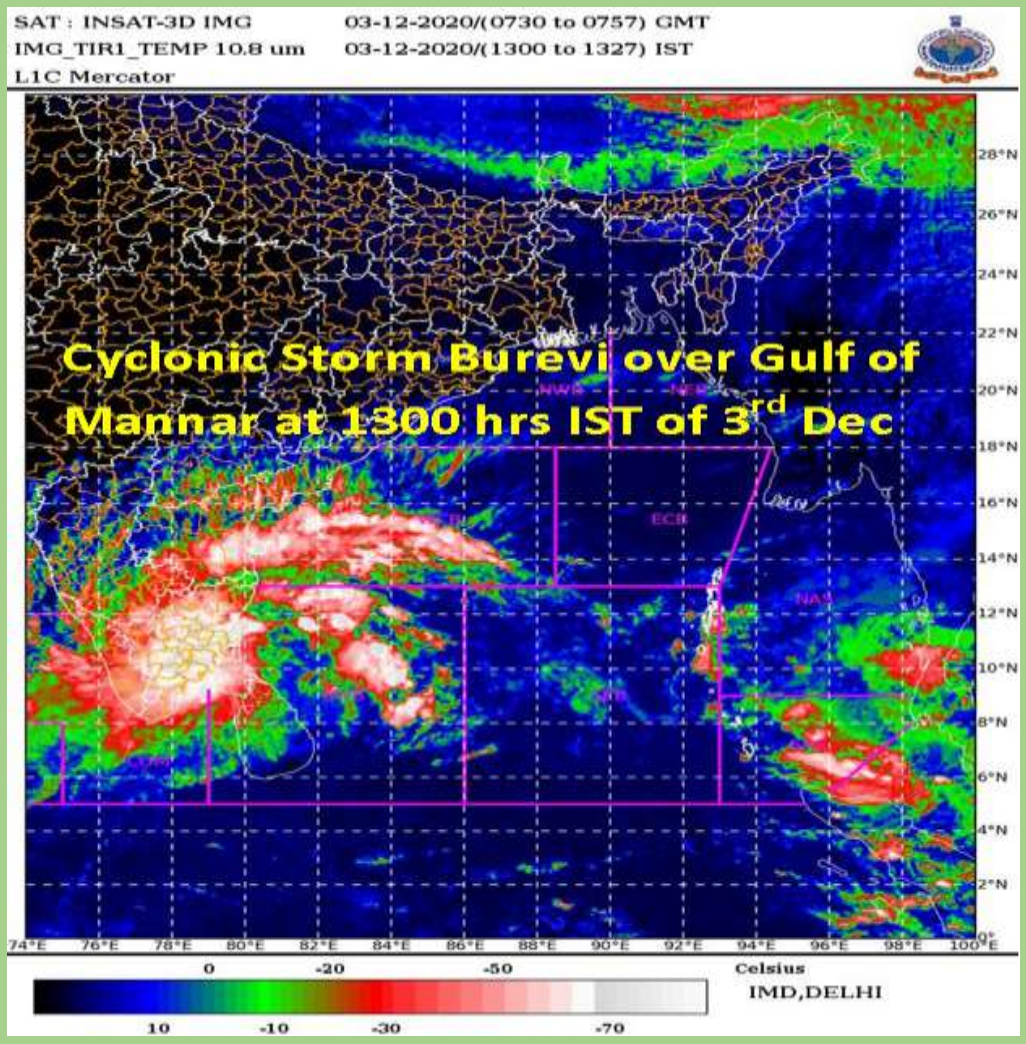
GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
INDIA METEOROLOGICAL DEPARTMENT

Cyclonic Storm, 'BUREVI' over the Bay of Bengal (30th November - 05th December 2020): A Report



INSAT-3D enhanced colored IR imagery of 1300 Hrs IST, 3rd December, 2020

Cyclone Warning Division

India Meteorological Department

New Delhi

December, 2020

Cyclonic Storm "BUREVI" over the Bay of Bengal (30th November - 05th December 2020)

1. Introduction

The cyclonic storm, 'Burevi' originated as a Low Pressure area in the equatorial easterly wave over South Andaman Sea and adjoining areas of Southeast Bay of Bengal & Equatorial Indian Ocean on 28th November 2020, which became a Well Marked Low pressure area over Southeast Bay of Bengal & adjoining areas of South Andaman Sea and Equatorial Indian Ocean on 29th. Under favourable environmental conditions, it concentrated into a Depression in the early morning (0530 hrs IST / 0000 UTC) of 30th November 2020 over Southeast Bay of Bengal. Moving nearly westwards, it intensified into a Deep Depression in the early morning of 01st December 2020 over Southwest and adjoining Southeast Bay of Bengal. Subsequently it moved west-northwestwards and intensified into Cyclonic Storm 'Burevi' over Southwest Bay of Bengal in the evening (1730 hrs IST / 1200 UTC) of 01st December 2020. Continuing the west-northwestward movement, it crossed Sri Lanka coast close to north of Trincomalee near Lat. 8.85°N and Long. 81.0°E between 2230 and 2330 hrs IST (1700 & 1800 UTC) of 2nd December 2020 as a Cyclonic Storm with a maximum sustained wind speed of 80-90 kmph gusting to 100 kmph. Moving across northern parts of Sri Lanka, it emerged into Gulf of Mannar in the morning and lay centred close to Pamban around noon (1130 hrs IST / 0600 UTC) of 03rd December. It crossed Pamban area around 0800 UTC of 3rd. Continuing to move west-northwestwards, it weakened into a Deep Depression over the same region in the evening (1200 UTC) of 03rd December. Thereafter the movement slowed down significantly and it remained practically stationary over Gulf of Mannar close to Ramanathapuram district coast for nearly 18 hours and further weakened into a Depression in the evening of 04th December over the same region. Further remaining stationary at the same place for subsequent 18 hours, it gradually weakened into a well marked Low pressure area around noon (1130 hrs IST / 0600 UTC) of 05th December. This system during its initial stage as a Low pressure area had caused fairly widespread rainfall with isolated very heavy falls over Andaman & Nicobar Islands on 29th November. Under the influence of this system, widespread rainfall with heavy to very heavy falls at a few places & extremely heavy (≥ 20 cm) falls at isolated places occurred over Tamil Nadu during 02nd – 04th December.

The observed track of the system during 30th November to 05th December is presented in Fig. 1.

2. Salient Features:

- Burevi, after weakening, remained practically stationary for nearly 36 hours over Gulf of Mannar close to Ramanathapuram district. It is mainly due to the fact that it came under the regime of very light steering winds in the middle & upper tropospheric levels over this region, sandwiched between two upper level

anticyclonic circulations to it's northeast and northwest. In meteorological parlance, such a region is known as a 'col' region.

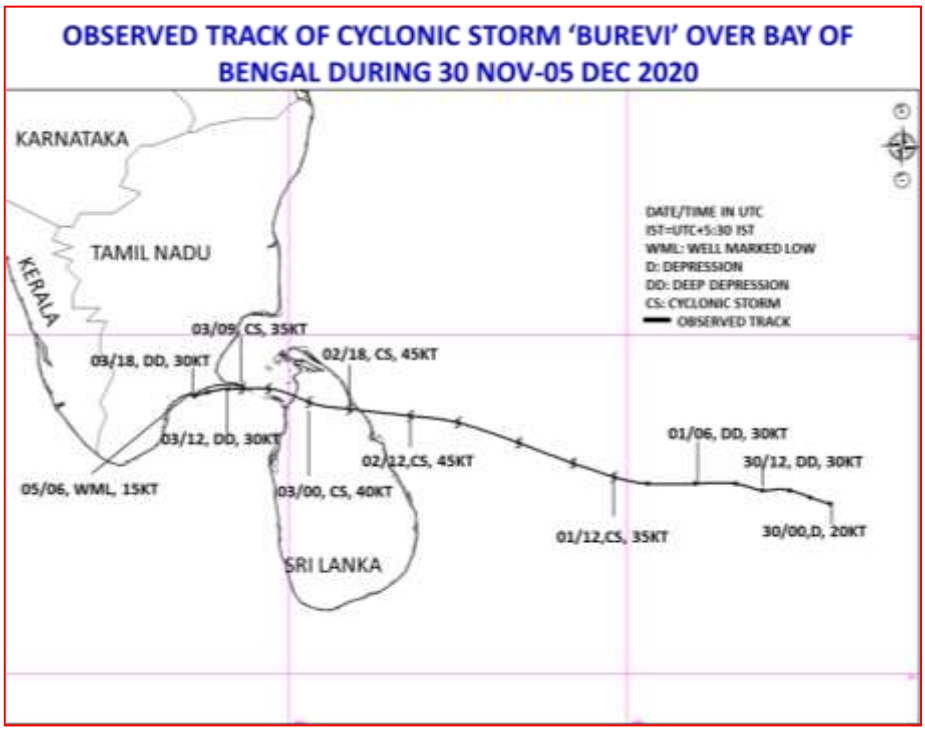


Fig.1: Observed track of cyclonic storm "BUREVI" over Bay of Bengal

- It could intensify only upto cyclonic storm stage, due to following reasons
  - It's predecessor very severe cyclonic storm "NIVAR" caused upwelling over the Sea region in which Burevi matured. As a result there was relative cooling of Sea surface and thus couldn't get enough energy from the Sea for further intensification.
  - Also the cyclone Burevi had originated in the near equatorial region experiencing lower Coriolis force. Higher Coriolis force which is directly proportional to the latitude of occurrence of the cyclone favours intensification.
  - The interaction with the land surface as it lay close to Sri Lanka and south Tamil Nadu coasts also limited its intensification.
  - The vertical wind shear remained moderate to high as it approached towards the coast. The high wind shear is unfavourable for intensification.
- Climatologically, during the recorded history (1891-2019), out of a total of 58 cyclonic storms & above intensity storms developing over the Bay of Bengal in the grid (5^0N-10^0N & 75^0E-80^0E) during October-December, total 11 (about 19%) reached the state of Kerala. Out of these 11, 3 crossed Kerala after emerging from Sri Lanka and remaining 8 reached Kerala after crossing Tamil Nadu (Fig. 2 a).
- Also, during the period 1891-2019, there have been 13 cyclonic storms and above intensity storms that crossed the east coast of Sri Lanka (Fig. 2 b). Out of these, 10 emerged into Gulf of Mannar-Comorin area & crossed Tamil Nadu coast (7 near Pamban, 3 near Kanniyakumari) and 2 weakened over Sri Lanka with 1 moving

west-southwestwards towards southeast Arabian Sea. Considering season-wise distribution, out of 13 cyclonic storms and above intensity storms that crossed east coast of Sri Lanka, 11 crossed the east Sri Lanka coast during post monsoon season (October to December) (Fig. 2 c) and remaining 2 crossed east Sri Lanka during January, 1906 and March, 1907 (Fig. 2d).

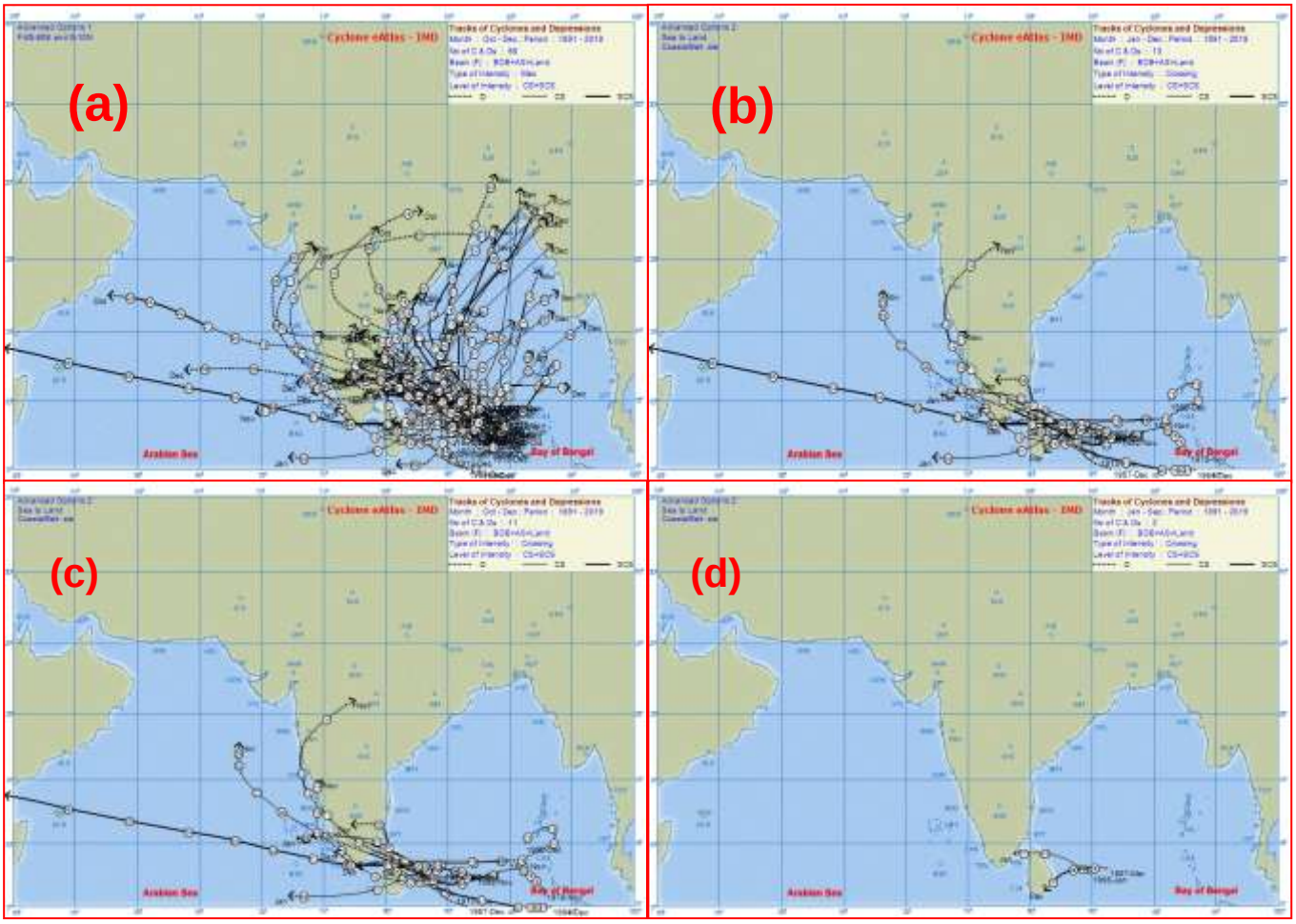


Fig. 2: Number of cyclonic storms and above intensity storms during 1891-2019 (a) developing in the grid (5^0N - 10^0N & 75^0E -80^0E), (b) developing over Bay of Bengal & crossing East Sri Lanka coast, (c) cyclones developing over Bay of Bengal and crossing East Sri Lanka coast during October-December and (d) cyclones developing over Bay of Bengal and crossing East Sri Lanka coast during January-September

- Track of the Cyclonic Storms which crossed south Tamil Nadu coast are given in **Fig. 3.** It may be noted that, the monthly frequency of Cyclonic storms crossing south Tamil Nadu coast during 1891 – 2019 has been 01 in January and 4 each during November & December. Rest of the months (viz., February to October) has not witnessed any cyclone crossing south Tamil Nadu. This also implies that no cyclone so far has crossed south Tamil Nadu coast during the pre-monsoon months. Thus Sri Lanka and south Tamil Nadu coasts are more prone to cyclonic activity during post-monsoon season, especially during November and December.

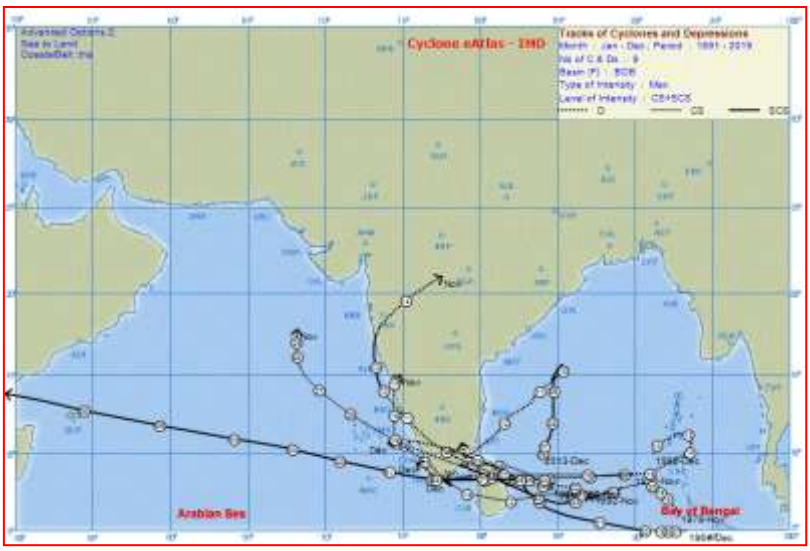


Fig.3: Track of Cyclonic Storms & Severe Cyclonic Storms which crossed south Tamil Nadu coast during 1891- 2019

- During 1891 – 2019, a total of 09 Cyclonic Storms crossed south Tamil Nadu coast & 58 crossed north Tamil Nadu coast.
- There were 5 years in which 2 or more number of systems crossed Tamil Nadu coast viz., 1906, 1964, 1966, 1978 & 2000. But none of these events were within a span of a week's time as occurred during this year when the Very Severe Cyclonic Storm 'NIVAR' (22nd – 27th November 2020) crossed Tamil Nadu coast, near Puducherry on 25th November and the Cyclonic Storm 'BUREVI' (30th November – 05th December) after moving across Sri Lanka, crossed Pamban area of south Tamil Nadu coast on 03rd December.

  Salient features of the past systems, when 2 or more Cyclonic Storms crossed Tamil Nadu coast is enlisted in the table below:

Sl. No	Year	Period	Characteristics
1	1906	15-17 Jan	Crossed Sri Lanka coast, emerged into Gulf of Mannar & weakened
		26-27 Dec	Crossed north Tamil Nadu coast & weakened
2	1964	4-8 Nov	Crossed north Tamil Nadu coast as Cyclonic Storm
		17-24 Dec	Crossed north of Pamban, weakened into a Depression and re-emerged into southeast Arabian Sea off Kerala coast
3	1966	28April – 4 May	Formed over southeast BoB, crossed north Tamil Nadu coast, moved across Karnataka as a Depression, re-curved over to Madhya Maharashtra and weakened.

		01 – 11 Nov.	Formed over Andaman Sea, crossed north Tamil Nadu coast, weakened into a Depression, moved west-southwestwards, moved across Kerala, emerged into southeast Arabian Sea, moved westwards, re-intensified into a Severe Cyclonic Storm over south Arabian Sea, moved west-northwestwards and crossed south Oman coast as an SCS on 11th Nov.
		08- 14 Nov	Formed over southwest BoB, crossed as a CS over northeast coast of Sri Lanka, emerged close to Pamban as a Depression, moved across Karnataka coast close to Mangaluru, re-intensified into an SCS over east-central Arabian Sea, re-curved northeastwards, crossed south Maharashtra coast, weakened into a Depression and dissipated over Marathwada.
		25 Nov – 4 Dec	Formed over Andaman Sea, crossed north Tamil Nadu coast close to Chennai as a Severe Cyclonic Storm, moved inland, weakened into a Cyclonic Storm, moved across Karnataka as a Depression & weakened over Goa.
4	1978	03-13 Nov	Formed over southwest BoB, crossed north Tail Nadu coast as a Depression, intensified into Severe Cyclonic Storm only after re-emerging into the Arabian Sea across north Kerala. After re-intensification, re-curved & crossed north Gujarat coast.
		18-29 Nov	Formed over southeast BoB, crossed northeast coast of Sri Lanka as an SCS, re-emerged & crossed south Tamil Nadu coast close to Pamban as SCS, weakened into a Depression, moved across Kerala coast, close to Kochi, re-emerged into the Arabian Sea, re-intensified into a Cyclonic Storm, moved north-westwards and weakened over east-central Arabian Sea.
5	2000	26-30 Nov	Formed over south Andaman Sea, crossed north Tamil Nadu coast as SCs, moved inland and weakened.
		23-28 Dec	Formed over southeast BoB, crossed north Sri Lanka as SCS, emerged into Gulf of Mannar, moved across Kanniyakumari, weakened into a Depression and moved along south Kerala coast.

- A system analogous to that of CS 'BUREVI' occurred during 15-17 January 1906 which crossed the east coast of Sri Lanka, close to north of Trincomali and moved across Pamban area and weakened near Ramanathapuram district coast. After 113 years, this is the first Cyclonic Storm following a similar track & intensity characteristic. However, unlike the previous one, it remained practically stationary for about 36 hrs near the coast.
- Considering the extraordinarily long stationary period of cyclone Burevi, during past 30 years (1990-2020), last such stationary behaviour was witnessed during 1999, Odisha Super Cyclone which remained stationary over land for 30 hours. However, cyclonic storm Burevi crossed that record and remained stationary over Gulf of Mannar close to Ramanathapuram for 36 hours.
- Plausible reasons for this stagnation probably could be attributed to the weakened dynamics of the system and the light steering environment as stated above. A few of the physical & dynamical features experienced by the system are re-produced below.

  (a) Shallow vertical extention & small horizontal scale.

Cyclonic Storm (BUREVI) emerged into Gulf of Mannar, after crossing north Sri Lanka. The topography of Sri Lanka is re-produced in the map (**Fig.4**). It may be noted that though the stretch of land across which the system moved is narrow, subsequent to the re-emergence, the system underwent land interaction, causing the system to loose momentum.

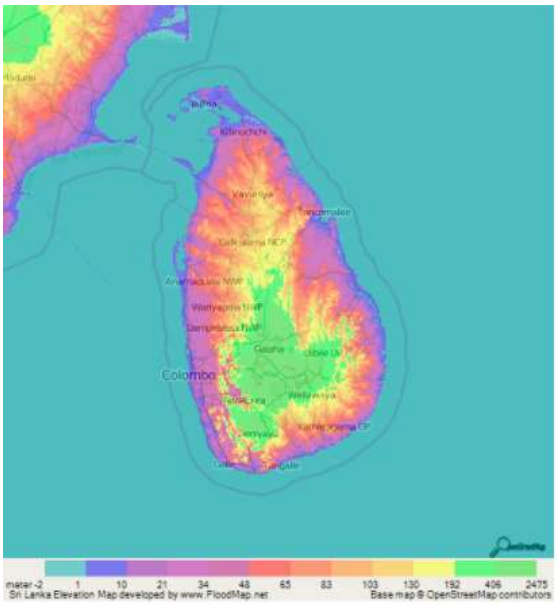


Fig.4: Topograhic features surrounding Gulf of Mannar.

Thus the vertical extention & horizontal scale of the system, reduced significantly after re-emerging into Gulf of Mannar. Vertically the cyclonic circulation extended roughly upto 7.6 km above mean sea level (400 hPa) and it had a rapidly expanding radius of maximum winds, implying weakening. (Figures not given).

(b) Less Ocean Thermal Energy

Tropical Cyclone Heat Potential (TCHP) is a measure of the integrated vertical temperature from the Sea surface to the depth of 26ºC isotherm. It is a measure of the Potential energy associated with the heat content available to any tropical cyclonic disturbance for resulting in intensity changes.

The slowing down of the cyclonic disturbances over the tropical Oceans cause an increase in momentum exchange from the cyclonic system to the Sea surface. This would lead to deeper vertical mixing and enhanced Sea surface cooling. As a consequence, the heat flux would decrease from the Ocean to the cyclonic disturbance, thereby inhibiting its further intensification. (Liu etal 2007, Lin etal 2009, Mei etal 2012, Horman etal 2014, Kim etal 2020). Fig. 5 shows the average Tropical Cyclone Heat Potential (TCHP) analysis (30th November – 10th December) from INCOIS analysis.

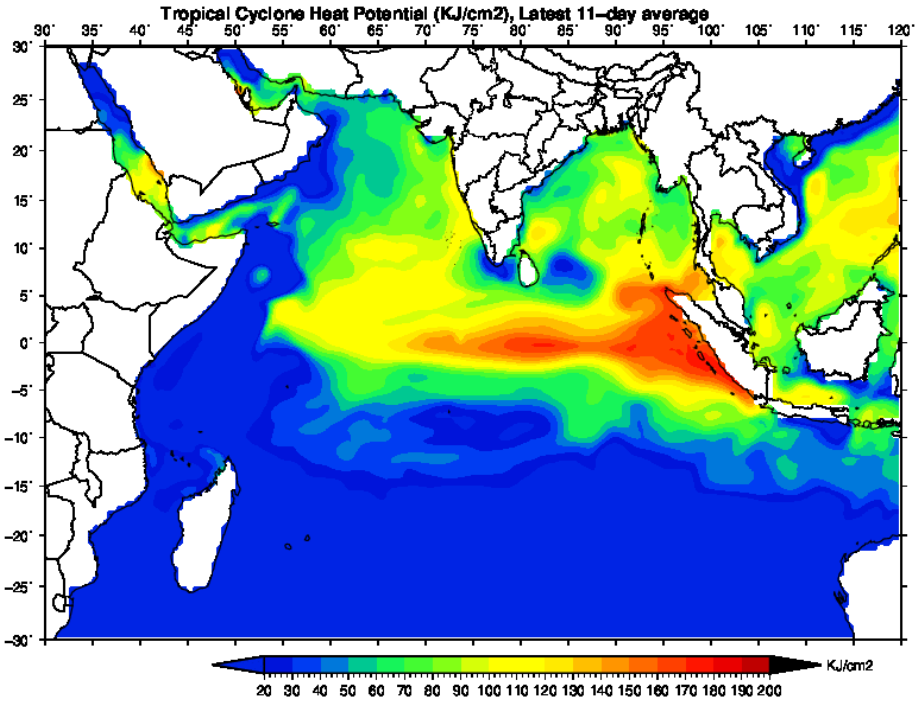


Fig. 5: TCHP pattern (Latest 11 day average ending on 10th December 2020) by INCOIS

(c) Vertical wind shear

The vertical wind shear (both directional as well as speed) during the life cycle of the system is given in **Fig.6.** It may be noted that the ssytem originated in the equatorial easterly wave regime and had reamined under the mid & upper level easterly steering influence and hence under low vertical wind shear field upto the early morning of 04th December.

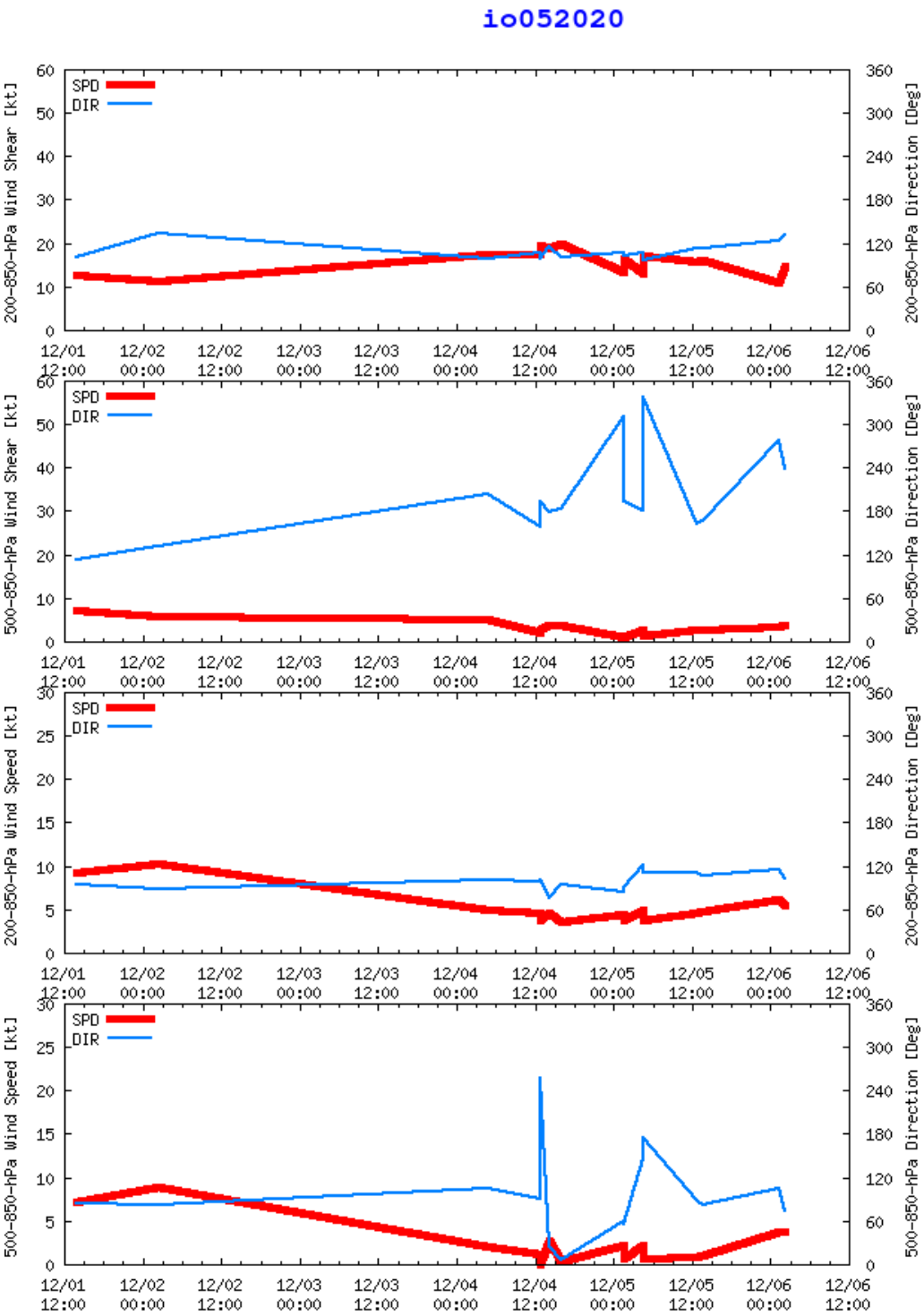


Fig. 6: Vertical wind shear associated with Cyclonic Storm BUREVI (courtsey: Cooperative Institute for Research in the Atmosphere website)

(a) Latent heat release due to the intense convection & heavy rainfall to the northeast of the system over coastal Tamil Nadu

Role of the mid-level warming as is evidenced in Fig.7, owing to the Latent heat of condensation associated with the meso-scale convective complex generated to the north of the system (resulting in extremely heavy rainfall) prior to & during the stagantion period needs to be further adressed.

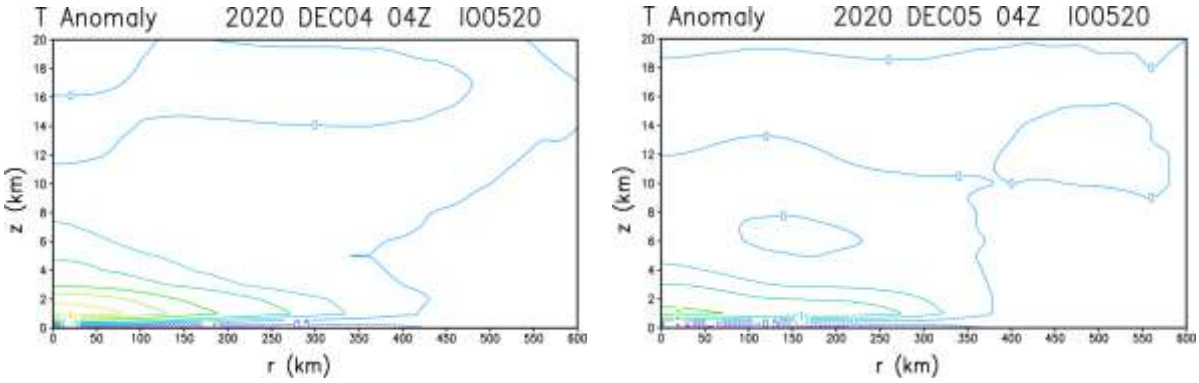
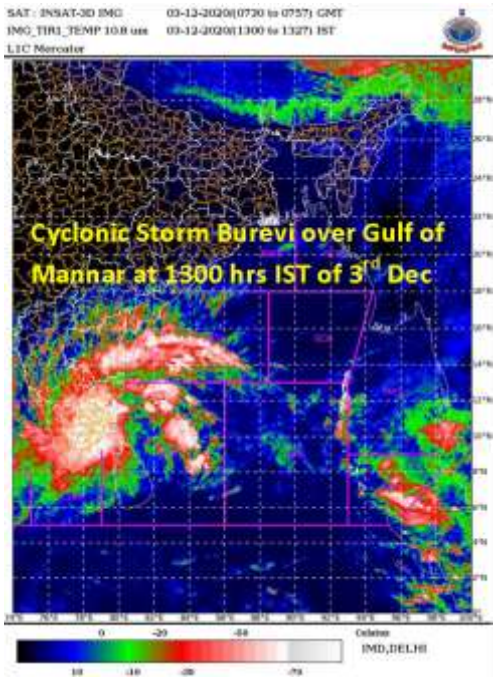


Fig. 7: Vertical thermal structure associated with Cyclonic Storm BUREVI (courtsey: Cooperative Institute for Research in the Atmosphere website)

All the above preliminary analyses indicate that due the prevailing middle to upper tropospheric environment with a COL region due to two anticyclones on either side to northeast and northwest of the cyclone over Gulf of Mannar, the system remained practically stationary for about 36 hrs. Further persistence over this land-locked region of Gulf of Mannar led to cooling of Gulf of Mannar through continuous rainfall and upwelling over the region and hence cooling of the Sea region. Further the increased wind shear and interaction of land surface favoured the weakening.
However this persistence of the system over Gulf of Mannar for such a long period led to extremely heavy rainfall over Tamil Nadu & Puducherry for a longer period and the rainfall was confined to Tamil Nadu and Puducherry only.

3. Monitoring of "BUREVI":

India Meteorological Department (IMD) maintained round the clock watch over the north Indian Ocean and the cyclone was monitored since 26th November, about 03 days prior to the formation of low pressure area over Southeast Bay of Bengal & Equatorial Indian Ocean on 28th November 2020 and 05 days prior to the formation of depression over southeast BoB on 30th November. The cyclone was monitored with the help of available satellite observations from INSAT 3D and 3DR, SCATSAT, polar orbiting satellites and available ships & buoy observations in the region. The system was also monitored by Doppler Weather RADARs (DWR) Chennai, Karaikal and Thiruvananthapuram (ISRO). 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. 8.



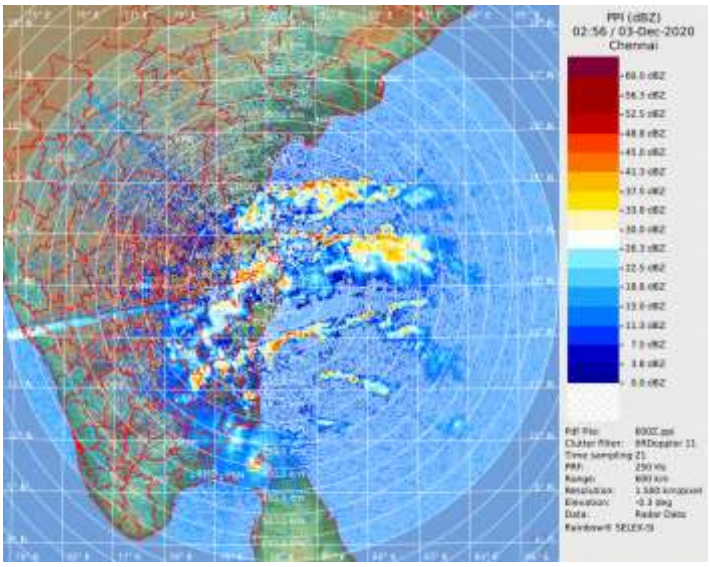


Fig.8: Typical satellite imagery of CS "BUREVI" & Doppler Weather RADAR Chennai - reflectivity image (PPZ (600KM and maximum range) product of 3rd December.

Table 1: Best track positions and other parameters of the Cyclonic Storm, 'BUREVI' over the Bay of Bengal during 30 Nov- 05 Dec., 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
30/11/2020	0000	7.5	88.0	1.5	1003	20	3	**D**
	0300	7.7	87.7	1.5	1002	25	4	D
	0600	7.8	87.4	1.5	1002	25	4	D
	1200	7.7	87.0	1.5	1002	25	4	D
	1800	7.8	86.6	1.5	1002	25	4	D
01/12/2020	0000	7.8	86.0	2.0	1000	30	6	**DD**
	0300	7.8	85.7	2.0	1000	30	6	DD
	0600	7.8	85.3	2.0	1000	30	6	DD
	1200	7.9	84.8	2.5	999	35	7	**CS**
	1500	7.9	84.5	2.5	999	35	7	CS
	1800	8.1	84.2	2.5	999	35	7	CS

	2100	8.4	83.4	2.5	999	35	7	CS
02/12/2020	0000	8.6	83.0	2.5	998	40	8	CS
	0300	8.7	82.5	2.5	998	40	8	CS
	0600	8.8	82.2	3.0	996	45	10	CS
	0900	8.8	81.8	3.0	996	45	10	CS
	1200	8.8	81.4	3.0	996	45	10	CS
	1500	8.8	81.4	3.0	996	45	10	CS
	Crossed Sri Lanka coast close to north of Trincomalee (near Lat 08.85^{0}N and Long 81.0^0 E) during 1700 – 1800 UTC of 02nd December 2020							
	1800	8.9	80.9	-	996	45	10	CS
	2100	9.0	80.8	-	998	40	8	CS
03/12/2020	0000	9.0	80.3	-	998	40	8	CS
	0300	9.1	80.2	-	998	40	8	CS
	0600	9.2	79.7	-	998	40	8	CS
	Crossed Pamban area (near Lat 09.2^{0}N and Log 79.35^0 E) during 0800 UTC of 03rd December 2020							
	0900	9.2	79.3	2.5	999	35	7	CS
	1200	9.2	79.1	2.0	1000	30	6	**DD**
	1500	9.2	78.8	2.0	1000	30	6	DD
	1800	9.1	78.6	2.0	1000	30	6	DD
	2100	9.1	78.6	2.0	1000	30	6	DD
04/12/2020	0000	9.1	78.6	2.0	1000	30	6	DD
	0300	9.1	78.6	2.0	1001	30	5	DD
	0600	9.1	78.6	2.0	1001	30	5	DD
	1200	9.1	78.6	1.5	1002	25	4	**D**
	1800	9.1	78.6	1.5	1003	25	4	D
05/12/2020	0000	9.1	78.6	1.5	1004	20	3	D
	0300	9.1	78.6	1.5	1006	20	3	D
	0600	Weakened into a Well-Marked Low Pressure Area over Gulf of Mannar close to Ramanathapuram district of Tamil Nadu						

3.1 Genesis, intensification and movement

An equatorial easterly wave trough which persisted over South Andaman Sea and adjoining areas of Southeast Bay of Bengal & Equatorial Indian Ocean gradually organized into a Well Marked Low pressure area over the same region on 29th November, within a time span of 48 hours. The favourable environmental conditions, which led to its concentration into a Depression on 30th November and subsequent intensification into a Deep Depression in the early morning of 01st December & into a Cyclonic Storm in the evening of the same day are discussed in this section.

After the initial westward movement, the system followed a west-northwestward track in general and made two landfalls. The peculiarities with respect to the movement of the system have been analysed in detail under Section 2.

The convectively active phase of the Madden Julian Oscillation (MJO) represented mathematically as MJO index lay in Phase 4 (western Maritime continent) with amplitude close to 1. Hence MJO favoured the development of the system. High Sea Surface Temperatures (SST) of the order of 29-30°C and high Tropical Cyclone Heat Potential (TCHP) values of about 80-100 KJ/cm^2 prevailed over the region of genesis. However, as the system moved further westwards, the SST & TCHP values reduced over southwest BoB to 28ºC & 70-90 KJ/cm^2 respectively on account of the past passage of VSCS NIVAR over the region.

At 0000 UTC of 30 November, lower level positive relative vorticity (100x10^{-6}s^{-1}) prevailed around system centre. Upper level positive divergence of 20x10^{-5}s^{-1} prevailed around the system centre. The lower level convergence was 20 x 10^{-5}s^{-1} around system centre. The vertical wind shear (VWS) was low to moderate (05-15 kts) over the region. The sub- tropical ridge at upper and middle Tropospheric levels ran along 17°N over the BoB. The system lay in the southern periphery of the above ridge. As a result, it was moving nearly westwards. The above environmental conditions remained to be favourable for Intensification of the system gradually into a cyclonic storm during the subsequent 36 Hours.

At 1200 UTC of 30 November, Lower level positive relative vorticity (100x10^{-6}s^{-1}) prevailed to the southeast of the system centre. Upper level divergence and lower level convergence had increased during past 12 hours while wind shear remained the same during the period. These features indicated that environmental conditions were favourable for further intensification of the system. The upper level positive divergence was around 30x10^{-5}s^{-1} to the northeast of the system centre. The lower level convergence was around 20 x 10^{-5}s^{-1} to the southeast of the system centre. The sub-tropical ridge at upper and middle tropospheric levels ran along 11.5°N over the BoB. The system lay in the southern periphery 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 2 days and then nearly westwards.

At 0000 UTC of 01 December, the Lower level positive relative vorticity (100x10^{-6}s^{-1}) prevails to the southeast of the system centre. The upper level positive divergence was around 20x10^{-5}s^{-1} of the system centre. The lower level convergence was around 20 x 10^{-5}s^{-1} to the northwest of the system centre. These features indicate that environmental features are favorable for further intensification of the system. The sub-tropical ridge at upper and middle tropospheric levels ran along 11.5°N over the BoB. The system lay in the southern periphery of the above ridge. As a result, it continued to move west northwestwards. Also there was another cyclonic vortex over south Indian Ocean near 10.5^{0}S/89.0^{0}E with estimated maximum sustained wind speed of 25 kts. These two vortices on either side of the equator (like Twin Cyclones) could have been interacting with each other.

At 1200 UTC of 01 December, the Lower level positive relative vorticity (100x10^{-6}s^{-1}) prevailed to the southeast of the system centre. The upper level positive divergence was around 20x10^{-5}s^{-1} to the northeast of the system centre. The lower level convergence was around 20 x 10^{-5}s^{-1} to the north of the system centre. These features indicate that environmental features continued to remain favourable for further intensification of the system and thus it intensified into a Cyclonic Storm. The sub-tropoical ridge at upper and middle tropospheric levels ran along 12.5°N over the BoB. The system lay in the southern periphery of the above ridge. As a result, it was moving west northwestwards. By this time, the vortex over south Indian Ocean had moved west-southwestwards and lay near 10.6^{0}S/87.1^{0}E with estimated maximum sustained wind speed of 25 kts.

At 0000 UTC of 02 December, the Lower level positive relative vorticity (100-150x$10^{-6}s^{-1}$) prevails to the south of the system centre. The upper level positive divergence was around 30-40x$10^{-5}s^{-1}$ to the southwest of the system centre. The lower level convergence was around 30-40 x $10^{-5}s^{-1}$ to the southwest of the system centre. These features indicate that environmental features were favorable for further intensification of the system. But the system did not intensify further. The sub-tropical ridge at upper and middle tropospheric levels ran along 12°N over the BoB. The system continued to lie in the southern periphery of the above ridge. The vortex over south Indian Ocean lay near 8.3^0S/83.3^0E with estimated maximum sustained wind speed of 20 kts.

At 1200 UTC of 02 December, the Lower level positive relative vorticity (150x10-6s-1) prevails to the south of the system centre. The upper level positive divergence was around 30x10-5s-1 around the system centre. The lower level convergence was around 30 x 10-5s-1 to the southwest of the system centre. The sub-tropical ridge at upper and middle tropospheric levels ran along 13°N over the BoB. The system lay in the southern periphery of the above ridge. As a result, it was moving west northwestwards. The vortex over south Indian ocean lay near 8.30S/83.30E with estimated maximum sustained wind speed of 20 kts.

At 0000 UTC of 03 December, the Lower level positive relative vorticity (200x10-6s-1) prevailed around the system centre. The upper level positive divergence was around 30x10-5s-1 and the lower level convergence was around 30 x 10-5s-1 over the system centre. The wind shear had increased with value 15-20 kts. The upper tropospheric ridge at upper and middle tropospheric levels run along 13°N over the BoB. The system lay in the southern periphery of the above ridge. As a result, it was moving west northwestwards. It was expected to be steered by the above ridge resulting in westward movement for next 24 hours. At 0800 UTC of 03 December, it crossed Pamban area (second landfall) and started showing signs of weakening owing to Land interaction, shallow bathymetry, increased vertical wind shear and other adverse environmental features.

At 1200 UTC of 03 December, it continued to interact with land surface as it lies very close to south Tamil Nadu coast. As a result system weakened into a deep depression at 1200 UTC. Also the high wind shear over the region was favoring further weakening of the system. The convective cloud mass was sheared to the north from the low level circulation centre in the satellite imagery. The winds were also stronger in the northern sector.

At 0000 UTC of 04 December, it remained practically stationary, sandwiched between two anti-cyclones and was weakening further under the increased windshear regime. Thus for the remaining period it remained over the same region and gradually weakened further.

The Total Precipitable Water vapour (TPW) imageries during 01-06 Dec. 2020 are presented in Fig.9. These imageries indicate continuous warm and moist air advection from the southeast sector into the system, all through its life period. However, as the system approached Tamil Nadu coast, there was land interaction and moisture supply also reduced relatively as evident from TPW imageries on 04th and 05th Dec. However, being in the Low latitude easterly wave regime over the BoB, there was no cold air advection which could be attributed to the weakening of the system.

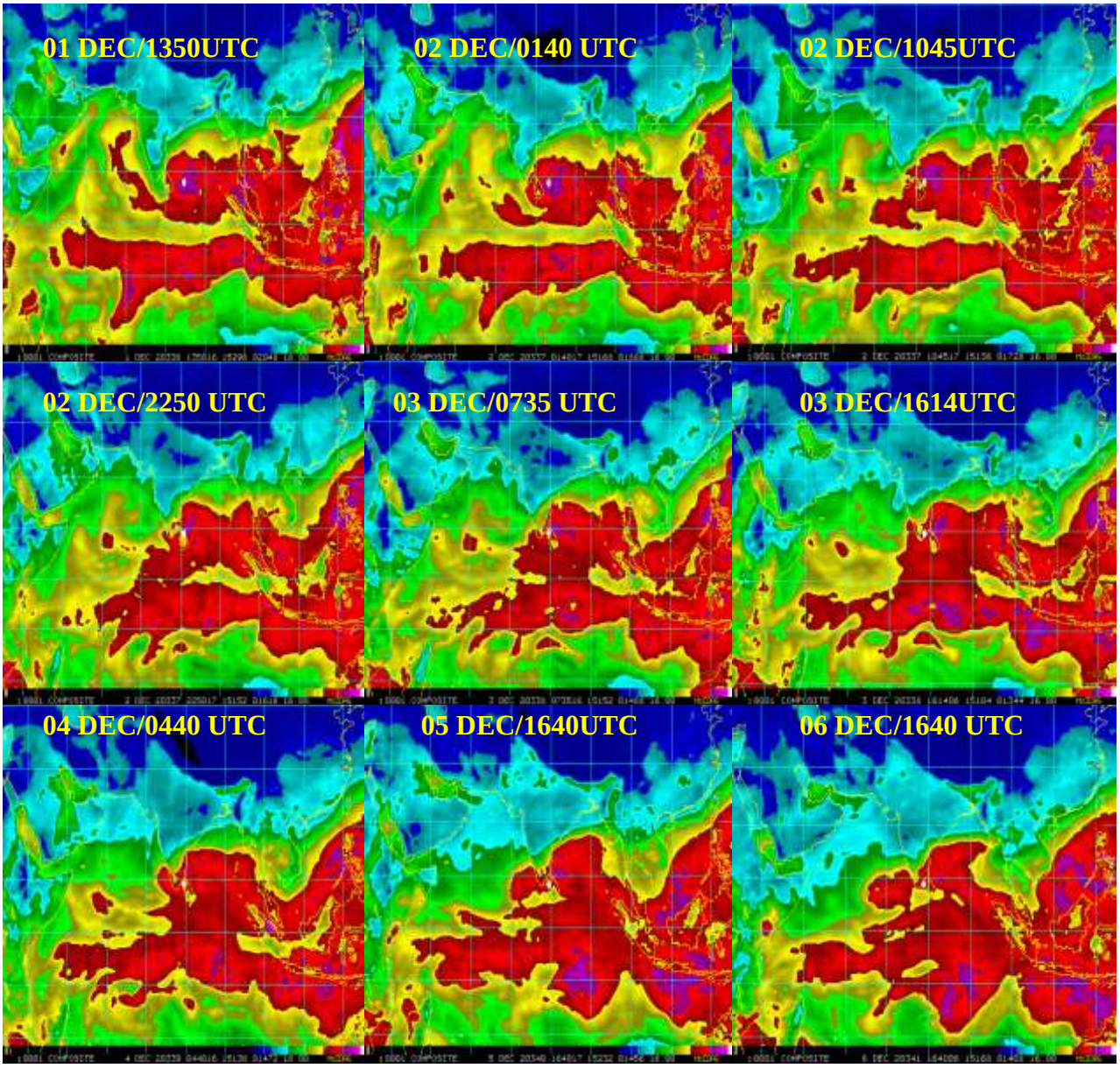


Fig. 9: Total Precipitable Water (TPW) imageries during CS BUREVI during 01-06 December, 2020

The wind speed in middle and deep layer around the system centre is presented in **Fig.6.** The wind shear around the system between 200 & 850 hPa levels remained low to moderate (15-20 knots) initially. However, it increased gradually from the genesis stage to dissipation stage. The direction of 200-850 hPa wind shear was southeasterly during the entire period. It caused the convective cloud mass to be sheared to the northeast of the system centre.

4.1 Maximum Sustained Surface Wind speed and estimated central pressure

The lowest estimated central pressure and the maximum sustained wind speed are presented in Fig.10a. There was gradual fall in pressure during the period 0000 UTC of 30th November to 0000 UTC of 2nd December. The lowest estimated central pressure

was 996 hPa during 0600 UTC to 1800 UTC of 2nd December. The estimated maximum sustained surface wind speed (MSW) was 45 knots during the period with pressure drop of 10 hPa. Thereafter, the pressure gradually increased till 1200 UTC of 3rd and thereafter, the system maintained it's intensity till 0000 UTC of 5th.

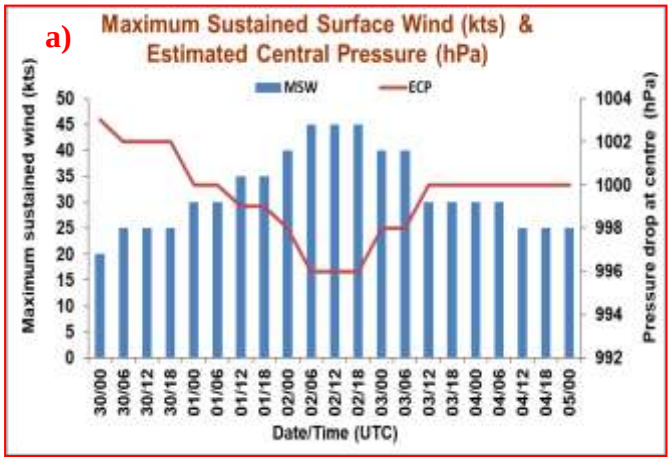


Fig.10. (a) Maximum sustained surface winds (kts) & Estimated Central Pressure

4.2 Translational speed & direction of movement

The twelve hourly movement of CS BUREVI is presented in **Fig.10b**. The 12 hourly average translational speed of the cyclone was about 9.5 kmph against the normal speed of 12.9 kmph for CS category over the BoB during post monsoon season. 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. 10a.

Fig.10(b) Mean Translational Speed during life cycle of CS BUREVI

5. Monitoring

5.1 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.11(a) – 11(d). The system showed curved band pattern during genesis and developing stage spiral band pattern during the mature stage. It showed sheared pattern after landfall.

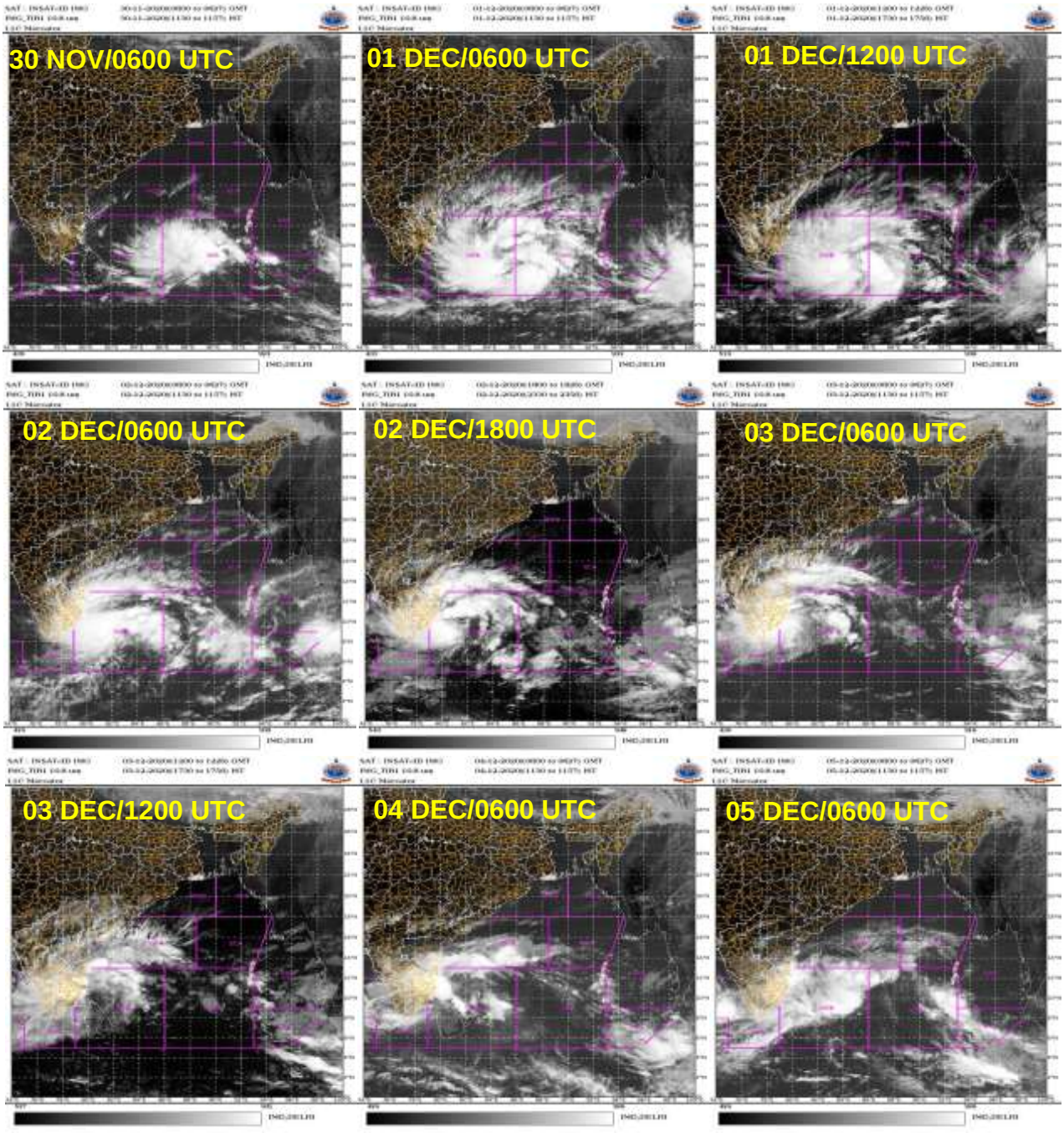


Fig. 11(a): INSAT-3D IR imageries during life cycle of CS BUREVI (30 Nov-05 DEC), 2020

At 0000 UTC of 30 November as per satellite imagery, intensity was T1.5. Broken low and medium clouds with embedded intense to very intense convection lay over south east Bay of Bengal between lat 6.0N & 10.5N and long 83.0E & 90.5E in association with the system. Minimum Cloud Top Temperature (CTT) was - 85ºC.

At 1200 UTC of 30 November as per satellite imagery, the intensity of the system was T1.5. Broken low and medium clouds with embedded intense to very intense convection lay over southeast Bay of Bengal and neighbourhood between lat 5.5N & 12.5N and long 83.0E & 90.0E in association with the system. Minimum CTT was - 93ºC.

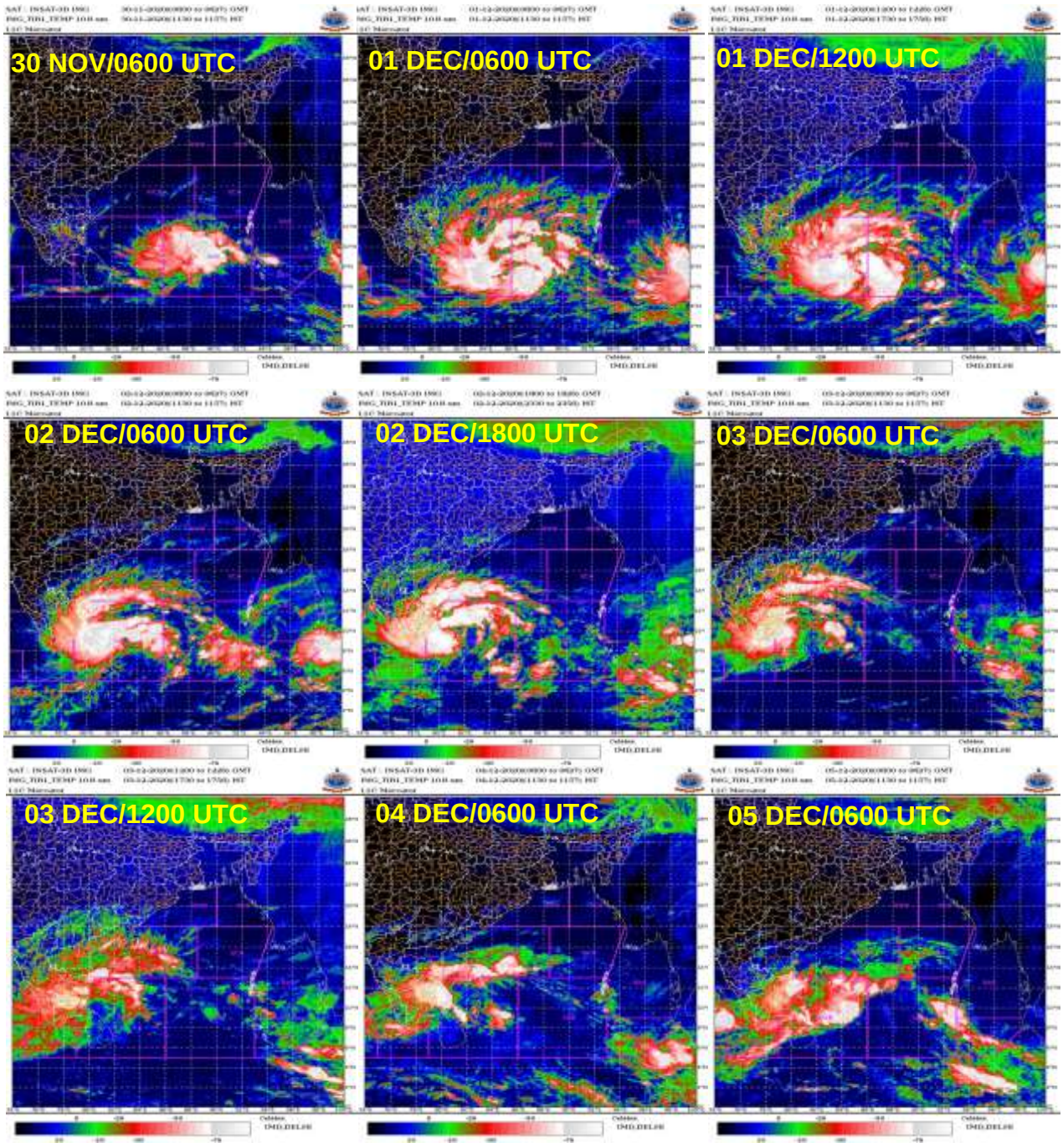


Fig. 11(b): INSAT-3D enhanced colored imageries during life cycle of CS BUREVI (30 Nov-05 DEC), 2020

At 0000 UTC of 01 December, as per satellite imagery the intensity of the system was T2.0/2.0. Centre was not clearly defined in satellite imagery. Broken low and medium clouds with embedded intense to very intense convection lay over south Bay of Bengal between lat 4.5^0N & 14.5^0N and long 81.5^0E & 92.5^0E in association with the system. Minimum CTT was - 93^0C.

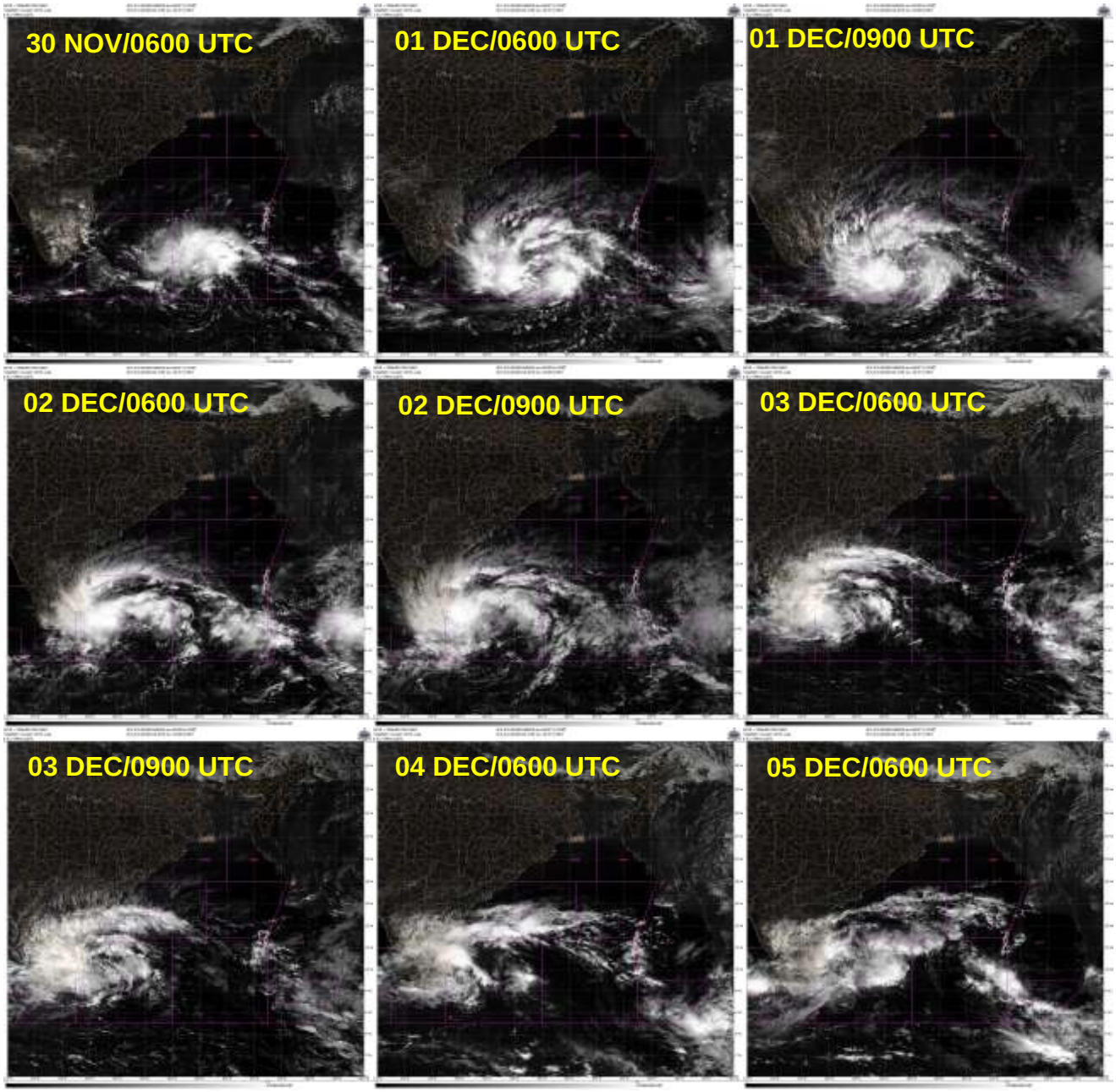


Fig. 11(c): INSAT-3D Visible imageries during life cycle of CS BUREVI (30 Nov-05 DEC), 2020

At 1200 UTC of 01 December, as per satellite imagery, the intensity of the system was T2.5 with shear pattern. Broken low and medium clouds with embedded intense to very intense convection lay over south Bay of Bengal between lat 5.0^{0}N & 13.5^{0}N and long 80.0^{0}E & 90.0^{0}E and also over Sri Lanka in association with the system. Minimum CTT was - 93^{0}C.

At 0000 UTC of 02 December, as per satellite imagery, the intensity of the system was T2.5. Broken low and medium clouds with embedded intense to very intense convection lay over south Bay of Bengal between lat 6.0^{0}N & 13.5^{0}N and long 81.5^{0}E & 90.0^{0}E and moderate to intense convection over Sri Lanka in association with the system. Minimum CTT was - 93^{0}C.

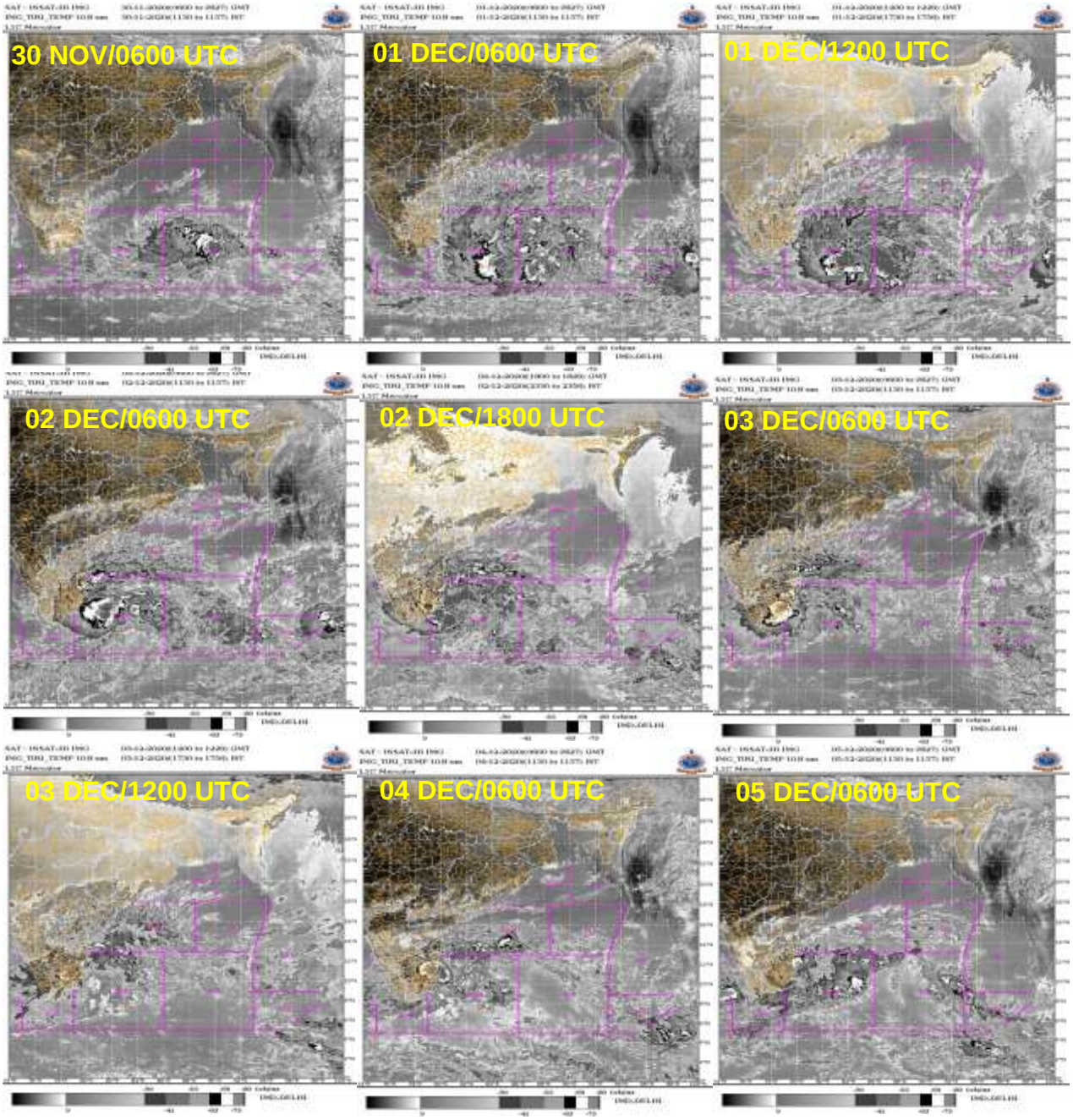


Fig. 11(d): INSAT-3D BD curve imageries during life cycle of CS BUREVI (30 Nov-05 DEC), 2020

At 1200 UTC of 02 December, as per satellite imagery, the intensity of the system was T3.0. Broken low and medium clouds with embedded intense to very intense convection lay over south & adjoining central Bay of Bengal between lat 7.0^0N &14.0^0N and long 80.0^0E & 87.0^0E and over east Tamil Nadu, Palk strait and Sri Lanka. Minimum CTT was - 93^0C. As the system was approaching coast, intense convective cloud was found over Sri Lanka and cloud band was interacting with land. Another cloud band associated with the system was also lying over coastal Tamil Nadu and Gulf of Mannar.

At 0000 UTC of 03 December, as per satellite imagery, the system was over land of Sri Lanka. The centre was not clearly defined and associated broken low / medium clouds with embedded intense to very intense convective clouds lay over southwest and adjoining west central Bay of Bengal between lat 8.0^0N & 14.0^0N and long 77.0^0E & 84.0^0E and also over Tamil Nadu and adjoining Andhra Pradesh, Gulf of Mannar & north Sri Lanka with minimum cloud top temperature - 93^0C.

At 1200 UTC of 03 December, as per satellite imagery, the intensity of the system was T2.0. Associated broken scattered to broken low/medium clouds with embedded intense to very intense convective clouds lay over Tamil Nadu and moderate to intense convection over Palk strait, Gulf of Mannar & Comorin area with minimum cloud top temperature - 93^0C.

At 0000 UTC of 04 December, as per satellite imagery, associated broken low/medium clouds with embedded intense to very intense convective clouds lay over Tamil Nadu, Gulf of Mannar and Palk strait with minimum cloud top temperature - 93^0 C.

At 1200 UTC of 04 December, as per satellite imagery, associated broken low/medium clouds with embedded intense to very intense convective clouds lay over Tamil Nadu, Gulf of Mannar, Palk strait and Comorin with minimum cloud top temperature - 93^0 C.

At 0600 UTC of 05 December, as per satellite imagery, associated broken low/medium clouds with embedded moderate to intense convection lay over Tamil Nadu, Gulf of Mannar, Palk strait, Comorin area and Sri Lanka.

Typical Scatterometer (ASCAT) and Microwave imageries are presented in **Fig.11(e)** & **11(f)** respectively.

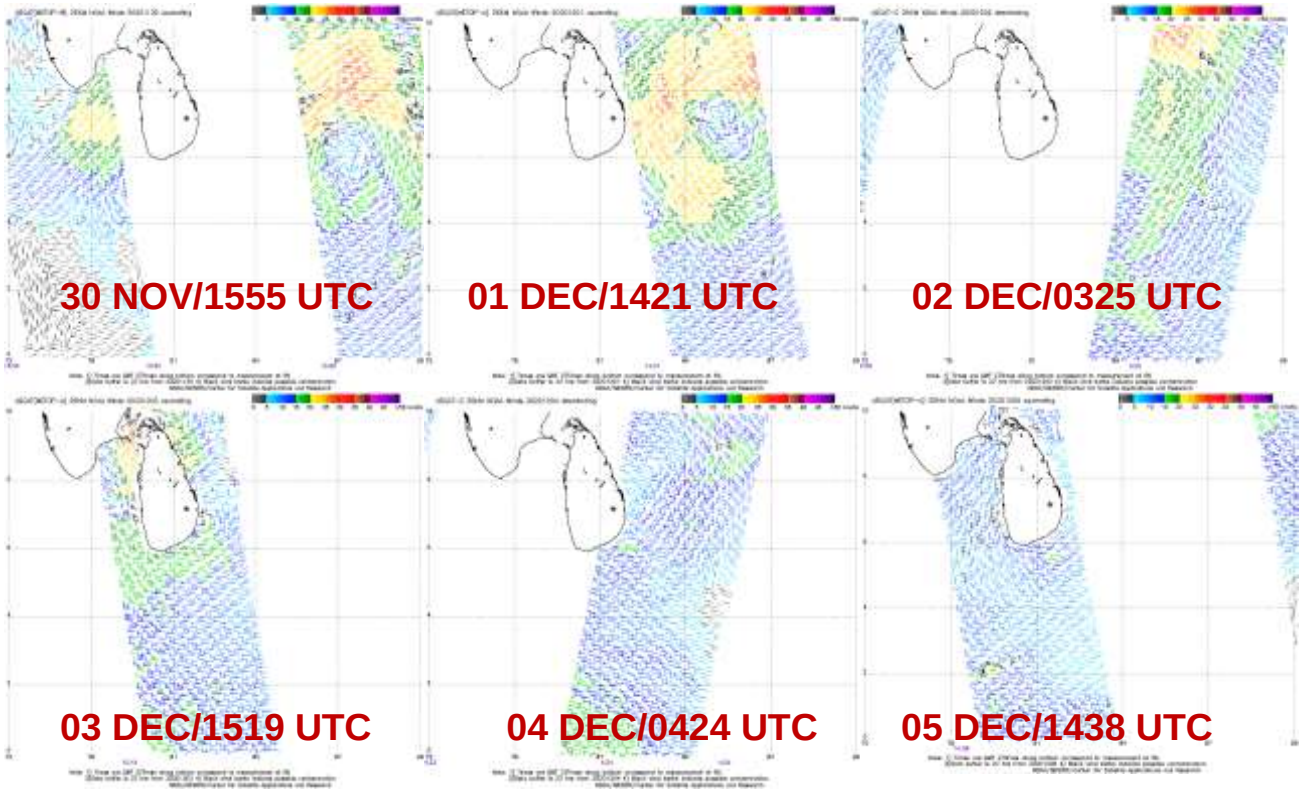


Fig. 11(e): ASCAT imageries during life cycle of CS BUREVI (30 Nov-05 Dec, 2020)

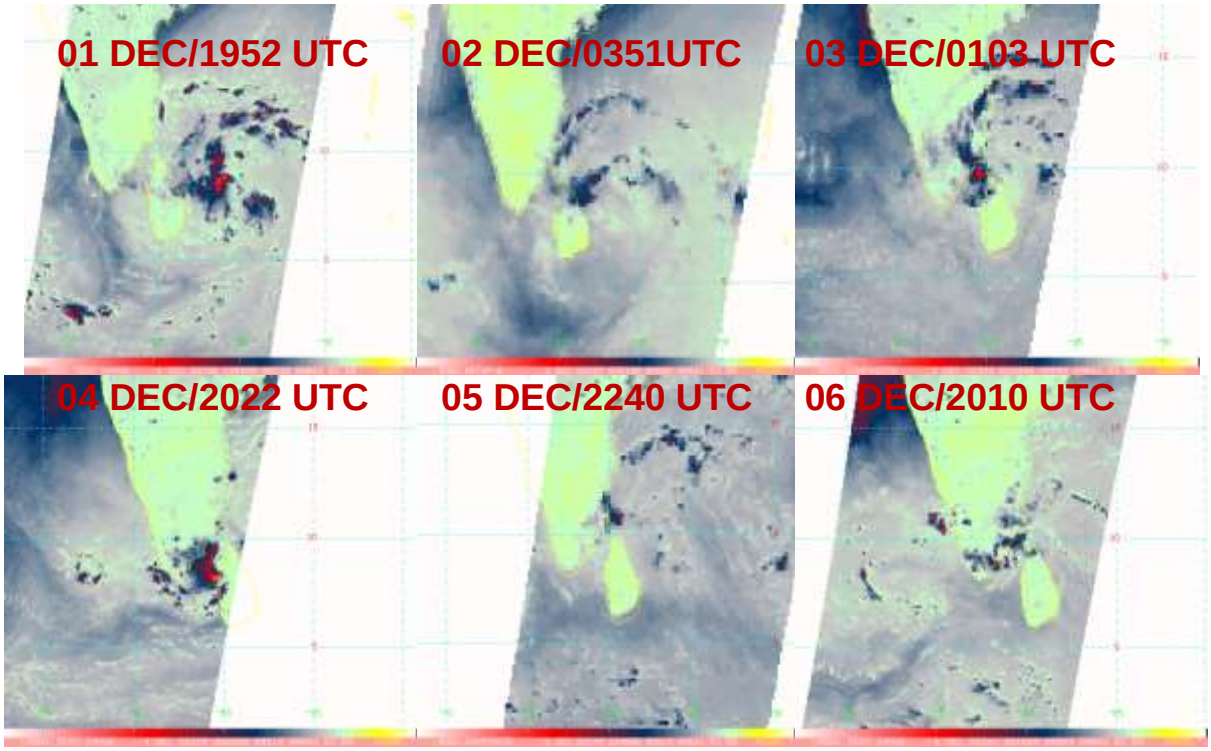


Fig. 11(f): Microwave imageries during life cycle of CS BUREVI (30 Nov-05 Dec, 2020)

6. **Dynamical features**

IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels during 30th November - 05th December are presented in **Fig. 12(a) – 12(f).** Forecast fields are not presented. The analysis of IMD-GFS T-1534 model forecasts based on 0000 UTC of 30th November, 2020 indicated presence of a Depression (D) over southeast BoB on 30th November, its rapid intensification into a Very Severe Cyclonic Storm (VSCS) over southeast & adjoining southwest BoB on 01st December, as VSCS over eastern coast of Sri Lanka on 02nd, after moving across north Sri Lanka, as a D over extreme south coastal Tamil Nadu on 03rd, weakening as a trough of Low over Lakshadweep – Maldives area on 04th, westward movement as a Well Marked Low Pressure Area (WML) over to southeast Arabian Sea (AS) and adjoining Lakshadweep area on 05th and further westward movement and weakening over southeast AS on 08th December.

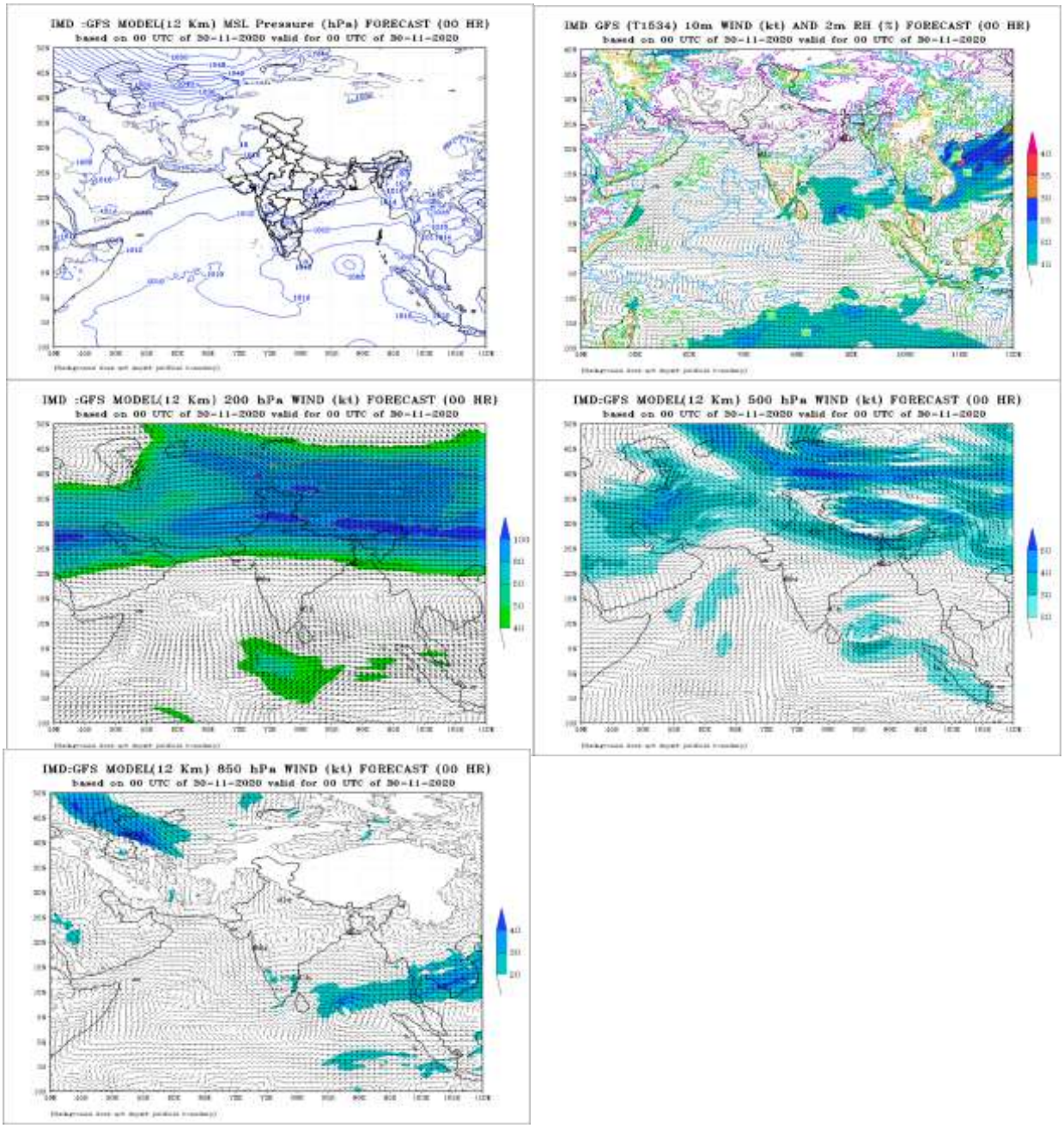


Fig. 12(a): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 30th November 2020

The analysis of IMD-GFS T-1534 model forecasts based on 0000 UTC of 01st December, 2020 indicates presence of a Deep Depression (DD) over southeast & adjoining southwest BoB on 01st December, its intensification into a Cyclonic Storm (CS) over southwest BoB off Sri Lanka coast on 02nd December, after crossing Sri Lanka coast, rapid intensification into a Very Severe Cyclonic Storm (VSCS) over Comorin area, very close to south Tamil Nadu coast on 03rd, crossing south Tamil Nadu coast & emerging as a Low Pressure Area (LPA) over southeast Arabian Sea (AS) off south Kerala coast on 04th, moving westwards and re-intensifying into a Depression (D) over southeast AS and adjoining Lakshadweep area on 05th, into a CS over southeast & adjoining east-central AS on 06th, CS over central & adjoining south AS on 07th, rapid weakening into an LPA over southwest AS on 08th and LPA over southwest AS off Somalia coast on 09th and weakening on 10th December.

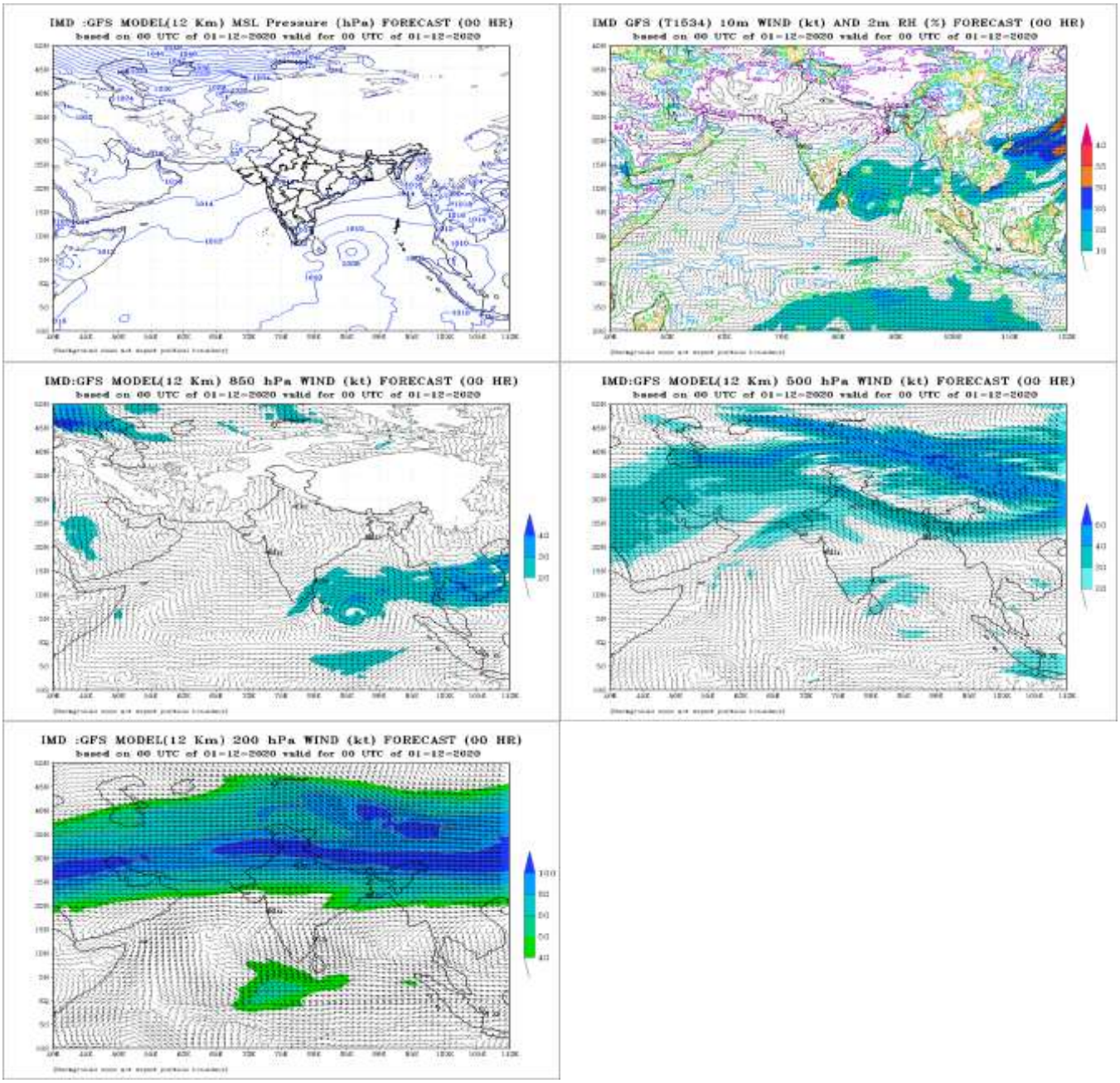


Fig. 12(b): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 1st December 2020

The analysis of IMD-GFS T-1534 model forecasts based on 0000 UTC of 02nd December, 2020 indicates presence of a Super Cyclonic Storm (SuCS) southwest BoB off Sri Lanka coast on 02nd December, after crossing Sri Lanka, as an Extremely Severe Cyclonic Storm (ESCS) over Gulf of Mannar, close to south Tamil Nadu coast on 03rd, as a Depression over south coastal Tamil Nadu on 04th, re-emerging and re-intensification into a Cyclonic Storm (CS) over Lakshadweep area on 05th,westward movement & further intensification into an ESCS over southeast Arabian Sea (AS) on 06th, as an SuCS over southeast & adjoining east-central AS on 07th, over central parts of AS on 08th, further west-southwestward movement & gradual weakening into an ESCS over west-central AS on 09th, Very Severe Cyclonic Storm (VSCS) over southwest AS on 10th, as D over southwest AS off Somalia coast on 11th and rapid weakening on 12th.

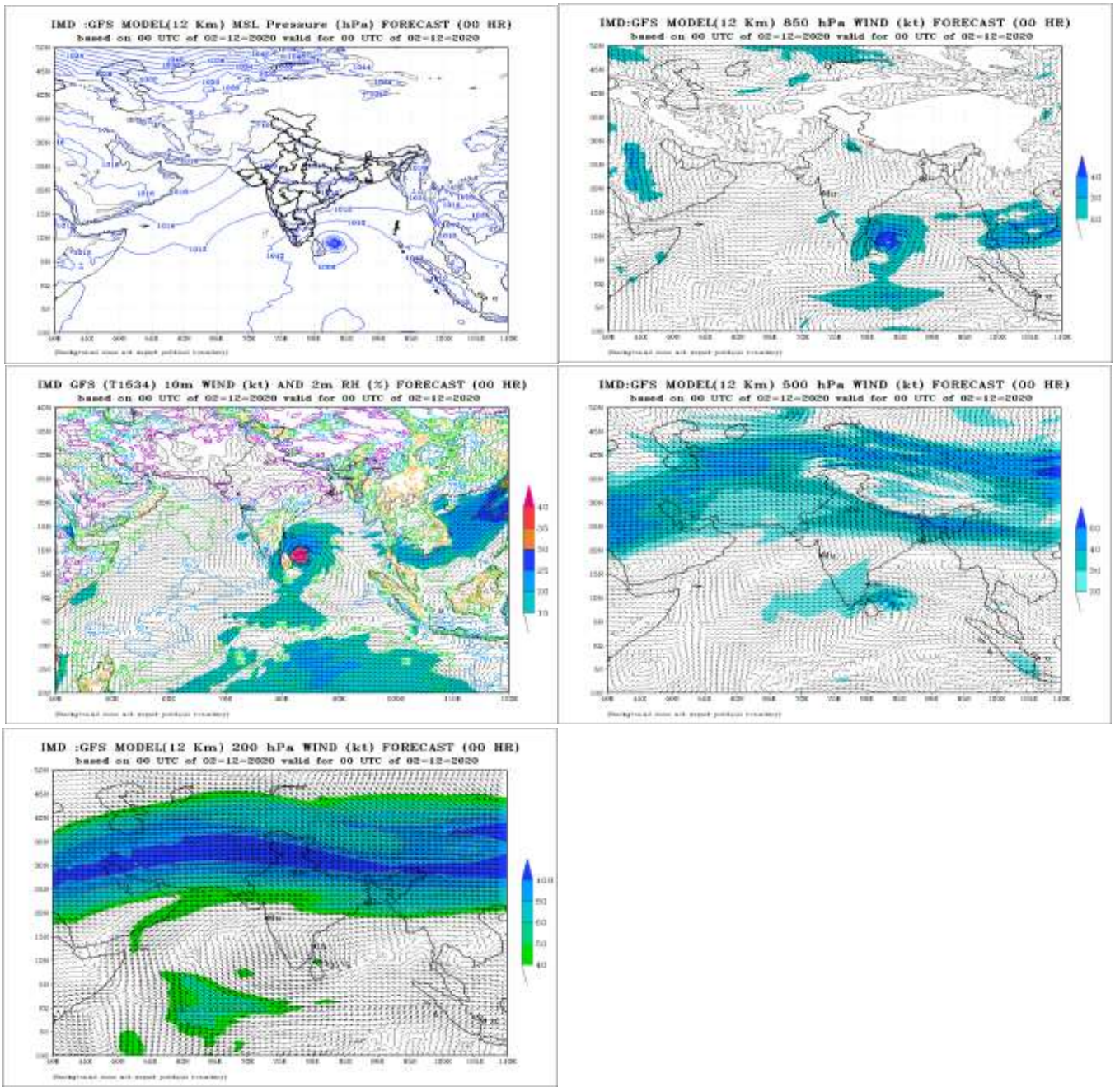


Fig.12 (c): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 2nd December 2020

The analysis of IMD-GFS T-1534 model forecasts based on 0000 UTC of 03rd December, 2020 indicates presence of a Very Severe Cyclonic Storm (VSCS) over north Sri Lanka coast on 03rd December, a Depression over south Tamil Nadu coast on 04th, emerging as a Low pressure Area (LPA) over southeast Arabian Sea (AS) and adjoining Lakshadweep area on 05th, westward movement & slight re-organisation over southeast Arabian Sea (AS) on 06th, further westward movement without any significant intensification over to southwest AS during 07th – 10th December and weakening over the same region on 11th & 12th December. So unlike the forecasts based on 02nd December, the forecasts based on 3rd December initial conditions were found to be ruling out the chance of re-intensification over the AS.

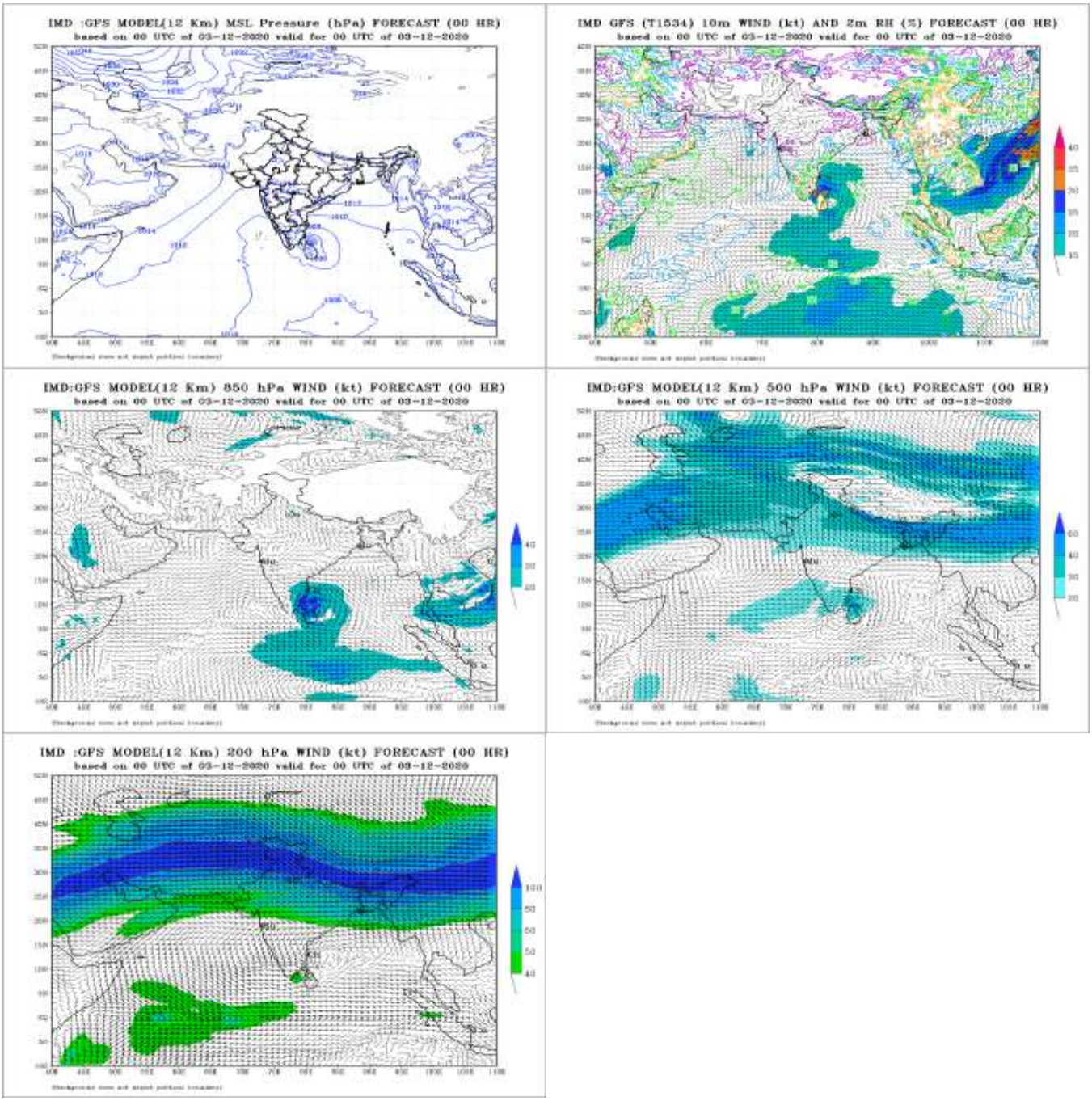


Fig.12 (d): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 3rd December 2020

The analysis of IMD-GFS T-1534 model forecasts based on 0000 UTC of 04th December, 2020 indicates presence of a Depression (D) over Gulf of Mannar on 04th, emerging as a Low pressure Area (LPA) over southeast Arabian Sea (AS) off Kerala coast on 05th, persistence on 06th, as an extended Low over southeast BoB on 07th, again as an LPA over southeast & adjoining southwest AS on 08th and its gradual westward movement without any significant intensification over to southwest AS during 09th – 11th December and weakening over southwest AS off Somalia coast by 13th December.

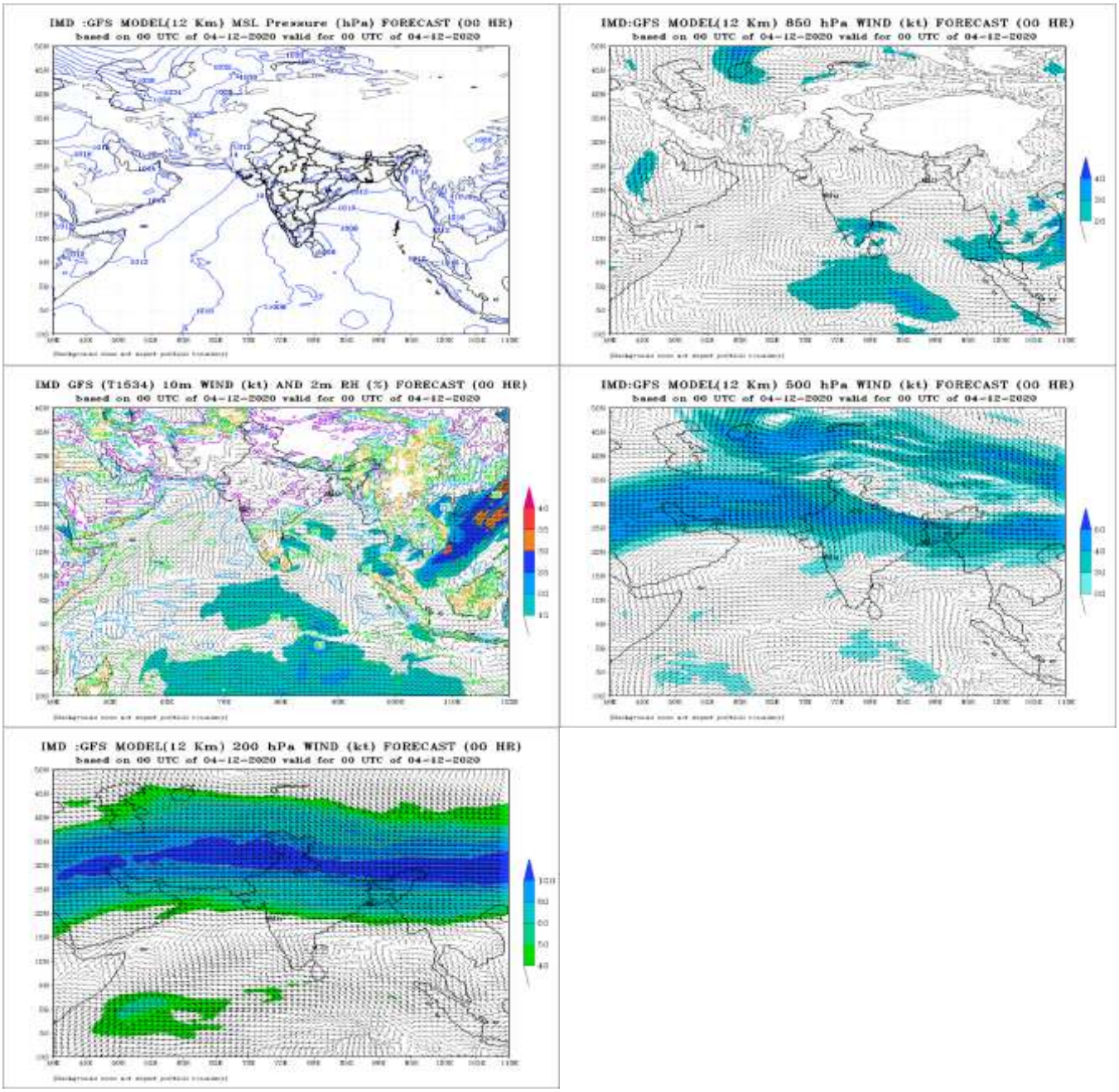


Fig. 12(e): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 4th December 2020

The analysis of IMD-GFS T-1534 model forecasts based on 0000 UTC of 05th December, 2020 indicates presence of a Depression (D) over Gulf of Mannar on 05th, its weakening into a Low Pressure Area (LPA) over the same region on 06th, emerging as an extended over southeast Arabian Sea (AS) on 07th, again as an LPA over southeast AS on 08th and its gradual westward movement without any significant intensification over to southwest AS during 09th – 13th December and weakening over southwest AS on 14th December.

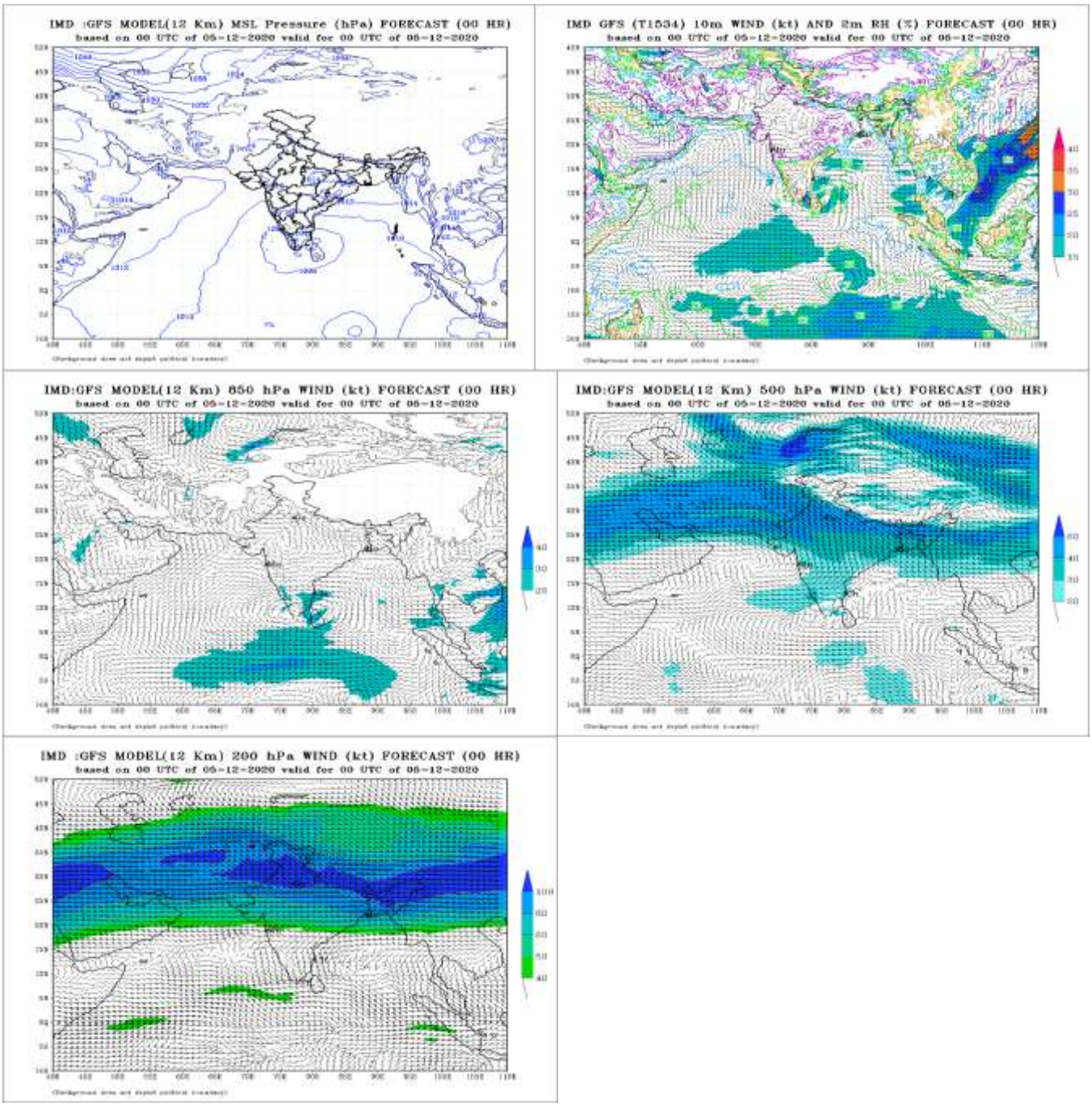


Fig. 12(f): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 5th December 2020

7. Realized Weather

7.1 Rainfall

Rainfall associated with CS BUREVI based on IMD-NCMRWF GPM merged gauge rainfall data is depicted in **Fig 13**. It indicates heavy rainfall (7-12 cm) over southwest BoB during 30th November to 02nd December and heavy to very heavy rainfall (7-19 cm) at many places over coastal Tamil Nadu with extremely heavy falls (≥20 cm) at a few places during 02nd – 05th December.

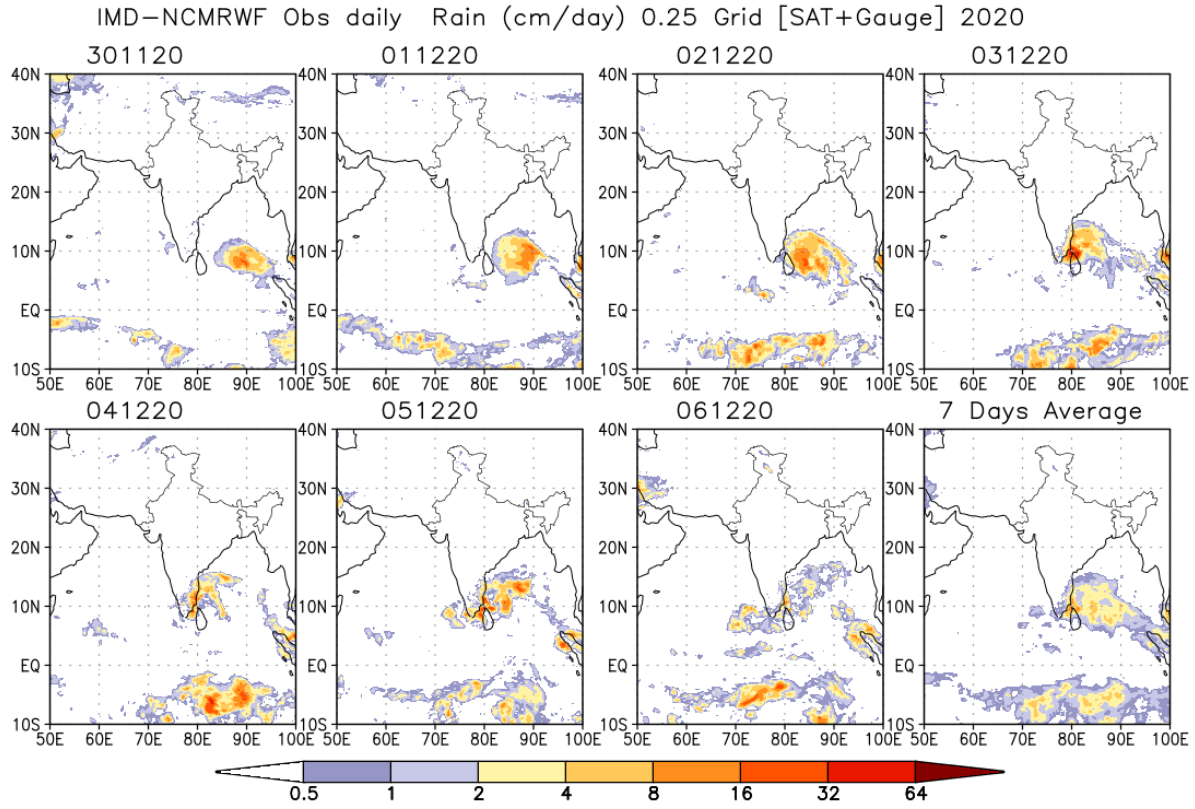


Fig.13: IMD-NCMRWF GPM merged gauge rainfall during 30th Nov- 01st Dec and 7 days average rainfall (cm/day)

Realized 24 hrs accumulated rainfall (≥7cm) over Tamil Nadu, Puducherry & Karaikal during the life cycle of the system is presented below:

2nd December:

Vedaranyam (dist Nagapattinam) - 20, Karaikal (dist Karaikal)- 16, Thalaignayer (dist Nagapattinam) & Tirupoondi (dist Nagapattinam) -15 each, Nagapattinam (dist Nagapattinam)- 14, Thiruthuraipoondi (dist Tiruvarur) -13, Mayiladuthurai (dist Nagapattinam) , Rameswaram (dist Ramanathapuram)- 12 each, Mudukulatur (dist Ramanathapuram) - 11, Sirkali (dist Nagapattinam), Kodavasal (dist Tiruvarur) , Adirampatnam (dist Thanjavur) , Manjalaru (dist Thanjavur) - 10 each, Tiruvarur (dist Tiruvarur) ,Aduthurai (dist Thanjavur) , Tambaram (dist Chengalpattu) , Pattukottai (dist Thanjavur) - 9 each, Nannilam (dist Tiruvarur), Marakkanam (dist Villupuram), Pamban

(dist Ramanathapuram), Thiruvidaimaruthur (dist Thanjavur), Thirukalukundram (dist Chengalpattu), Puducherry (dist Puducherry), Valangaiman (dist Tiruvarur) -8 each, Manalmedu (dist Nagapattinam), Kollidam (dist Nagapattinam), Kelambakkam (dist Chengalpattu), K.M.koil (dist Cuddalore), Vanur (dist Villupuram), Mannargudi (dist Tiruvarur), Taramani (dist Chennai), Madukkur (dist Thanjavur), Parangipettai (dist Cuddalore), Ayyampettai (dist Thanjavur), ThanjaiPapanasam (dist Thanjavur), Cuddalore (dist Cuddalore), Needamangalam (dist Tiruvarur) -7 each

3rd December:

Kollidam (dist Nagapattinam) - 36, Chidambaram (dist Cuddalore) - 34, Parangipettai (dist Cuddalore) - 26, Manalmedu (dist Nagapattinam), Kurinjipadi (dist Cuddalore) - 25 each, Thiruthuraipoondi (dist Tiruvarur) - 22, Sirkali (dist Nagapattinam) , Kodavasal (dist Tiruvarur) - 21 each, Rameswaram (dist Ramanathapuram) - 20, Peravurani (dist Thanjavur), Manjalaru (dist Thanjavur), Bhuvanagiri (dist Cuddalore), Mayiladuthurai (dist Nagapattinam)- 19 each, Karambakudi (dist Pudukkottai), Pattukottai (dist Thanjavur)-17 each, Madukkur (dist Thanjavur)-16, Srimushnam (dist Cuddalore)-15, Tindivanam (dist Villupuram), Nannilam (dist Tiruvarur), Thiruvidaimaruthur (dist Thanjavur)-14 each, Kumbakonam (dist Thanjavur), Ayyampettai (dist Thanjavur), Valangaiman (dist Tiruvarur), Panruti (dist Cuddalore), Ulundurpet (dist Villupuram)-13 each, Aduthurai (dist Thanjavur), Alangudi (dist Pudukkottai), Pandavaiyar Head (dist Tiruvarur) 12 each, Tiruvarur (dist Tiruvarur), Budalur (dist Thanjavur), Mahabalipuram (dist Chengalpattu), Mannargudi (dist Tiruvarur)-11 each, Vallam (dist Thanjavur), Perambalur (dist Perambalur), Thanjavur (dist Thanjavur), Thirumanur (dist Ariyalur) , Needamangalam (dist Tiruvarur)-10 each, Sendurai (dist Ariyalur) , Tirukattupalli (dist Thanjavur) , Vilupuram (dist Villupuram) , Mylam Aws (dist Villupuram) , Cholavaram (dist Tiruvallur) , Vanur (dist Villupuram) , Gandarvakottai (dist Pudukkottai) , Marakkanam (dist Villupuram) , Chengalpattu (dist Chengalpattu) , Gingee (dist Villupuram) - 9 each, Keeranur (dist Pudukkottai) , Thalaignayer (dist Nagapattinam) , Agaram Seegoor (dist Perambalur) , Eraiyur (dist Perambalur) , Gummidipoondi (dist Tiruvallur) , Adirampatnam (dist Thanjavur) , Manamelkudi (dist Pudukkottai) , Pullambadi (dist Trichy) , Annavasal (dist Pudukkottai) , Samayapuram (dist Trichy) , Pamban (dist Ramanathapuram) , Perungalur (dist Pudukkottai) , Tarangambadi (dist Nagapattinam) - 8 each , Labbaikudikadu (dist Perambalur) , Tozhudur (dist Cuddalore) , Tirukoilur (dist Villupuram) , Thuvakudi Imti (dist Trichy) , Uthukottai (dist Tiruvallur) , Ariyalur (dist Ariyalur) , Anna UTY (dist Chennai) , Uthiramerur (dist Chengalpattu) , Tirupoondi (dist Nagapattinam) , Tirumayam (dist Pudukkottai) , Tondi (dist Ramanathapuram) , TRP Town (dist Trichy) - 7 each

4th December:

Nagapattinam (Nagapattinam) and Karaikal (Karaikal)-16 each, Kodavasal (Tiruvarur) and Bhuvanagiri (Cuddalore)- 15 each, Sethiyathope (Cuddalore)-14, Tarangambadi (Nagapattinam)-13, Sirkali (Nagapattinam), DGP Office (Chennai), Vembakkam (Tiruvannamalai) and Srimushnam (Cuddalore)- 12 each, Rameswaram (Ramanathapuram), Anna University (Chennai), Tirupoondi (Nagapattinam) and Kayalpattinam (Toothukudi)-11 each, Sriperumbudur (Kancheepuram), Kollidam (Nagapattinam), Mgr Nagar (Chennai) and Pelandurai (Cuddalore)-10 each, Uthukottai (Tiruvallur), Chembarambakkam (Tiruvallur), Tuticorin (Toothukudi), Thalaignayer (Nagapattinam)-9 each

5th December:

Muthupet (dist Tiruvarur)-10, Mahabalipuram (dist Chengalpattu)-7 each, Kodavasal (dist Tiruvarur), Nannilam (dist Tiruvarur) & Thalaignayer (dist Nagapattinam)-6 each and

Thiruthuraipoondi (dist Tiruvarur), Cheyyur (dist Chengalpattu), Kollidam (dist Nagapattinam), Cholavaram (dist Tiruvallur), Tirupoondi (dist Nagapattinam) and Chidambaram (dist Cuddalore) 5 each.

6th December:

Maniyachi (dist Toothukudi) -16, Vaippar (dist Toothukudi) -12, Kadambur (dist Toothukudi) -11, Kayathar (dist Toothukudi), Sirkali (dist Nagapattinam), Karaikal (dist Karaikal), Chittar–(dist Kanyakumari) - 9 each, Thalaignayer (dist Nagapattinam), Mayiladuthurai (dist Nagapattinam), Valinokam (dist Ramanathapuram), Needamangalam (dist Tiruvarur) - 8 each, Kodavasal (dist Tiruvarur) , Manalmedu (dist Nagapattinam), Palayamkottai (dist Tirunelveli), Vilathikulam (dist Toothukudi) - 7 each

8. Damage due to CS BUREVI

In Sri Lanka, 57 houses were destroyed with 2,753 others being damaged. According to the European Civil Protection and Humanitarian Aid Operations, 10,336 people were displaced. Burevi left 11 people dead and 5 others missing as on 6th December, 2020.

The Wellington Dam's water level reached above the highest flood stage, flooding isolated many villages from the capital city of Chennai. The Chidambaram Nataraja Temple in the district of Cuddalore was flooded after receiving 340 mm of precipitation. In Barathampattam, agricultural land was flooded, causing crop damage.

Fig.14(a): Paddy crop and sugarcane crop have suffered severe damage (source: https://www.newsclick.in/) **(b)** Flood in Tamil Nadu (source :https://www.thenewsminute.com/) **(c)** Uprooted trees in Chennai (source: http://www.uniindia.com) **(d)** A scene in Jaffna (source: tamilguardian.com)

In Puducherry, precipitation amounts of 138 mm were recorded on December 4, 2020. The power supply of the city was briefly cut off on December 3. In the area, damage to trees, crops and huts was reported.

9. Performance of operational NWP models

IMD operationally runs a regional model, 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 (T2.5) 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. The SCIP model is used for 12 hourly intensity predictions up to 72-h and a rapid intensification index (RII) is developed and implemented for the probability forecast of rapid intensification (RI). Decay model is used for prediction of intensity after landfall. In this report performance of the individual models, MME forecasts, SCIP, GPP, RII for the cyclonic storm Burevi are presented and discussed.

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

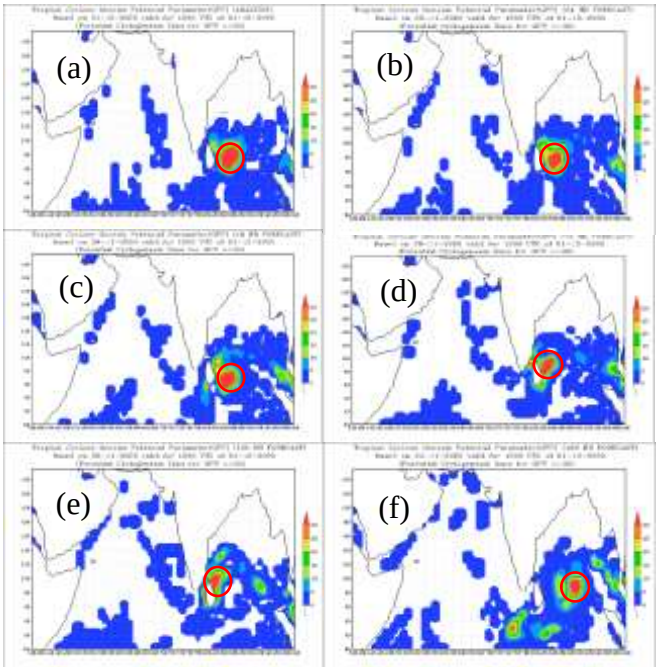


Fig.15 (a-f): Predicted zone of Cyclogenesis based on 1200 UTC from 24 November-1 December 2020

The model could predict cyclogenesis zone correctly about 144 hrs in advance. 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 a low pressure system which is having potential to develop into a CS, the Threshold value of average GPP could be ≥ 8.0 whereas for a non-developing system, the threshold value of GPP would be < 8.0. In the present case, this product had indicated potential for intensification of the system into a Cyclonic storm based on initial condition of 00 UTC of 29th November onwards. The area average values of GPP figure are shown in Fig.16.

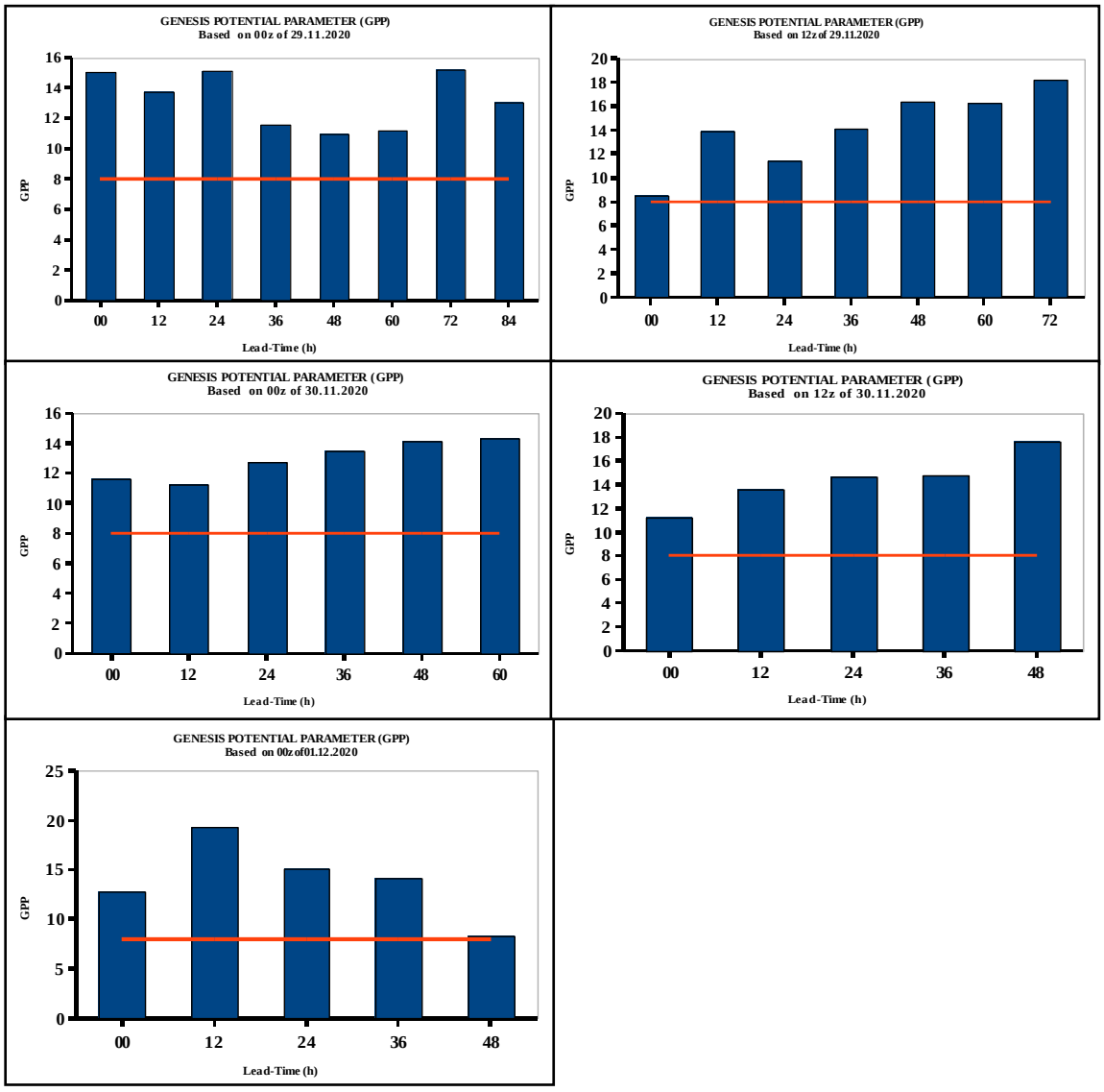


Fig. 16: Area average analysis and forecasts of GPP based on (i) 0000 UTC of 29.11.2020 (ii) 1200 UTC of 29.11.2020 (iii) 0000 UTC of 30.11.2020 (iv) 1200 UTC of 30.11.2020 (v) 0000 UTC of 01.12.2020

9.2 Track prediction by NWP models

Track prediction by various NWP models during 30th November to 02nd December is presented in **Fig.17**. Based on initial conditions of 0000 UTC of 30th November, most of the models indicated initial west-northwestward movement and crossing east coast of Sri Lanka over the northern part. NCEP GFS & IMD GFS models consistently indicated that after crossing Sri Lanka coast, it could re-emerge into Comorin area, maintaining the Cyclone intensity and further move westwards across south Kerala.

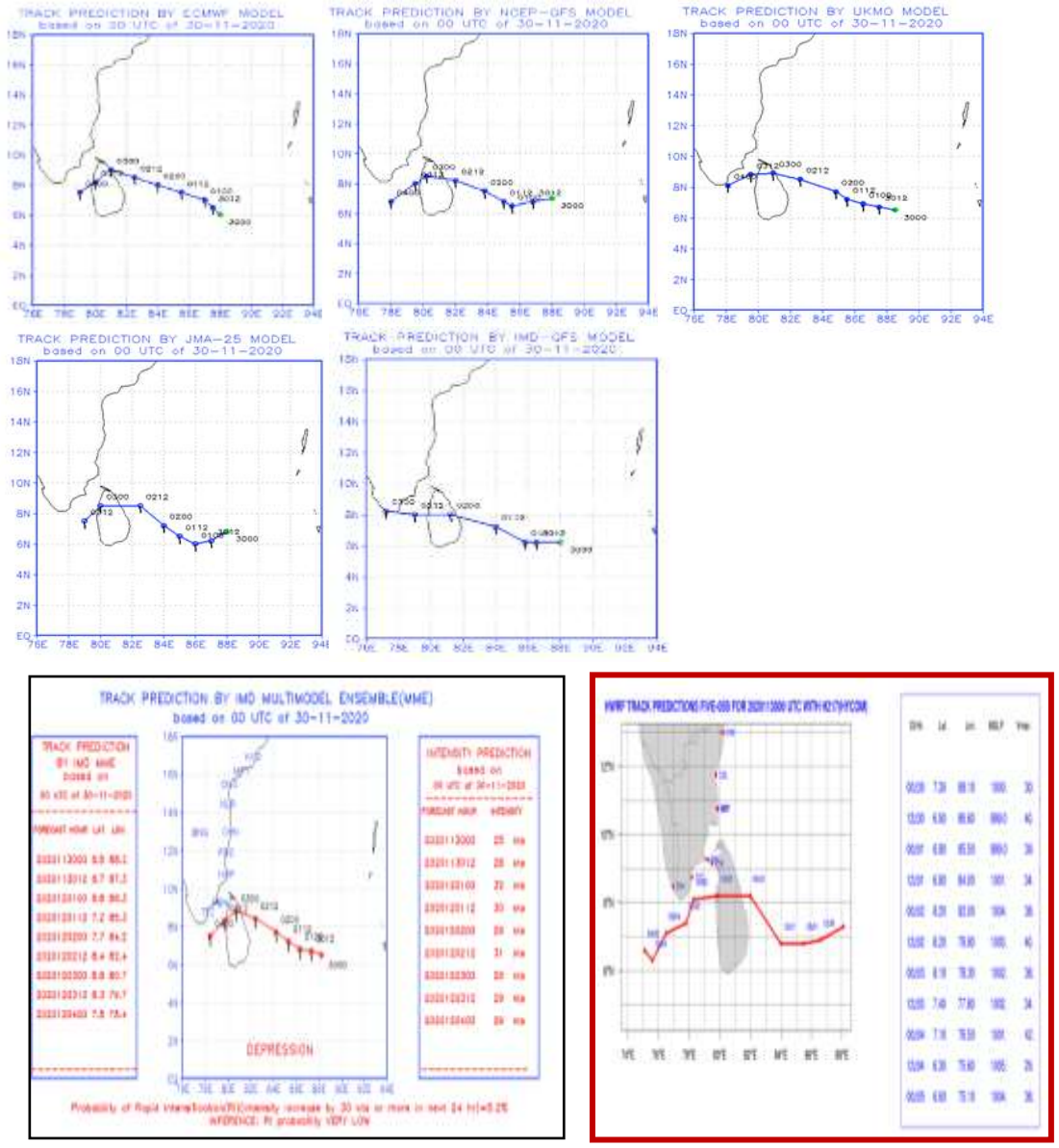


Fig. 17 (a): NWP model track forecast based on 0000 UTC of 30.11.2020

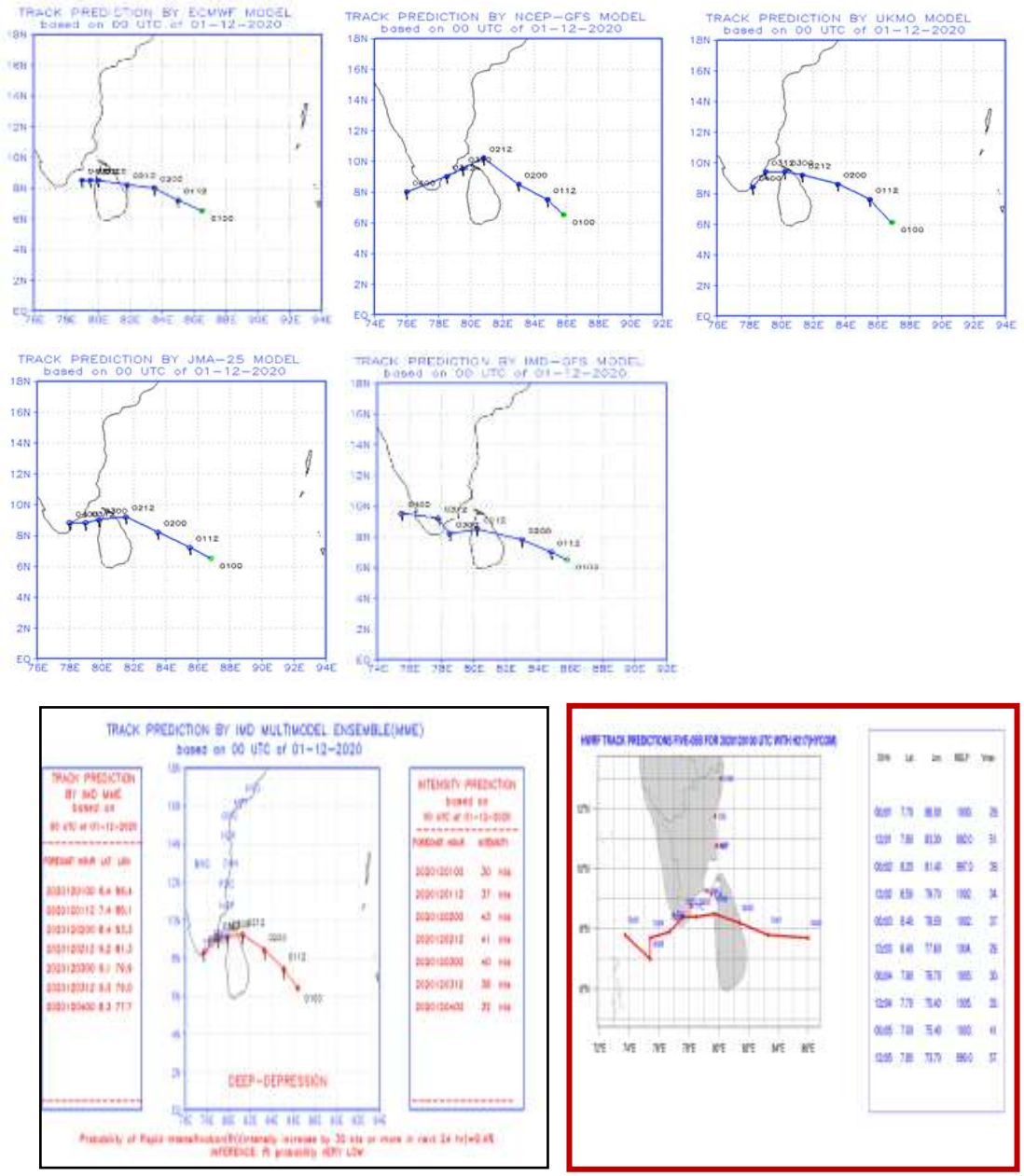


Fig. 17 (b): NWP model track forecast based on 0000 UTC of 01.12.2020

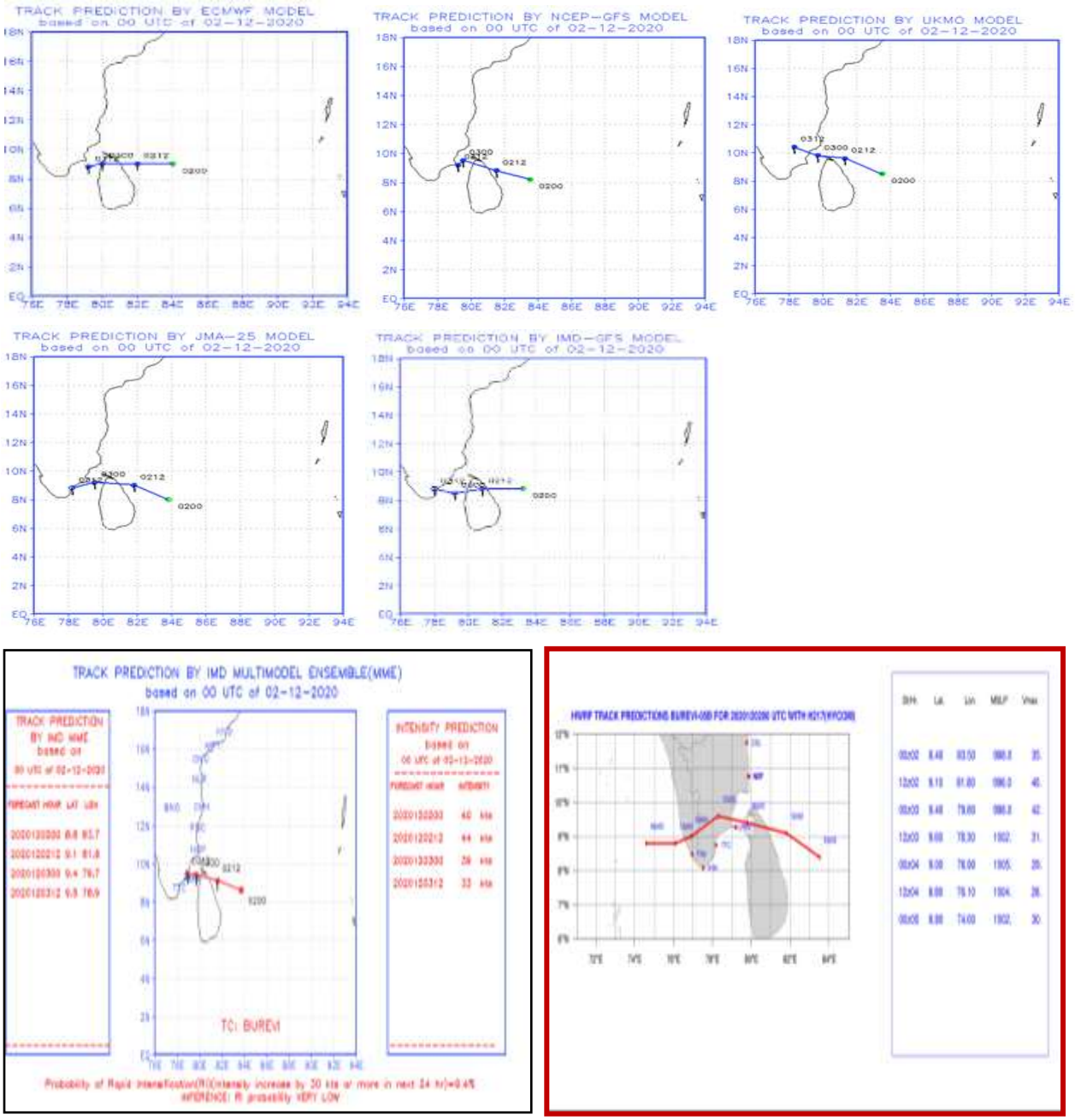


Fig. 17 (c): NWP model track forecast based on 0000 UTC of 02.12.2020

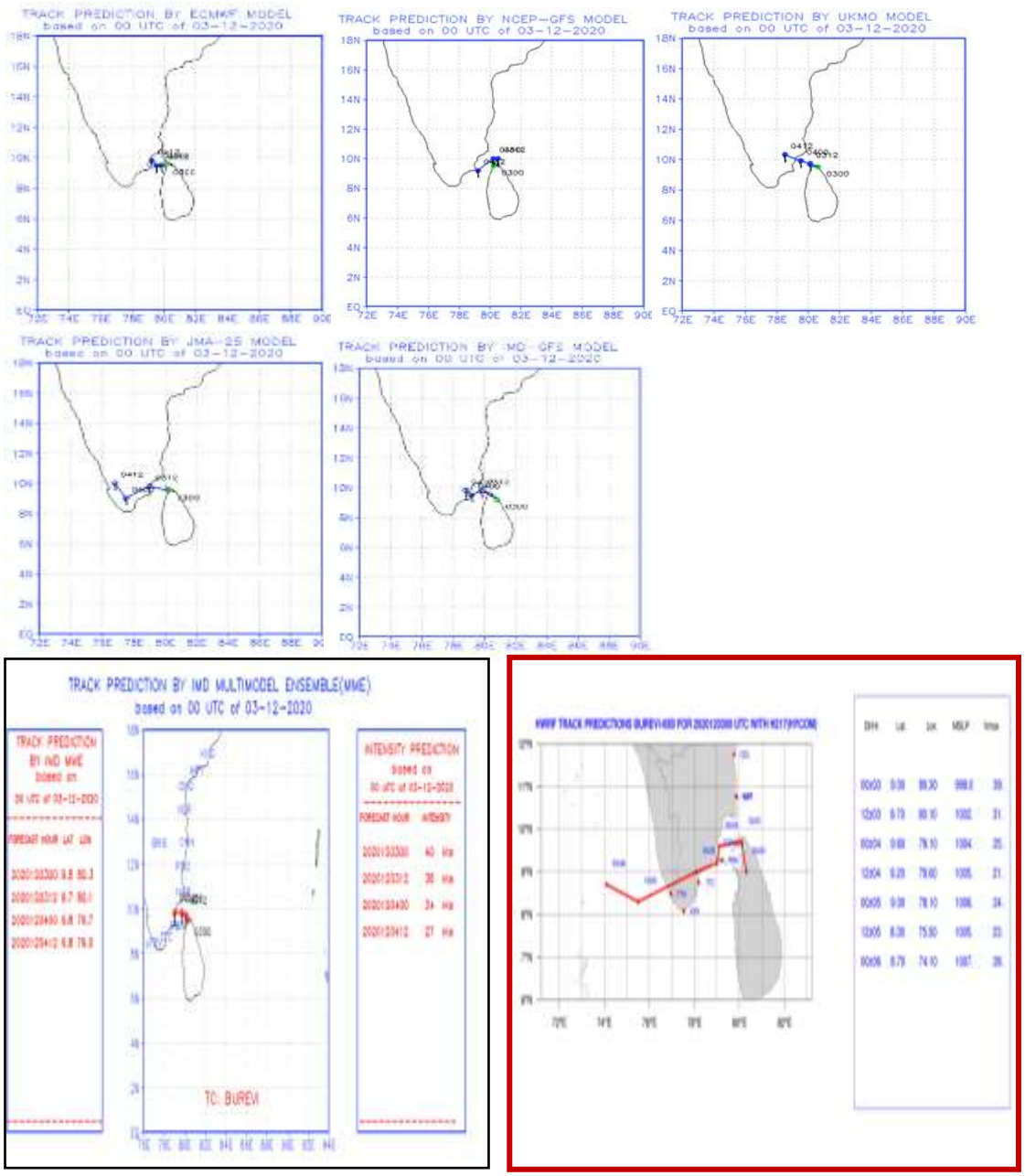


Fig. 17 (d): NWP model track forecast based on 0000 UTC of 03.12.2020

It may also be noted that HWRF was not consistent in its predictions on a day-to-day basis. Initially it predicted a west-southwestward movement across Comorin area after the first landfall and later as moving across interior Tamil Nadu & South Kerala and re-emerging over Lakshadweep area.

Thus it may be noted that the numerical models could not clearly indicate the unusually prolonged stagnation underneath the COL region in advance. Also, since the MME

solutions do not work for Islands / land locked regions as in the present case, the in-situ weakening of the system over the region also could not be predicted by MME.

9.3 Track forecast errors by various NWP Models

The average track forecast errors (Direct Position Error) in km at different lead period (hr) of various models are presented in **Table 2**. From the verification of the forecast guidance available from various NWP models, it is found that the average track forecast errors of MME model was minimum for 24 and 48 hr and 72 hours forecast. HWRF forecasts fared well next to MME only for the 12 hour period. Performance of NEPS, NCUM (G) & ECMWF were generally better following MME for the 24, 48 & 72 hours forecast.

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**	**96h**	**108h**	**120h**
IMD-MME	84(7)	76(7)	71(7)	73(4)	53(3)	76(3)	120(1)	179(1)	--	--
ECMWF	96(7)	88(7)	101(7)	123(4)	116(3)	82(3)	149(1)	183(1)	--	--
NCEP-GFS	81(7)	94(7)	103(7)	79(4)	58(3)	165(3)	140(1)	264(1)	--	--
UKMO	93(7)	94(7)	101(7)	103(4)	74(3)	80(3)	62(1)	124(1)	--	--
JMA	108(7)	107(7)	146(7)	125(4)	61(3)	83(3)	189(1)	**	--	--
IMD-GFS	109(7)	101(7)	156(7)	223(4)	235(3)	327(3)	**	**	--	--
HWRF	53 (19)	87 (17)	104 (15)	105 (13)	180 (11)	229 (9)	286 (7)	321 (4)	409 (2)	423 (1)
NCUMG	107 (8)	86 (8)	91 (7)	93 (4)	133 (6)	130 (7)	177 (7)	160 (7)	213 (7)	160 (6)
NCUMR	93 (9)	86 (8)	128 (9)	159 (10)	177 (8)	190 (8)				
NEPSG	94 (10)	76 (10)	73 (10)	79 (10)	80 (10)	113 (10)	120 (10)	155 (10)	178 (9)	130 (7)

9.4 Landfall forecast errors by MME Model

Fig.18 shows the landfall forecast point & Time error by MME, with respect to the first and second landfall over east coast of Sri Lanka and south Tamil Nadu respectively.

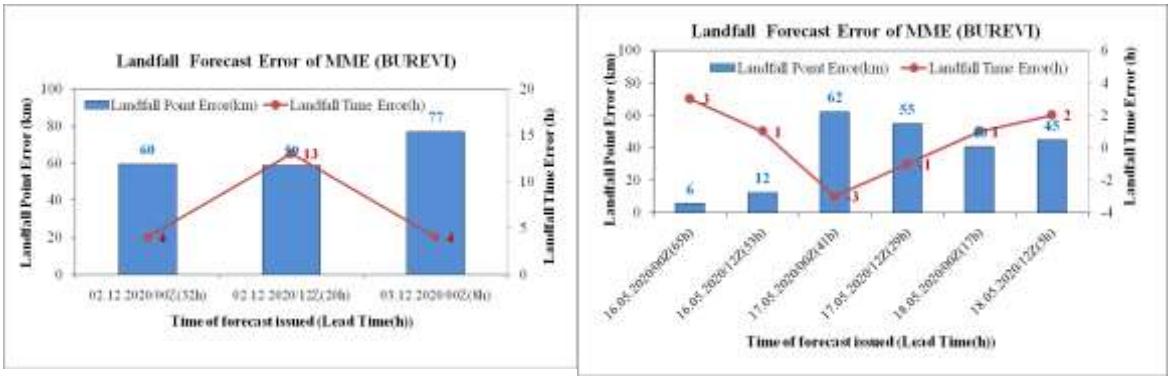


Fig. 18: MME Landfall Point and Time Forecast Error (BUREVI) (a) Sri Lanka (b) Tamil Nadu

9.5 Intensity forecast errors by various NWP Models

The intensity forecasts of IMD-SCIP model and HWRF model are shown in Table **3.** The intensity error was very high with NCUM (R) followed by HWRF model. Performance of Intensity prediction by SCIP model is presented in **Fig. 19(a) & (b).**

a. Intensity prediction by SCIP Model

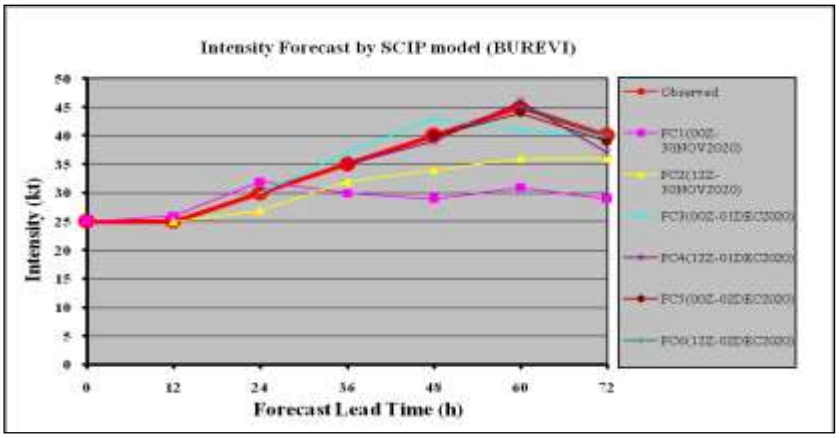


Fig. 19(a): SCIP Intensity Forecast Error (BUREVI)

b.Landfall intensity predicted by SCIP Model

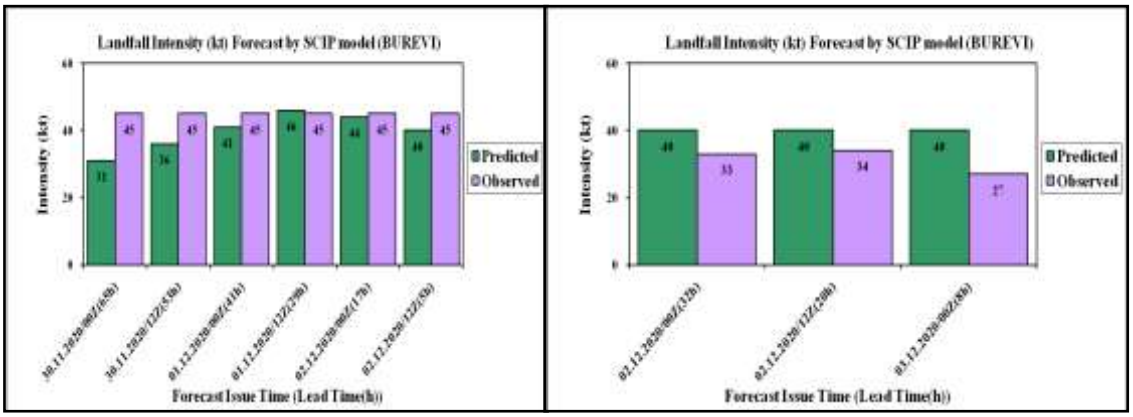


Fig. 19(b): SCIP Landfall Intensity Forecast Error (BUREVI) (i) Sri Lanka (ii) Tamil Nadu

Table-3 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	84 Hr	96 Hr	108 Hr	120 Hr
IMD-SCIP (AAE)	1.3(6)	2.0(5)	4.5(4)	6.7(3)	9.0(2)	11.0(1)				
HWRF (AAE)	7.8 (19)	4.4 (17)	4.5 (15)	5.0 (13)	4.5 (11)	5.0 (9)	6.1 (7)	12.1 (4)	12.7 (2)	16.0 (1)
IMD-SCIP (RMSE)	1.6	2.2	4.6	10.0	10.3	11.0				
HWRF (RMSE)	9.8 (19)	5.1 (17)	5.4 (15)	6.5 (13)	5.3 (11)	6.4 (9)	7.2 (7)	11.9 (4)	18.7 (2)	16.0 (1)
NCUM(R) (MEA)	12	06	09	08	09	5.5				
NCUM(G) (MEA)	05	05	04	04	07	10	06	04	05	07
NEPS(G)	04	04	03	03	04	05	05	4.5	05	06

10. Operational Forecast Performance

10.1 Genesis, track, landfall and intensity forecast:

- The extended range outlook issued on 26th November, indicated that there is a 'High' (68 – 100 %) probability for cyclogenesis over southwest Bay of Bengal during the second half of week (27th November – 03rd December). Actually, the Depression formed over southeast BoB on 30th November.
- First information that a low pressure area would form over southeast Bay of Bengal around 28th November with high (76-100%) probability of it's intensification into depression around 30th was issued in the Tropical Weather Outlook at 1130 hrs IST of 27th November. Actually low pressure area formed over south Andaman Sea on 28th November (0830 hrs IST) and it concentrated into a depression over southwest Bay of Bengal on 30th (0530 hrs IST).
- The information that a low pressure area would form over southeast Bay of Bengal around 29th November was also provided in the Press Release issued at 1600 hrs IST of 27th November. All warnings w.r.t. heavy rainfall, strong wind, state of Sea and advisory for fishermen was issued in the Press Release. Extremely heavy rainfall warning over Tamil Nadu & Puducherry on 2nd & 3rd December was also indicated in the Press Release. Special bulletins were issued by Area Cyclone Warning Centre, Chennai and Cyclone Warning Centre, Thiruvananthapuram also.
- In the first Press Release issued on 27th November, it was also indicated that the system would intensify further and move towards Tamil Nadu-Puducherry coasts.
- The bulletin issued at 0930 hrs IST of 30th, indicated that the system would intensify upto cyclonic storm stage, cross Sri Lanka coast between 7.5-9.0 degree N around

evening of 2nd December. It was also indicated that the system would emerge into Gulf of Mannar and Comorin area on 3rd December morning. Actually, the system crossed Sri Lanka coast as a cyclonic storm near 08.85 N and Log 81.0 E during 2230 – 2330 UTC of 02nd December 2020. It emerged into Gulf of Mannar during forenoon of 3rd December.

- The warnings were further updated and at 0210 hrs IST of 1st December, it was indicated that the system would emerge into Gulf of Mannar- Comorin area on 3rd December morning and move towards south Tamil Nadu coast.
- The warnings were further updated and at 1430 hrs IST of 1st December, it was indicated that the system would emerge into Gulf of Mannar and adjoining Comorin area on 3rd December morning and cross south Tamil Nadu coast between Kanniyakumai and Pamban around early morning of 4th December.
- At 1130 hrs IST of 2nd December, it was further indicated that the system would be centered very close to Pamban around noon of 3rd December and it's impact over Ramanathapuram district will commence from 3rd December forenoon.
- The observed and forecast track of cyclonic storm "BUREVI" based on 0000 UTC of 30th November and 0000 UTC of 2nd December along with cone of uncertainty and wind distribution are presented in **Fig. 20** and **Fig.21.**

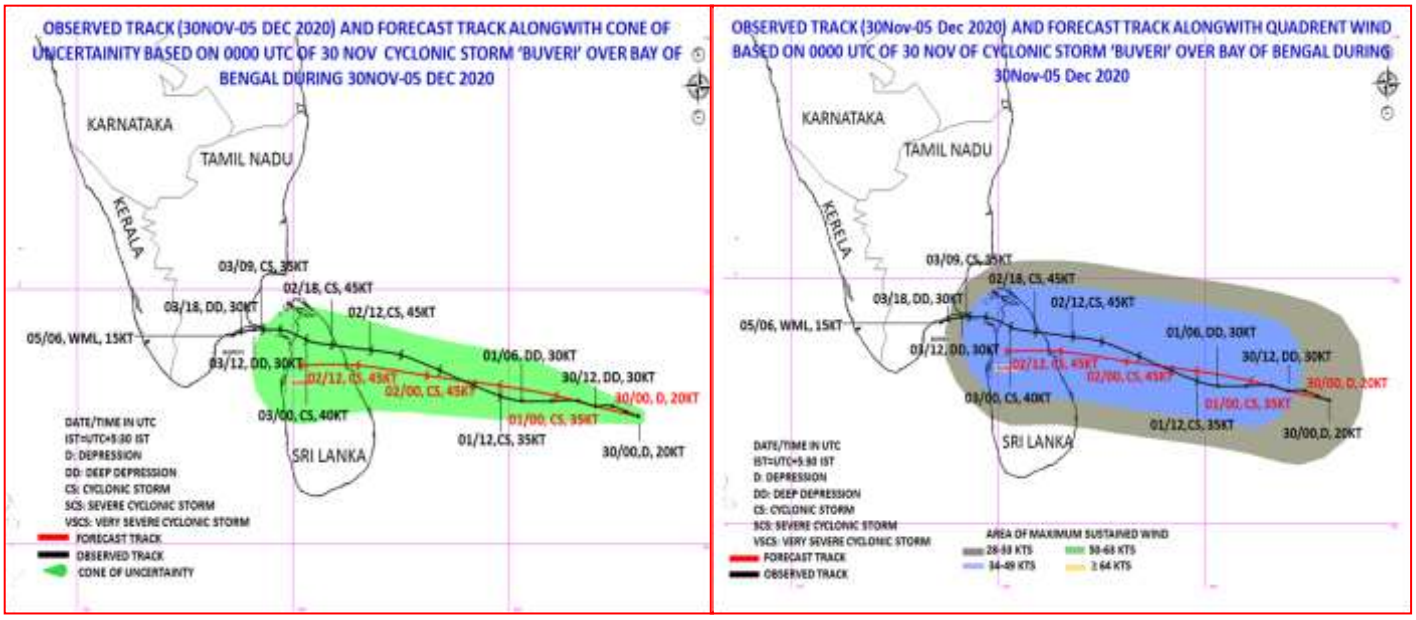


Fig. 20: The observed and forecast track of cyclonic storm "BUREVI" based on 0000 UTC of 30th November demonstrating accuracy in landfall, track and intensity prediction (about 60 hrs prior to landfall over Sri Lanka)

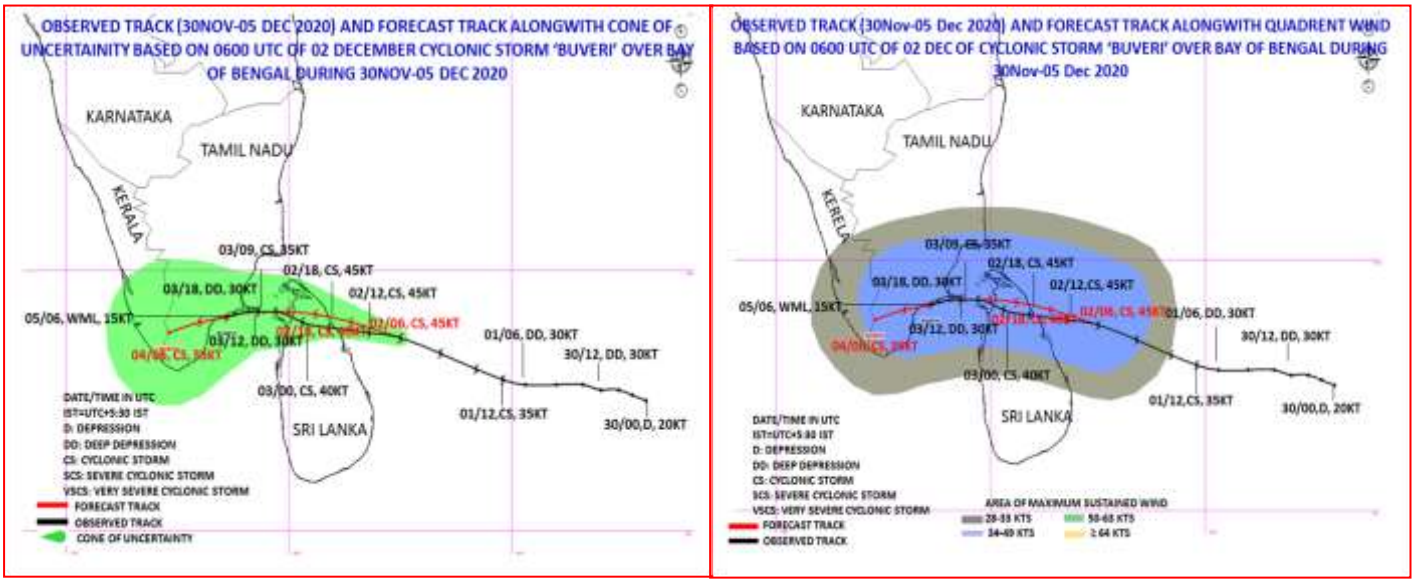
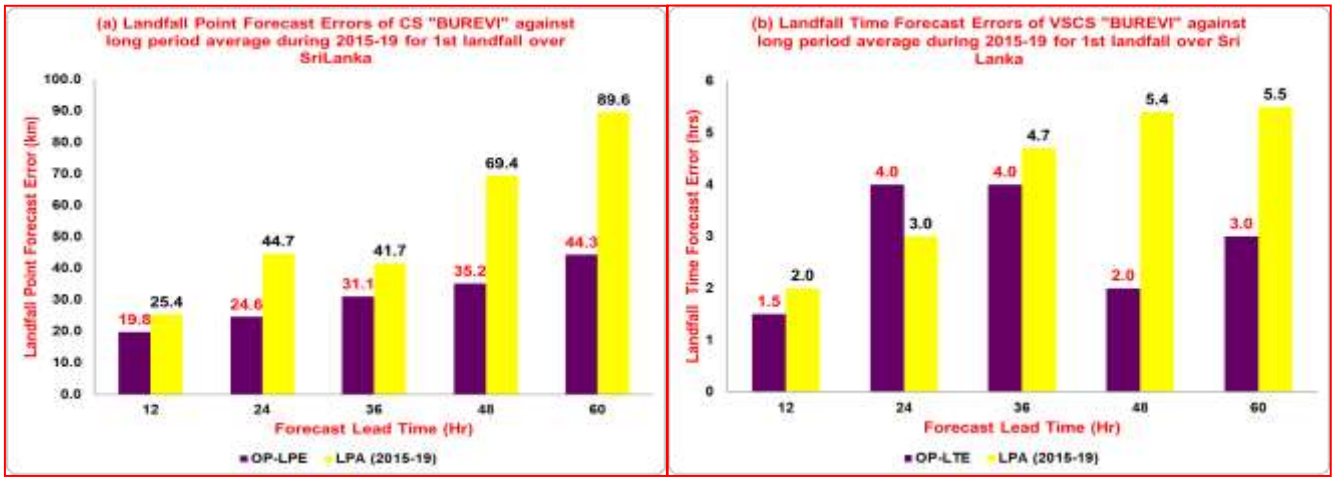


Fig. 21: The observed and forecast track of cyclonic storm "BUREVI" based on 0600 UTC of 2nd December demonstrating accuracy in landfall, track and intensity prediction (about 24 hrs prior to landfall over Pamban Area)

10.2 Landfall forecast error

Cyclonic storm 'BUREVI" made landfall over Sri Lanka coast close to north of Trincomalee near latitude 08.85^{0}N and longitude 81.0^0 E, during 1700 – 1800 UTC of 02nd December 2020 and Pamban area near latitude 09.2^{0}N and longitude 79.35^0 E during 0800 UTC of 03rd December 2020.

The landfall point and time forecast errors compared to long period average (LPA) errors during 2015-19 for landfall over Sri Lanka are presented in **Fig. 22 (a-b).** The landfall point forecast errors for 12, 24, 48 and 60 hrs lead period were 20, 25, 35 and 44 km respectively against the LPA errors (2015-19) of 25, 45, 69 and 99 km during 2015-19 respectively. The landfall time forecast errors for 12, 24, 48 and 60 hrs lead period were 1.5, 4.0, 2.0 and 3.0 hours respectively against the LPA errors (2015-19) of 1.5, 3.0, 5.4 and 5.5 hours during 2015-19 respectively. **For all lead periods, the landfall point and time errors were exceptionally less than the LPA errors during 2015-19.**



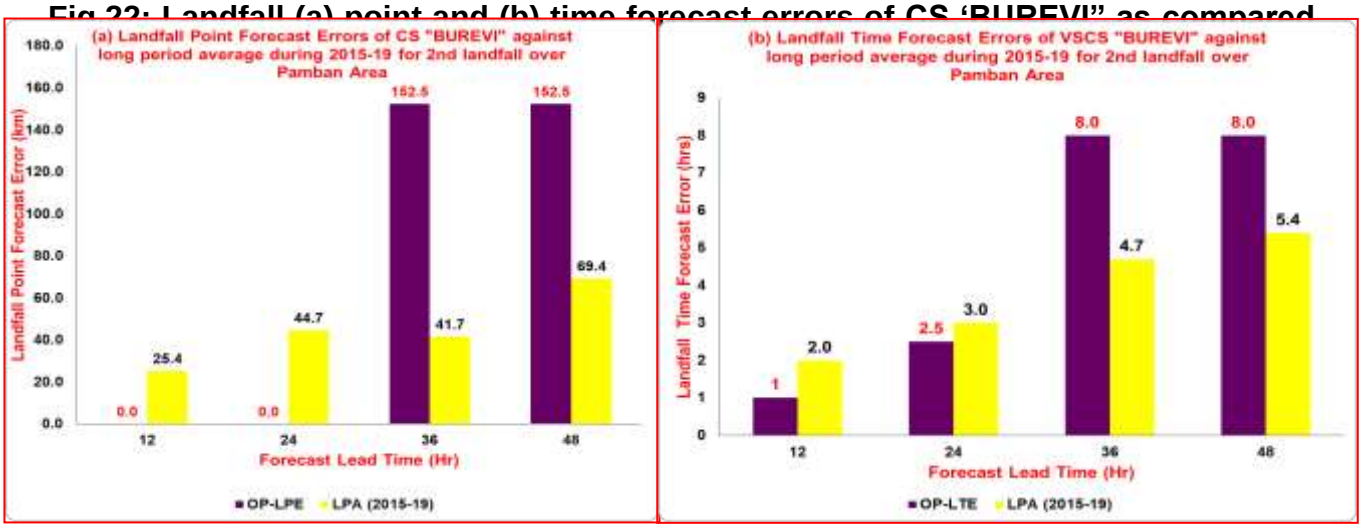


Fig.23: Landfall (a) point and (b) time forecast errors of CS 'BUREVI" as compared to long period average (2015-19) for landfall over Pamban Area

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. 24 (a-b).** The track forecast errors for 24, 48 and 72 hrs lead period were 55.3, 61.6, and 131.2 km respectively against the LPA errors (2015-19) of 80.6, 125.5, and 171.2 km respectively (Fig.22a). The track forecast skill was about 67%, 78%, and 72% against the LPA skill of 61%, 73%, and 74% for 24, 48 and 72 hrs lead period respectively (Fig.24b).

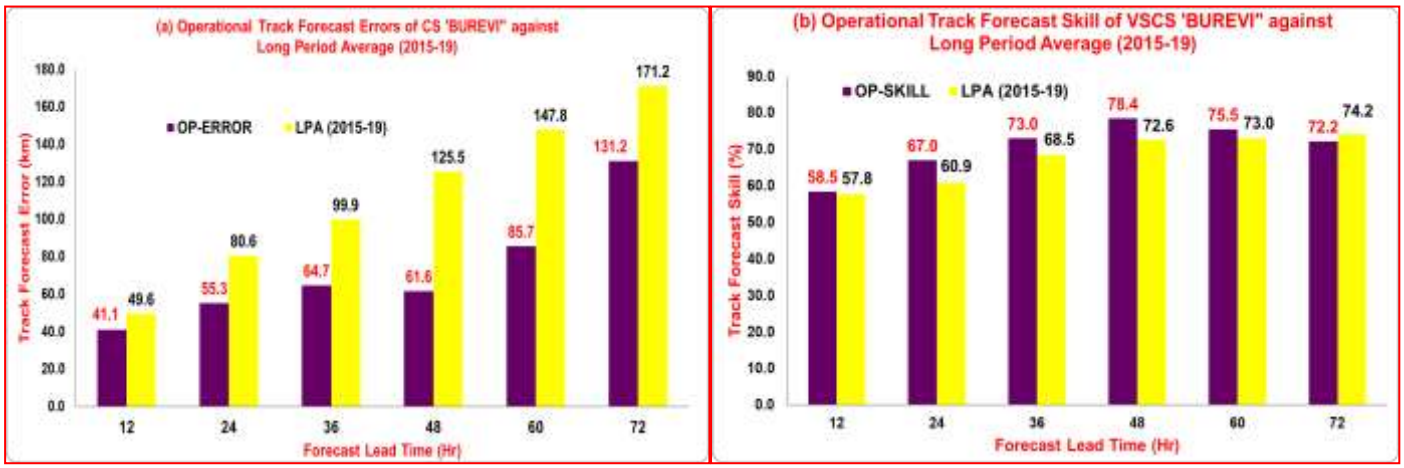


Fig.24: Track forecast (a) errors and (b) skill of CS 'BUREVI" as compared to long period average (2015-19)

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. 25 & 26 respectively. The absolute error (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 4.2,

4.7 and 9.3 knots against the LPA errors of 8.9, 13.0, and 15.4 knots during 2015-19 respectively (Fig. 25a). The root mean square error (RMSE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 5.2, 5.9 and 9.7 knots against the LPA errors of 11.5, 16.7, and 19.2 knots respectively (Fig. 25b). The skill (%) in intensity forecast as compared to persistence forecast based on AE for 24, 48 and 72 hrs lead period was 47%, 78% and 66% against the LPA of 45%, 69% and 72% respectively (Fig. 26a). The skill (%) in intensity forecast based on RMSE for 24, 48 and 72 hrs lead period was 56%, 70% and 77% against the LPA of 49%, 63% and 76% respectively (Fig. 26b).

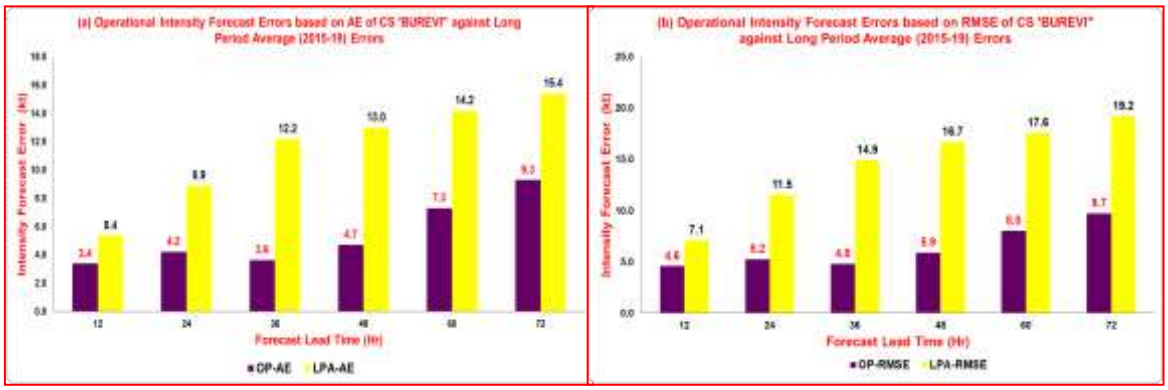


Fig.25: Absolute errors(AE) and Root Mean Square errors(RMSE) in intensity forecast (winds in knots) of CS 'BUREVI" as compared to long period average (2015-19)

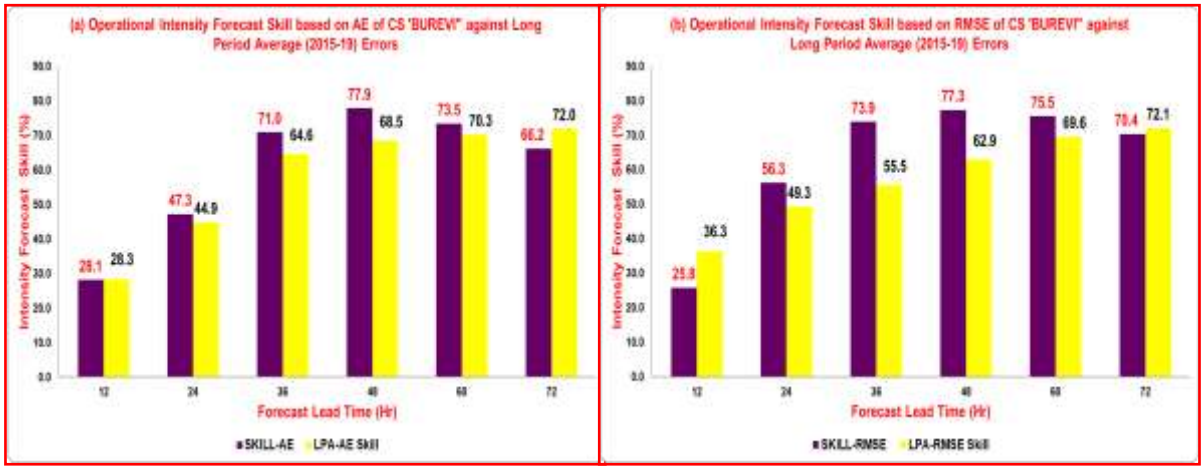


Fig.26: Skill (%) in intensity forecast based on (a) Absolute errors (AE) and (b) Root Mean Square errors (RMSE) of CS 'BUREVI" as compared to long period average (2015-19)

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 10-12. It is found that all the three types of adverse weather were predicted accurately and well in advance.

Table 4: Verification of Heavy Rainfall Forecast

Date/Base Time of	24 hr Heavy rainfall warning ending at 0300 UTC of next day	Realised 24-hour heavy rainfall ending at 0300 UTC of date

observation		
30.11.2020 /0300UTC	• Heavy to very heavy rainfall at a few places with isolated Extremely heavy falls over south Tamilnadu(Kanniyakumari, Tirunelveli, Thoothukudi, Tenkasi, Ramanathapuram and Sivagangai; south Kerala(Thiruvananthapuram, Kollam, Pathanamthitta and Alappuzah) on 2nd and 3rd December, 2020 and Isolated heavy to very heavy rainfall likely over these regions on 1st and 4th December 2020. • Heavy to very heavy rainfall at Isolated places very likely over north Tamilnadu, Puducherry, Mahe & Kariakal and north Kerala during 2 nd and 3rd December, 2020 and isolated heavy rainfall during 1st and 4th December. • Heavy rainfall at isolated places over south Coastal Andhra Pradesh during 2nd & 03rd December and over Lakshadweep during 03rd and 4th December, 2020.	**2nd December:** Vedaranyam - 20, Karaikal - 16, Thalaignayer & Tirupoondi -15 each, Nagapattinam - 14, Thiruthuraipoondi - 13, Mayiladuthurai, Rameswaram - 12 each, Mudukulatur - 11, Sirkali, Kodavasal , Adirampatnam, Manjalaru - 10 each, Tiruvarur,Aduthurai, Tambaram, Pattukottai - 9 each, Nannilam, Marakkanam, Pamban, Thiruvidaimaruthur, Thirukalukundram, Puducherry, Valangaiman -8 each, Manalmedu, Kollidam, Kelambakkam, K.M.koil, Vanur, Mannargudi, Taramani, Madukkur, Parangipettai, Ayyampettai, Thanjai Papanasam, Cuddalore, Needamangalam -7 each **3rd December:** Kollidam - 36, Chidambaram - 34, Parangipettai - 26, Manalmedu, Kurinjipadi - 25 each, Thiruthuraipoondi - 22, Sirkali, Kodavasal - 21 each, Rameswaram - 20, Peravurani, Manjalaru, Bhuvanagiri, Mayiladuthurai - 19 each, Karambakudi, Pattukottai -17 each, Madukkur -16, Srimushnam - 15, Tindivanam, Nannilam, Thiruvidaimaruthur -14 each, Kumbakonam, Ayyampettai, Valangaiman, Panruti, Ulundurpet -13 each, Aduthurai, Alangudi, Pandavaiyar Head 12 each, Tiruvarur, Budalur, Mahabalipuram, Mannargudi - 11 each, Vallam, Perambalur, Thanjavur, Thirumanur, Needamangalam -10 each, Sendurai, Tirukattupalli, Vilupuram, Mylam AWS,
01.12.2020 /0300	•Heavy to very heavy rainfall at a few places with isolated Extremely heavy falls over south Tamilnadu (Kanniyakumari, Tirunelveli, Thoothukudi, Tenkasi, Ramanathapuram and Sivagangai) on 2nd and 3rd December, 2020; over south Kerala(Thiruvananthapuram, Kollam, Pathanamthitta and Alappuzah) on 3rd December and isolated heavy to very heavy rainfall likely over south Tamilnadu on 2nd & 4th December 2020 and south Kerala on 3 rd & 4th December, 2020. • Heavy to very heavy rainfall at Isolated places over north Tamilnadu, Puducherry, Mahe & Kariakal and north Kerala during 2nd & 3 rd December, isolated heavy rainfall on 4th December and isolated heavy rainfall over coastal Tamilnadu on 1st December. • Heavy rainfall at isolated places over south Coastal Andhra Pradesh during 2nd & 03rd December and over Lakshadweep during 03rd and 4th December, 2020.	
02.12.2020 /0300	• Heavy to very heavy rainfall at a few places with isolated Extremely heavy falls very likely over south Tamilnadu (Ramanathapuram, Thoothukudi,	

	Tirunelveli, Kanniyakumari, Tenkasi and Sivagangai districts) on 2nd & 3 rd December, 2020; over south Kerala (Thiruvananthapuram, Kollam, Pathanamthitta and Alappuzha) on 3rd December and isolated heavy to very heavy rainfall likely over south Tamilnadu on 4 th December 2020 and south Kerala on 2nd & 4th December, 2020. • Heavy to very heavy rainfall at isolated places very likely over north Tamilnadu, Puducherry, Mahe & Karaikal and north Kerala on 3 rd December, isolated heavy rainfall on 2nd & 4th December. • Heavy rainfall at isolated places very likely over south Coastal Andhra Pradesh and Lakshadweep on 3 rd & 04th December.	Cholavaram, Vanur, Gandarvakottai, Marakkanam, Chengalpattu, Gingee - 9 each, Keeranur, Thalaignayer, Agaram Seegoor, Eraiyur, Gummidipoondi, Adirampatnam, Manamelkudi, Pullambadi, Annavasal, Samayapuram, Pamban, Perungalur, Tarangambadi - 8 each , Labbaikudikadu, Tozhudur, Tirukoilur, Thuvakudi Imti, Uthukottai, Ariyalur, Anna UTY, Uthiramerur, Tirupoondi, Tirumayam, Tondi, TRP Town - 7 each **4th December:** Nagapattinam and Karaikal -16 each, Kodavasal and Bhuvanagiri - 15 each, Sethiyathope -14, Tarangambadi -13, Sirkali, DGP Office, Vembakkam and Srimushnam - 12 each, Rameswaram, Anna University , Tirupoondi and Kayalpattinam -11 each, Sriperumbudur, Kollidam, MGR Nagar and Pelandurai -10 each, Uthukottai , Chembarambakkam, Tuticorin , Thalaignayer -9 each **5th December:** Muthupet -10, Mahabalipuram - 7 each, Kodavasal, Nannilam; Thalaignayer -6 each and Thiruthuraipoondi, Cheyyur, Kollidam, Cholavaram, Tirupoondi and Chidambaram 5 each. **6th December:** Maniyachi -16, Vaippar -12, Kadambur -11, Kayathar, Sirkali, Karaikal, Chittar- 9 each, Thalaignayer, Mayiladuthurai, Valinokam , Needamangalam - 8 each, Kodavasal, Manalmedu,
03.12.2020 /0300	• Heavy to very heavy rainfall at a few places with isolated Extremely heavy falls very likely over south Tamilnadu (Ramanathapuram, Thoothukudi, Tirunelveli, Kanniyakumari, Tenkasi, Virudhunagar, Theni, Madurai and Sivagangai districts) and over south Kerala (Thiruvananthapuram, Kollam, Pathanamthitta, Idukki and Alappuzah) on 3rd December and isolated heavy to very heavy rainfall likely over south Tamilnadu and south Kerala on 4th December, 2020. • Heavy to very heavy rainfall at isolated places very likely over north Tamilnadu, Puducherry, Mahe & Karaikal and north Kerala on 3 rd December, isolated heavy rainfall on 4 th December. • Heavy rainfall at isolated places very likely over south Coastal Andhra Pradesh and Lakshadweep on 3rd & 04th December.	
04.12.2020 /0000 UTC	• Heavy to very heavy rainfall at isolated places with extremely heavy falls at isolated places very likely over Tamilnadu, Puducherry and Karaikal today, the 4th December and heavy to very heavy rainfall at isolated places on 05th December. • Heavy to very heavy rainfall at isolated places very likely over Kerala & Mahe on 04th & 05th December. India Meteorological Department (Ministry of Earth Sciences) Spatial rainfall	

	distribution: Isolated: ≤25%, A few: 26-50%, Many: 51-75%, Most: 76-100% Rainfall amount (mm): Heavy rain: 64.5 – 115.5, Very heavy rain: 115.6 – 204.4, Extremely heavy rain: 204.5 or more. • Heavy rainfall at isolated places very likely over south coastal Andhra Pradesh on 04 th & 05th December and over Lakshadweep on 05th December.	Palayamkottai, Vilathikulam - 7 each
05.12.2020 /0000 UTC	• Heavy to very heavy rainfall at isolated places very likely over Tamilnadu & Puducherry on 05th & 06th December. • Heavy rainfall at isolated places over south Kerala & Mahe on 05th and heavy to very heavy rainfall at isolated places very likely over Kerala on 06th December. • Heavy to very heavy rainfall at isolated places very likely over Lakshadweep on 05th & 06th December.	

Table 5: Verification of Gale/Squally Wind Forecast issued by IMD

The system had crossed Sri Lanka coast close to north of Trincomalee between 2230 and 2330 hrs IST (1700 & 1800 UTC) of 2nd December 2020 as a Cyclonic Storm with a maximum sustained wind speed of 80-90 kmph gusting to 100 kmph. Moving across northern parts of Sri Lanka, it emerged into Gulf of Mannar in the morning and lay centred close to Pamban around noon (1130 hrs IST / 0600 UTC) of 03rd December. It had crossed Pamban area around 0800 UTC of 3rd.

Date/Base Time of observation (0300 UTC)	Gale/ Squally wind Forecast at 0300 UTC of date	
30.11.2020	• Squally wind speed reaching 45-55 kmph gusting to 65 kmph very likely over central parts of South Bay of Bengal on 30th November. • It would gradually increase becoming 55-65 kmph gusting to 75 kmph over southeast and adjoining southwest Bay of Bengal from 1st December night and 70-80 kmph gusting to 90 kmph over southwest Bay of Bengal, along & off Sri Lanka coast and 45-55 kmph gusting to 65 kmph over Comorin Area, Gulf of Mannar and south Tamilnadu-Kerala coasts from 2nd December forenoon for subsequent 24 hours. • The squally wind speed reaching 55-65 kmph gusting to 75 kmph is very likely to prevail over Gulf of Mannar, along & off south Tamilnadu & Kerala coasts, Comorin Area, Lakshadweep-Maldives area and	Crossed Sri Lanka coast close to north of as a Cyclonic Storm with maximum sustained wind speed of 80-90 kmph gusting to 100 kmph. Crossed Pamban area as a cyclonic storm with maximum sustained wind speed of 60-70 kmph gusting to 80 kmph

	adjoining southeast Arabian Sea from 3 rd December morning for subsequent 48 hours.	
01.12.2020	• Squally wind speed reaching 50-60 kmph gusting to 70 kmph very likely over central parts of South Bay of Bengal during next 12 hours. • It would gradually increase becoming gale wind speed reaching 60-70 kmph gusting to 80 kmph over southwest and adjoining southeast Bay of Bengal from 1 st December evening. It would gradually increase becoming 70-80 kmph gusting to 90 kmph over southwest Bay of Bengal, along & off Sri Lanka coast from 2nd December morning for subsequent 24 hours. • Squally wind speed reaching 45-55 kmph gusting to 65 kmph very likely over Comorin Area, Gulf of Mannar and south Tamilnadu-Kerala coasts from 2nd December forenoon. It will gradually increase becoming 55-65 kmph gusting to 75 kmph over Gulf of Mannar, along & off south Tamilnadu & Kerala coasts, over Comorin Area, Lakshadweep-Maldives area and adjoining southeast Arabian Sea from 3rd December morning and 70-80 kmph gusting to 90 kmph from evening of 3rd December for subsequent 24 hours.	
02.12.2020	• Gale wind speed reaching 75-85 kmph gusting to 95 kmph prevails over southwest Bay of Bengal and along & off Sri Lanka coast. It is very likely to increase becoming 80-90 kmph gusting to 100 kmph from afternoon for subsequent 12 hours. It will gradually decrease thereafter. • Squally wind speed reaching 45-55 kmph gusting to 65 kmph very likely over Comorin Area, Gulf of Mannar and along and off south Tamilnadu coast (Ramanathapuram, Thoothukudi, Tirunelveli and Kanniyakumari districts) and south Kerala coast (Thiruvananthapuram, Kollam, Pathanamthitta and Alappuzah districts). It will gradually increase becoming 55-65 kmph gusting to 75 kmph from 2nd December evening and 70-80 kmph gusting to 90 kmph from 3rd December forenoon for subsequent 24 hours and decrease thereafter. • Squally wind speed reaching 45-55 kmph gusting to 65 kmph very likely over Lakshadweep-Maldives area and adjoining southeast Arabian Sea from 3 rd December morning for next 48 hours.	
03.12.2020	• Gale wind speed reaching 70-80 kmph	

	gusting to 90 kmph prevails around the system centre covering extreme north Sri Lanka and adjoining areas of Gulf of Mannar & southwest Bay of Bengal. • Squally wind speed reaching 55-65 kmph gusting to 75 kmph prevails along and off south Tamilnadu coast (Ramanathapuram, Thoothukudi, Tirunelveli and Kanniyakumari districts) and 30-40 kmph gusting to 50 kmph prevails along & off south Kerala coast (Thiruvananthapuram, Kollam, Pathanamthitta and Alappuzah districts). • It will gradually increase becoming 70-80 kmph gusting to 90 kmph from 3rd December noon for subsequent 24 hours along and off south Tamilnadu coast (Ramanathapuram, Thoothukudi, Tirunelveli and Kanniyakumari districts) and 55-65 kmph gusting to 75 kmph prevails along & off south Kerala coast (Thiruvananthapuram, Kollam, Pathanamthitta and Alappuzah districts). and decrease thereafter. • Squally wind speed reaching 45-55 kmph gusting to 65 kmph very likely over Lakshadweep-Maldives area and adjoining southeast Arabian Sea on 3 rd and 4th December.	
04.12.2020	• Squally wind speed reaching 50-60 kmph gusting to 70 kmph is very likely during next 12 hours along and off south Tamilnadu coast (Ramanathapuram, Thoothukudi, Tirunelveli and Kanniyakumari districts) and it will gradually decrease to 40-50 kmph gusting to 60 kmph by night of 4 th December. • Squally wind speed reaching 35-45 kmph gusting to 55 kmph very likely to prevail along & off south Kerala coast (Thiruvananthapuram, Kollam, Pathanamthitta and Alappuzah districts) from tonight for subsequent 12 hours. • Squally wind speed reaching 35-45 kmph gusting to 55 kmph very likely over Lakshadweep-Maldives area and adjoining southeast Arabian Sea from early morning of 05th December.	
05.12.2020	• Squally wind speed reaching 40-50 kmph gusting to 60 kmph is very likely over Gulf of Mannar & adjoining southwest Bay of Bengal, along & off south Tamilnadu coast (Ramanathapuram, Thoothukudi, Tirunelveli and Kanniyakumari districts) during next 12 hours. It will gradually decrease to 35-45	

	kmph gusting to 55 kmph for subsequent 12 hours. • Squally wind speed reaching 35-45 kmph gusting to 55 kmph very likely over Lakshadweep-Maldives & Comorin area, southeast Arabian Sea and along & off south Kerala coast on 5th and 6th December.	

Table 6: Verification of Storm Surge Forecast issued by IMD

Date/Base Time of observation (0300 UTC)	Storm Surge Forecast at 0300 UTC of date	Realised surge
02.12.2020	• Storm surge of about 1.0 m height above astronomical tide is very likely to inundate low lying areas of south coastal Tamilnadu (Ramanathapuram, Thoothukudi, Tirunelveli and Kanniyakumari districts) during the time of landfall.	No report of significant storm surge available.
03.12.2020	• Storm surge of about 1.0 m height above astronomical tide is very likely to inundate low lying areas of south coastal Tamilnadu (Ramanathapuram, Thoothukudi, Tirunelveli and Kanniyakumari districts) during the time of landfall and northwest Sri Lanka coast during next 06 hours.	

12. Warning & advisories issued by IMD

- Regular press release since 27th November (before formation of low pressure area over southeast Bay of Bengal) till 6th December
- **Pre-Cyclone watch** for South Tamil Nadu and South Kerala issued at 0930 IST of 30th November, from the stage of a Depression itself (**about 72 hrs before the CS reached near Pamban**)
- **Cyclone Alert** for South Tamil Nadu and South Kerala issued at 1130 hrs IST of 1st December, when the system was a Deep Depression (**about 48 hrs before the CS reached near Pamban**)
- **Cyclone Warning** for South Tamil Nadu and South Kerala issued at 1130 hrs IST of 2nd December (**about 24 hrs before the CS reached near Pamban**)
- Extremely heavy rainfall warnings for Tamil Nadu & Puducherry on 2nd, 3rd were issued since 0930 hrs IST of 30th November
- Seven bulletins were issued by Director General of Meteorology to Prime Minister Office, Control Room Ministry of Home Affairs & National Disaster Management Authority, Cabinet Secretariat, Minister of Science & Technology, Headquarter Integrated Defense Staff, Director General Doordarshan, All India Radio, National Disaster Response Force, Press Information Bureau, Ministry of Railways, Shipping & Surface Transport, Chief Secretary to Government

- Total No. of national Bulletins to the Control Room, Ministry of Home Affairs & National Disaster Management Authority, Cabinet Secretariat, Minister of Science & Technology, Headquarter Integrated Defense Staff, Director General Doordarshan, All India Radio, National Disaster Response Force, Press Information Bureau, Chief Secretaries to the Government of Tamil Nadu, Puducherry, Kerala, Andhra Pradesh, Odisha, West Bengal and Administrator Lakshadweep Islands-35
- Total No. of special tropical weather outlooks and tropical cyclone advisories to 13 WMO/ESCAP member countries including Maldives and Srilanka-35
- Total No. of tropical cyclone advisory bulletins for international civil aviation to Met Watch offices in Asia Pacific regions and middle east through GTS to issue Significant Meteorological information for International Civil Aviation and WMO's Aviation Disaster Risk Reduction (ADRR), Hong Kong-12

Bulletins issued by RSMC New Delhi, IMD are presented in Table 7(a).
Table 7 (a): Bulletins issued by RSMC New Delhi

S. No.	Bulletin type	No. of Bulletins	Issued to
1	National Bulletin	36	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 Andhra Pradesh , Tamil Nadu, Andaman & Nicobar Islands, Kerala, Lakshadweep.
2	RSMC Bulletin	36	1. IMD's website 2. WMO/ESCAP member countries through GTS and E-mail.
3	GMDSS Bulletins		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	11	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	11	Modelling group of IMD, National Centre for Medium Range Weather Forecasting Centre

	Vital Statistics		(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) 2319 to General Public by IMD Headquarters (ii) 126 to disaster managers by IMD Headquarters (iii) 2414675 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	7	Disaster Managers, Media persons by email and uploaded on website
9	Press Briefings	Daily	Regular briefing daily
10	Hourly Updates	-	-

Table 7(b): Bulletins issued by ACWC Chennai / CWC Visakhapatnam /CWC Thiruvananthapuram

S.No.	Type of Bulletin Number	No. of Bulletins issued		
		ACWC Chennai	CWC Thiruvananthapuram	CWC Visakhapatnam
1.	Sea Area Bulletins	-	-	-
2.	Coastal Weather Bulletins	20	12	16
3.	Fishermen Warnings issued	28	24	24
4.	Port Warnings	6	2	10
5.	Heavy Rainfall Warning	25	20	-
6.	Gale Wind Warning	20	-	-
7.	Storm surge Warning	4	-	-
8.	Information & Warning issued to State Government and other Agencies	40	36 each	3
9.	SMS	210	17	110
10.	No. of Press releases		-	3
11.	No. of impact based warnings for a. District b. City	a. 30 b. 25	- 5	-

12.	No. of whatsapp messages	34	37	25
13.	No. of updates on facebook	20	49	23
14.	No. of updates on twitter	20	49	3
15	No. of warning video released	-	2	28
16.	No. of Audio bites released	25	-	28

13. Summary

The cyclonic storm, 'Burevi' originated as a Low Pressure area in the equatorial easterly wave over South Andaman Sea and adjoining areas of Southeast Bay of Bengal & Equatorial Indian Ocean on 28th, which became a Well Marked Low pressure area over Southeast Bay of Bengal & adjoining areas of South Andaman Sea and Equatorial Indian Ocean on 29th. Under favourable environmental conditions, it concentrated into a Depression in the early morning (0530 hrs IST / 0000 UTC) of 30th over Southeast Bay of Bengal. Moving nearly westwards, it intensified into a Deep Depression in the early morning of 01st over Southwest and adjoining Southeast Bay of Bengal. Subsequently it moved west-northwestwards and intensified into Cyclonic Storm 'Burevi' over Southwest Bay of Bengal in the evening (1730 hrs IST / 1200 UTC) of 01st.Continuing the west-northwestward movement, it crossed Sri Lanka coast close to north of Trincomalee near Lat. 8.85°N and Long. 81.0°E between 2230 and 2330 hrs IST (1700 & 1800 UTC) of 2nd as a Cyclonic Storm with maximum sustained wind speed of 80-90 kmph gusting to 100 kmph. Moving across northern parts of Sri Lanka, it emerged into Gulf of Mannar in the morning and lay centred close to Pamban around noon (1130 hrs IST / 0600 UTC) of 03rd. It crossed Pamban area on (0800 UTC) 3rd. Continuing to move west-northwestwards, it weakened into a Deep Depression over the same region in the evening (1200 UTC) of 03rd.Thereafter the movement slowed down significantly and it remained practically stationary over Gulf of Mannar close to Ramanathapuram district coast for nearly 18 hours and further weakened into a Depression in the evening of 04th December over the same region. Further remaining stationary at the same place for subsequent 18 hours, it gradually weakened into a well marked Low pressure area around noon (1130 hrs IST / 0600 UTC) of 05th. This system during its initial stage as a Low pressure area had caused fairly widespread rainfall with isolated very heavy falls over Andaman & Nicobar Islands on 29th. Under the influence of this system, widespread rainfall with heavy to very heavy falls at a few places & extremely heavy (≥ 20 cm) falls at isolated places occurred over Tamil Nadu during 02nd – 04th.

14. Acknowledgement:

India Meteorological Department (IMD) and RSMC New Delhi duly acknowledge contribution from WMO in dissemination of bulletins and warnings associated with CS BUREVI.

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, Cyclone Warning Centre (CWC) Visakhapatanam,Thiruvananthapuram and coastal observatories along the southeast coast of India. The contribution from Numerical Weather Prediction Division, Satellite and Radar Division, Surface & Upper air instruments Divisions, New Delhi and Information System and Services Division at IMD is also duly acknowledged.
