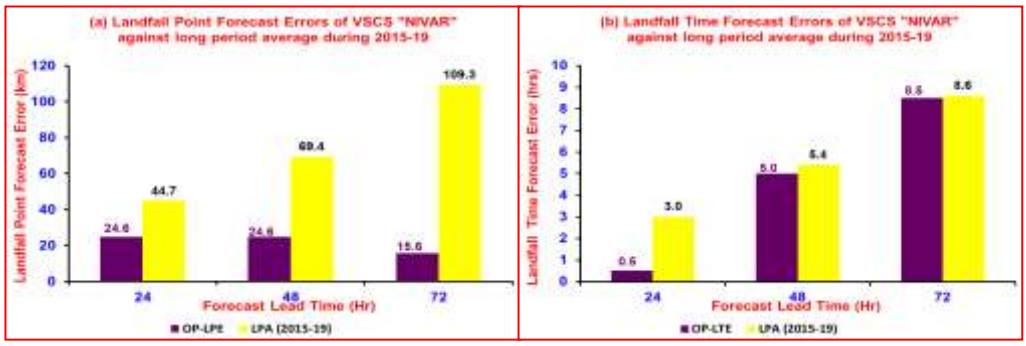


Fig.16: Landfall (a) point and (b) time forecast errors of VSCS 'NIVAR" as compared to long period average (2015-19)

10.3 Track forecast error and skill

The track forecast errors (Forecast position – Actual position of Cyclone centre) and skill as compared to Climatological and Persistence forecast are presented in Fig. 17 (a-b). The track forecast errors for 24, 48 and 72 hrs lead period were 86.1, 126.8, and 185.0 km respectively against the LPA errors (2015-19) of 80.6, 125.5, and 171.2 km respectively (Fig.17a). The track forecast skill was about 61%, 72%, and 79% against the LPA skill of 61%, 73%, and 74% for 24, 48 and 72 hrs lead period respectively (Fig.17b).

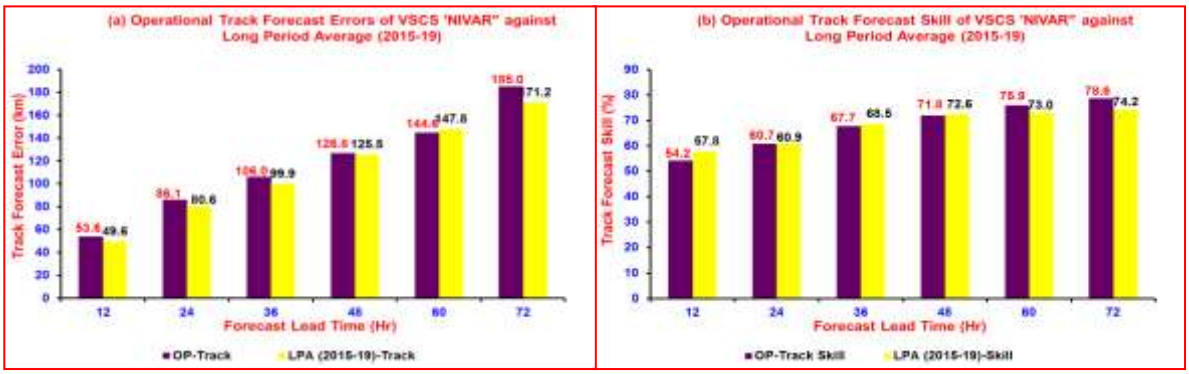


Fig.17: Track forecast (a) errors and (b) skill of VSCS 'NIVAR" as compared to long period average (2015-19)

10.4 Intensity forecast error and skill

The intensity forecast errors (Forecast wind – Actual wind) and skill based on absolute errors and root mean square errors are presented in Fig. 18 & 19 respectively.

The absolute error (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 4.3, 6.5 and 10.2 knots against the LPA errors of 8.9, 13.0, and 15.4 knots during 2015-19 respectively (Fig. 18a). The root mean square error (RMSE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 5.0, 9.2 and 11.8 knots against the LPA errors of 11.5, 16.7, and 19.2 knots respectively (Fig.18b).

The skill (%) in intensity forecast as compared to persistence forecast based on AE for 24, 48 and 72 hrs lead period was 79%, 76% and 59% against the LPA of 45%, 69% and 72% respectively (Fig. 19 a). The skill (%) in intensity forecast based on RMSE for 24, 48 and 72 hrs lead period was 82%, 75% and 65% against the LPA of 49%, 63% and 76% respectively (Fig. 19 b).

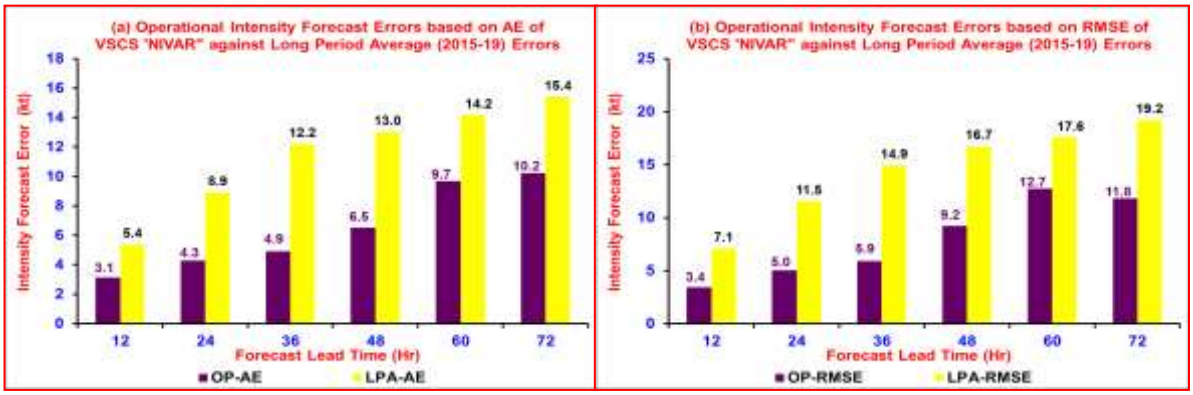


Fig.18: Absolute errors (AE) and Root Mean Square errors (RMSE) in intensity forecast (winds in knots) of VSCS 'NIVAR" as compared to long period average (2015-19)

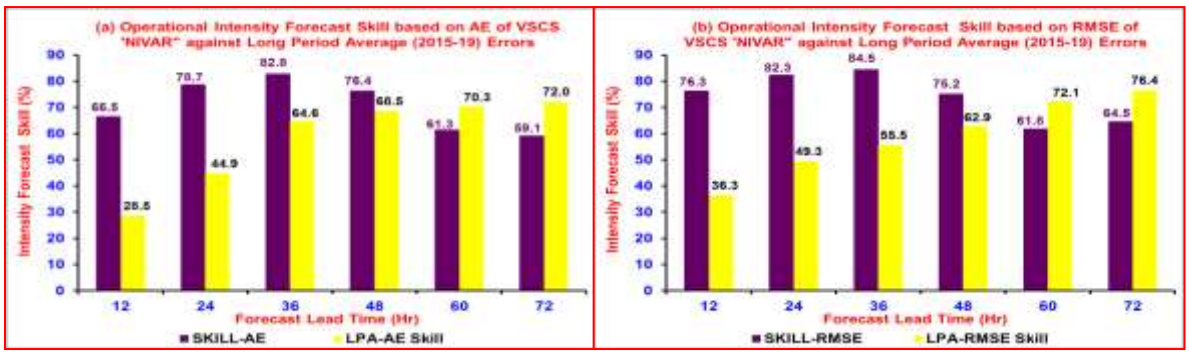


Fig.19: Skill (%) in intensity forecast based on (a) Absolute errors (AE) and (b) Root Mean Square errors (RMSE) of VSCS 'NIVAR" as compared to long period average (2015-19)

11. Adverse weather forecast verification

The verification of adverse weather like heavy rainfall, gale wind and storm surge forecast issued by IMD are presented in Table 5-7. It is found that all the three types of adverse weather were predicted accurately and well in advance.

Table 5: Verification of Heavy Rainfall Forecast

Date/Base Time of observation	24 hr Heavy rainfall warning ending at 0300 UTC of next day	Realised 24-hour heavy rainfall ending at 0300 UTC of date
23.11.2020/ 0300UTC	Fairly widespread to widespread rainfall/thunderstorm activity very likely over Tamilnadu, Puducherry & Karaikal during 24 th to 26 th November and over south Coastal Andhra Pradesh, Rayalaseema during 25 th to 26 th and Telangana during 26 th to 27 th November, 2020. Isolated extremely heavy rainfall activity also very likely over Tamilnadu &	**24 November 2020** **Tamilnadu, Puducherry & Karaikal:** Tambaram-9, MGR Nagar, Chennai-8 each, Alandur-7. **25 November 2020** **Tamilnadu, Puducherry & Karaikal:** Chennai (Nungambakkam)-16, Anna University, Chennai (Meenambakkam), Sholinganallur-15 each, Taramani, Anna University, DGP Office, MGR Nagar-14 each, Mahabalipuram, Alandur, Hindusthan University, Puzhal, Chembarambakkam-12 each, Tambaram,

	Puducherry (Pudukottai, Thanjavur, Tiruvarur, Karaikal, Nagapattinam, Cuddalore, Ariyalur & Perabalu districts during 24 th and Kadalur, Kallakurchi, Puducherry, Villupuram, Tiruvannamalai, Chengalpattu to Ariyalur, Perambalur and Karaikal districts during 25 th) and over south Coastal Andhra Pradesh & Rayalaseema (Nellore and Chittoor districts) on 25 th & 26 th and over Telangana on 26 th November, 2020.	Ambathur-11 each, Perambur, Red Hills, Kolapakkam, Poonamallee-10 each, Ennore, Thirupporur, Cholavaram- 9 each, Maduranthagam, Kelambakkam-8 each, Sriperumbudur-7. **26 November 2020** **Andhra Pradesh:** Kodur-25, Venkatagiri-24, Gudur-19, Rapur-16, Atmakur, Sullurpeta-15 each, Nellore, Kavali, Satyavedu, Sambepalle-14 each, Nagari, Rajampet, Tirupati-13 each, Thottambedu, Puttur-12 each, Palamaner, Srikalahasti, Tada-11 each, Penagaluru, Kalakada-10 each, Palasamudram, Royachoti, Amalapuram-9 each, Vinjamur, Udayagiri, Pullampeta, Pakala-8 each, Chittoor, Chinnamandem, Cuddapah, Madanapalle-7 each. **Tamilnadu, Puducherry & Karaikal:** Tambaram-31, Puducherry-30, Vilupuram-28, Cuddalore-27, DGP Office, Chennai-26, Sholinganallur-22, Thamaraipakkam-19, Parangipettai-18, Pallipattu-17, Cholavaram-16, Gingee, Poonamallee, Ambathur, Tiruvallur, Mahabalipuram, Gummidipoondi-15 each, Tindivanam, Maduranthagam, Chembarabakkam, Anna University, Vanur, Kollidam, Bhuvanagiri-14 each, MGR Nagar, Kancheepuram, Kurinjipadi, Alandur, Chidambaram, Red Hills, Marakkanam, Chengalpattu, Tiruttani, Chidambaram-13 each, Ulundurpet, Poondi, Keelpennathur, Vadapudupattu, Koratur, Sirkali-12 each, Chennai Airport, Vandavasi, Sethiyathope, Vembakkam, Poonamalle-11, Arakonam, Thirukalukundram, Sriperumbudur, Panruti-11 each, Ponneri, Arcot, Taramani, Perambur, Uthiramerur, Sholingur, Cheyyur-10 each, Anna University, Chembarambakkam, Thiruvalangadu, Tirukoilur, Polur, Mayiladuthurai, Thirupporur, Kelambakkam, Karaikal, Manalmedu, Puzhal-9 each, Arani, Chennai (Nungambakkam), Vridhachalam, Vepur, Hindusthan University, Ammundi, Vellore, R.K.Pet, Kodavasal, Manjalaru-8 each, Uthukottai, Ambur, Kaveripakkam, Agaram Seegoor, Tiruttani, Tozhudur,
24.11.2020/ 0300	Fairly widespread to widespread rainfall/thunderstorm activity very likely over coastal and north interior Tamilnadu, Puducherry & Karaikal during 24 th to 26 th November and over south coastal Andhra Pradesh, Rayalaseema during 25 th to 26 th and southeast Telangana during 26 th November, 2020. Isolated extremely heavy rainfall activity also very likely over coastal & north interior Tamilnadu & Puducherry (Pudukottai, Thanjavur, Tiruvarur, Karaikal, Nagapattinam, Cuddalore, Ariyalur & Perabalu districts during 24 th and Kadalur, Kallakurchi, Puducherry, Villupuram, Tiruvannamalai, Chengalpattu to Ariyalur, Perambalur and Karaikal districts during 25 th) and over Nellore and Chittoor districts of Andhra Pradesh on 25 th and over Rayalseema & southeast Telangana on 26 th November, 2020.	
25.11.2020/ 0300	Fairly widespread to widespread rainfall/thunderstorm activity very likely over coastal and north interior Tamilnadu, Puducherry & Karaikal, south coastal Andhra	

	Pradesh and Rayalaseema during 25 th and 26 th November and southeast Telangana during 26 th November, 2020. Isolated extremely heavy rainfall activity also very likely over coastal & north interior Tamilnadu & Puducherry (Thanjavur, Tiruvarur, Nagapattinam, Cuddalore, Chennai, Kanchipuram, Chengalpattu, Myladuthirai, Ariyalur, Perambalur, Kallakurchi, Villupuram, Tiruvannamalai, Puducherry and Karaikal districts) during 25 th ; over Nellore and Chittoor districts of Andhra Pradesh on 25 th and over Rayalaseema & southeast Telangana on 26 th November, 2020.	Tarangambadi, Pelandurai, Tiruvannamalai, Srimushnam, Ennore, Needamangalam, Sendurai, Katpadi, Cheyyar, Aduthurai-7 each. **27 November 2020** **Andhra Pradesh:** Kavali-27, Nambulipulikunta-25, Gurramkonda-21, Sambepalle-20, Royachoti, Madanapalle, Chinnamandem, Kalakada-18 each, Punganur, Udayagiri, Vinjamur- 17 each, Atmakur, Pullampeta, Thambalapalle, Palamaner-16 each, Chapad, Chittoor, Proddutur, Arogyavaram, Avanigada, Ongole, Amalapuram-15 each, Yanam, Marripudi, Podili, Veligandla, Kandukur, Utukuru(A), Vempalle, Kamalapuram-14 each, Atlur-13, Kakinada, Palakoderu, Cuddapah -12 each, Bheemavaram, Bapatla, Vijayawada Airport, Gudivada, Narsapuram, Chimakurthi, Duvvur-11, Raju Palem, Pakala, Palasamudram-11 each, Vallur, Kodur, Rajampet, Karamchedu, Repalle, Seetharamapuram, Tanuku-10 each, Mundlamuru, Addanki, Mangalagiri, Tadepalligudem, Masulipatnam, Peddapuram, Kaikalur, Jammalamadugu, Badvel, Porumamilla, Puttur-9 each, Pulivendla, Muddanur, Lakkireddipalle, Konakanamitla, Cumbum, Bestavaripeta, Markapur, Nellore, Darsi-8 each, Vijayawada, Tuni, Anakapalle, Rapur, Santhamaguluru, Guntur, Bhimadole, Racherla, Prathipadu, Visakhapatnam, Eluru, Penagaluru, Kadiri, Tanakal, Venkatagiri Kota-7 each. **Tamilnadu, Puducherry & Karaikal:** Sholingur-23, Vadapudupattu-16, Vellore, Ponnai Dam, Ammundi-14 each, Ambur, R.K.Pet-13 each, Alangayam, Katpadi-12 each, Vaniyambadi, Tirupuvanam, Kaveripakkam-9 each, Wallajah, Gudiyatham, Virinjipuram-8 each, Devakottai, Vembakkam, Melalathur-7 each.
26.11.2020/ 0300	Under its influence, rainfall at most/many places with heavy to very heavy falls at a few places and isolated extremely heavy falls likely to occur over Chittoor, Kurnool, Prakasam; Cuddappa districts of Andhra Pradesh and adjoining southeast Telangana on 26 th Nov. Heavy to very heavy rainfall at isolated places are very likely over north Tamilnadu, remaining districts of Andhra Pradesh and southeast Telangana.	
27.11.2020/ 0000 UTC	Under its influence, light to moderate rainfall at many places with heavy falls at isolated places is likely over coastal Andhra Pradesh during next 24 hours.	

Table 6: Verification of Gale/Squally Wind Forecast issued by IMD

Date/Base Time of observation	Gale/ Squally wind Forecast at 0300 UTC of date	Realised wind
24.11.2020/	• Gale wind speed reaching 70-80 kmph gusting to 90	It crossed

0300UTC	kmph is prevailing over Southwest Bay of Bengal. It would further increase becoming 100-110 kmph gusting to 120 kmph over the southwest Bay of Bengal from 25th November morning for subsequent 18 hours. • Squally wing speed reaching 30-40 kmph gusting to 50 kmph is prevailing along & off Tamil Nadu, Puducherry and adjoining South Andhra Pradesh coast and over Gulf of Mannar. It will gradually increase and becomE 100-110 kmph gusting to 120 kmph along & off coastal districts of north Tamil Nadu and Puducherry (Nagapattinam, Karaikal, Myladuthurai, Cuddalore, Puducherry, Villupuram & Chengalpattu districts; 80-90 gusting to 100 kmph very likely over Tiruvarur, Kanchipuram, Chennai, Tiruvallaur districts) during forenoon to night of 25 th November, 2020. • Gale wind speed reaching 65-75 kmph gusting to 85 kmph very likely over adjoining westcentral Bay of Bengal and along & off South Andhra Pradesh (Nellore & Chittoor districts), Gulf of Mannar and along and off districts of south coastal districts of Tamil Nadu during forenoon to night of 25th November.	Tamilnadu and Puducherry coasts as a very severe cyclonic storm with estimated wind speed of 120 kmph gusting to 135 kmph
25.11.2020/ 0300UTC	• Gale wind speed reaching 105-115 kmph gusting to 130 kmph is prevailing over Southwest Bay of Bengal. It would further increase becoming 120-130 kmph gusting to 145 kmph during afternoon of 25th to early hours of 26th November. • Squally wind speed reaching 55-65 kmph gusting to 75 kmph is prevailing along & off Tamil Nadu, Puducherry and adjoining South Andhra Pradesh coast and over Gulf of Mannar. It will gradually increase and become gale wind speed reaching 120-130 kmph gusting to 145 kmph along & off coastal districts of north Tamil Nadu and Puducherry (Nagapattinam, Karaikal, Myladuthurai, Cuddalore, Puducherry, Villupuram & Chengalpattu) and 80-90 gusting to 100 kmph very likely over Tiruvarur, Kanchipuram, Chennai, Tiruvallur districts during afternoon of 25th to early hrs of 26th November, 2020. • Gale wind speed reaching 65-75 kmph gusting to 85 kmph very likely over adjoining westcentral Bay of Bengal and along & off South Andhra Pradesh (Nellore & Chittoor districts), Gulf of Mannar and along and off south coastal districts of Tamil Nadu during afternoon of 25th to early hrs of 26th November, 2020.	
26.11.2020/ 0300UTC	• Gale wind speed reaching 70-80 kmph gusting to 90 kmph is prevailing over Southwest Bay of Bengal. It will gradually decrease becoming 50-60 kmph gusting to 70 kmph by evening of today, the 26th November, 2020. • Gale wind speed reaching 70-80 kmph gusting to 90	

	kmph is prevailing along & off Puducherry, Villupuram, Chengalpattu, Kanchipuram, Chennai & Tiruvallu districts of north Tamil Nadu. It will gradually decrease becoming 50-60 kmph gusting to 70 kmph by evening and squally wind speed reaching 35-45 kmph gusting to 55 kmph by night of today, the 26th November, 2020. • Squally wind speed reaching 45-55 gusting to 65 kmph very likely to prevail over interior districts (Ranipet, Tiruvannamalai, Tirupattur, Vellore) of Tamilnadu and Chittoor district of Andhra Pradesh till noon of today, 26th November, 2020 and gradual decrease thereafter. • Squally wind speed reaching 35-45 gusting to 55 kmph very likely over Nagapattinam, Karaikal, Myladuthurai, Cuddalore & Tiruvarur districts of Tamilnadu during next 06 hours and gradual decrease thereafter.	
27.11.2020/ 0000UTC	• Squally wind speed reaching 40-50 kmph gusting to 60 kmph is likely to prevail over westcentral Bay of Bengal and along & off south Andhra Pradesh coast during next 12 hours.	

Table 7: Verification of Storm Surge Forecast issued by IMD

Date/Base Time of observation	Storm Surge Forecast at 0300 UTC of date	Realised surge
24.11.2020/0300UTC	Tidal wave of about 1m height above the astronomical tide is very likely to inundate the low lying areas of north coastal districts of Tamilnadu & Puducherry near the place of landfall.	No significant surge was reported in association with this system.
25.11.2020/0300UTC	Tidal wave of about 1-1.5m height above the astronomical tide is very likely to inundate the low lying areas of north coastal districts of Tamilnadu & Puducherry near the place of landfall.	

12. Warning & advisories issued by IMD

- **First Press Release and Special Bulletin** for east coast states were issued at 1500 hrs IST of 21st November (4 days 10 hrs prior to landfall)
- **Pre cyclone watch for Tamilnadu and Puducherry coasts** was issued at 1300 hrs IST of 22nd November when the system lay as a well marked low pressure over central parts of south BoB (about 3 days and 16 hours prior to landfall of NIVAR).
- **Cyclone Alert for Tamilnadu and Puducherry coasts** was issued at 0550 hrs IST of 23rd at depression stage (about 70 hours prior to landfall)
- **Cyclone Warning for Tamil Nadu & Puducherry coasts** was issued at 0900 hrs IST of 24th (about 40 hours prior to landfall)
- **Post Landfall Outllook for interior districts of TN & Puducherry** was issued at 1345 hrs IST of 25th (about 10 hours prior to landfall)

- A total of 38 bulletins to national level disaster managers & chief secretaries of Tamilnadu, Puducherry, Andhra Pradesh, Telangana, Andaman & Nicobar Islands, West Bengal, Odisha, Kerala and Lakshadweep. In addition, 7 Nos. of press release, 6 bulletins from Director General of Meteorology to senior Government Officers, 13 bulletins for civil aviation, regular media briefings and joint press conference addressed by DGM IMD and DG NDRF on 24th. The 3 hourly advisories were uploaded on all websites of IMD namely www.mausam.imd.gov.in and www.rscmcnewdelhi.imd.gov.in. Warnings were also uploaded on all social networking sites including Facebook, Twitter, Whatsapp etc. frequently and SMS were also sent to registered users on RSMC website, national level disaster managers and chief secretaries of concerned states. Hourly bulletins were also issued 12 hours prior to landfall.
- **The cyclone warning track and wind graphics were provided in IMD and RSMC, New Delhi website through interactive web-GIS map.**

Bulletins issued by RSMC New Delhi, IMD are presented in Table 8(a).
Table 8 (a): Bulletins issued by RSMC New Delhi

S.No.	Type of Bulletin Number	No. of Bulletins issued				
		CWC Bhubaneswar	RMC Mumbai	CWC Thiruvananthapuram	CWC Visakhapatnam	MC AMARAVATI
1.	Sea Area Bulletins	NIL	12	-	-	-
2.	Coastal Weather Bulletins	08	10	10	24	-
3.	Fishermen Warnings issued	16	20	18	32	12
4.	Port Warnings	12	5	-	14	-
5.	Heavy Rainfall Warning	NIL	NIL	12	11	17
6.	Gale Wind Warning	NIL (Wind Warning for Odisha Coast issued) NIL	NIL	-	5	12
7.	Storm surge Warning	NIL	NIL	-	-	-
8.	Information & Warning issued to State Government and other Agencies	04 (In addition to regular Bulletins)	NIL	32	11	17

9.	SMS	NIL	358	7	377	1000
10.	No. of Press releases	NIL	NIL	-	11	9
11.	No. of impact based warnings for a. District b. City	 NIL NIL	NIL	-	50 34	 12 5
12.	No. of whatsapp messages	2908	All bulletins and warning communicated to concerned group	32	20	184 whatsapp messages sent to 13287 receipents.
13.	No. of updates on facebook	27	5	32	44	18
14.	No. of updates on tweeter	46	5	32	44	23
15	No. of warning video released	04	-	-	5	3
16.	No. of Audio bites released	-	-	-	-	4

Table 8(b): Bulletins issued by CWC Visakhapatnam /CWC Thiruvananthapuram

S. No.	Bulletin type	No. Of Bulletins	Issued to
1	National Bulletin	38	1. IMD's website, RSMC New Delhi website 2. FAX and e-mail to Control Room Ministry of Home Affairs & National Disaster Management Authority, Cabinet Secretariat, Minister of Science & Technology, Secretary MOES, Headquarter Integrated Defense Staff, Director General Doordarshan, All India Radio,PIB MOES,UNI,DG National Disaster Response Force, Director, Punctuality, Indian Railways, Chief Secretary: Government of Tamilnadu, Puducherry, Andhra Pradesh, Telangana, Andaman & Nicobar Islands, West Bengal, Odisha, Kerala and Lakshadweep.
2	RSMC Bulletin	35	1. IMD's website 2. WMO/ESCAP member countries through GTS and E-mail.
3	GMDSS Bulletins	19	1. IMD website, RSMC New Delhi website 2. Transmitted through WMO Information System (WIS) to Joint WMO/IOC Technical Commission for Ocean and Marine Meteorology (JCOMM)

4	Tropical Cyclone Advisory Centre Bulletin	13	1. Met Watch offices in Asia Pacific regions and middle east through GTS to issue Significant Meteorological information for International Civil Aviation 2. WMO's Aviation Disaster Risk Reduction (ADRR), Hong Kong through ftp 3. RSMC website
5	Tropical Cyclone Vital Statistics	13	Modelling group of IMD, National Centre for Medium Range Weather Forecasting Centre (NCMRWF), Indian National Centre for Ocean Information Services (INCOIS), Indian Institute of Technology (IIT) Delhi, IIT Bhubaneswar etc.
6	Warnings through SMS	Frequently	SMS to disaster managers at national level and concerned states (every time when there was change in track, intensity and landfall characteristics) (i) 837 to General Public by IMD Headquarters (ii) 64 to disaster managers by IMD Headquarters (iii) 16,16,944 SMS to fishermen by INCOIS (iv) 32 Total bulletins sent through NAVIC (INCOIS) (iv) 3322543 to farmers by Kisaan Portal
7	Warnings through Social Media	Daily	Cyclone Warnings were uploaded on Social networking sites (Facebook and Tweeter) since inception to weakening of system (every time when there was change in track, intensity and landfall characteristics).
8	Press Release	5	Disaster Managers, Media persons by email and uploaded on website
9	Press Briefings	Daily	Regular briefing daily
10	Hourly Updates	12	1. IMD's website, RSMC New Delhi website 2. FAX and e-mail to Control Room Ministry of Home Affairs & National Disaster Management Authority, Cabinet Secretariat, Minister of Science & Technology, Secretary MOES, Headquarter Integrated Defense Staff, Director General Doordarshan, All India Radio,PIB MOES,UNI,DG National Disaster Response Force, Director, Punctuality, Indian Railways, Chief Secretary: Government of Tamilnadu, Puducherry, Andhra Pradesh, Telangana, Andaman & Nicobar Islands, West Bengal, Odisha, Kerala and Lakshadweep.

13. Summary

Low Pressure Area (LPA) formed over Equatorial Indian Ocean (EIO) and adjoining central parts of south Bay of Bengal (BoB) on 21st November. It lay as a Well

Marked Low Pressure Area (WML) over southwest & adjoining southeast Bay of Bengal on 22nd November.It concentrated into a depression over the same region in the early hours (0230 hrs IST / 2100 UTC of 22nd) of 23rd November.Moving west-northwestwards, it intensified into a deep depression in the evening of 23rd and further into the cyclonic storm **"NIVAR"** in the early morning (0530 hrs IST / 0000 UTC) of 24th over southwest BoB. Continuing to move west-northwestwards, it further intensified into a severe cyclonic storm in the midnight (2330 hrs IST / 1800 UTC) of 24th and into a very severe cyclonic storm in the afternoon (1430 hrs IST / 0900 UTC) of 25th. Moving further northwestwards, it crossed Tamilnadu & Puducherry coasts near Puducherry (near lat. 12.1°N and long. 79.9°E) during 2330 IST of 25th to 0230 IST of 26th as a very severe cyclonic storm with estimated wind speed of 120 kmph gusting to 135 kmph. Continuing to move northwestwards, it weakened into a severe cyclonic storm in the early morning hours (0230 hrs IST) of 26th.

Thereafter, it moved north-northwestwards and weakened into a cyclonic storm in the morning (0830 hrs IST / 0300 UTC) of 26th November, 2020 over north coastal Tamilnadu. Thereafter, it started recurving north-northeastwards and weakened into a deep depression in the afternoon (1430 hrs IST) of 26th over south Rayalaseema, into a depression in the same midnight (2330 hrs IST) over south coastal Andhra Pradesh. Thereafter, it weakened into a well marked low pressure area over south coastal Andhra Pradesh and adjoining westcentral BoB in the early morning (0000 UTC)of 27th November. Under the influence of this system, intense rainfall activity occurred over north Tamil Nadu & Puducherry, Rayalseema and south coastal Andhra Pradesh. Heavy to very heavy rainfall occurred at a few places and isolated extremely heavy rainfall (≥ 20 cm) occurred over north Tamilnadu, Puducherry on 24th, 25th & 26th and over Rayalaseema & south coastal AP on 25th and 26th.

14. Acknowledgement:

India Meteorological Department (IMD) and RSMC New Delhi duly acknowledge contribution from WMO in dissemination of bulletins and warnings associated with VSCS NIVAR. IMD and RSMC New Delhi also acknowledge the contribution from all the stake holders and disaster management agencies who contributed to the successful monitoring, prediction and early warning service of CS BUREVI. We acknowledge the contribution of all sister organisations of Ministry of Earth Sciences including National Centre for Medium Range Weather Forecasting Centre (NCMRWF), Indian National Centre for Ocean Information Services (INCOIS), National Institute of Ocean Technology (NIOT), Indian Institute of Tropical Meteorology (IITM) Pune, research institutes including IIT Bhubaneswar, IIT Delhi and Space Application Centre, Indian Space Research Organisation (SAC-ISRO) for their valuable support. The support from various Divisions/Sections of IMD including Area Cyclone Warning Centre (ACWC) Chennai, Kolkata, Cyclone Warning Centre (CWC) Thiruvananthapuram, Visakhapatnam. The contribution from Numerical Weather Prediction Division, Satellite and Radar Division, Surface & Upper air instruments Divisions, New Delhi and Information System Services Division, Agromet Advisory Services Division at IMD is also duly acknowledged.
