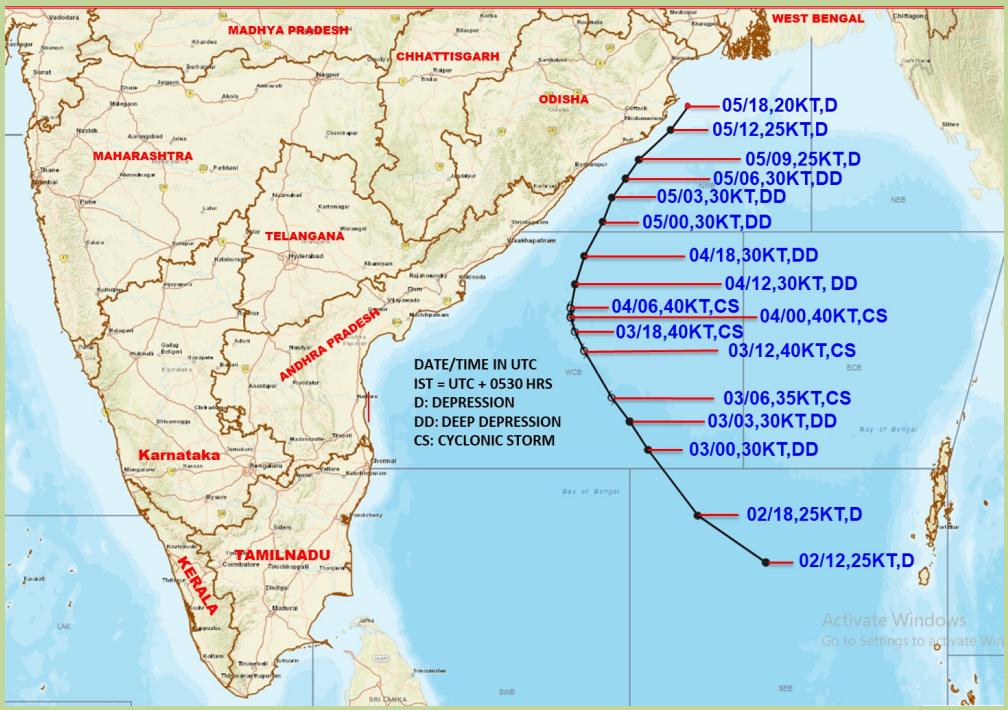
GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
INDIA METEOROLOGICAL DEPARTMENT

Cyclonic Storm JAWAD over southeast Bay of Bengal (02-05 December 2021)



Observed track of the Cyclonic Storm 'JAWAD'

Cyclone Warning Division

India Meteorological Department

New Delhi

December 2021

Cyclonic Storm JAWAD (pronounced as JOWAD) over Bay of Bengal

1. Life History:

- A Low Pressure Area formed over South Thailand & neighbourhood in the forenoon (0830 hours IST/0300 UTC) of 30th November.
- It emerged into central parts of Andaman Sea in the same evening (1730 hrs IST/1200 UTC) and lay as a well marked low pressure area over southeast Bay of Bengal (BoB) & adjoining Andaman Sea in the morning (0530 hrs IST/0000 UTC) of 2nd December.
- Under favourable environmental conditions, it concentrated into a depression over southeast Bay of Bengal in the same evening (1730 hours IST/1200 UTC).
- Moving north-northwestwards, it concentrated into a deep depression over westcentral & adjoining south BoB in the morning (0530 hours IST/0000 UTC) and into the Cyclonic Storm **"JAWAD"** (pronounced as JOWAD) over westcentral BoB in the forenoon (1130 hours IST/0600 UTC) of 3rd December.
- It moved north-northeastwards till morning (0530 hours IST/0000 UTC) of 4th December. Thereafter, the system started recurving along the western periphery of the anticyclone over Myanmar region. It moved northwards till evening (1730 hours IST/ 1200 UTC) of 4th and weakened into a deep depression over westcentral BoB at 1730 hours IST of 4th December.
- Thereafter, it moved north-northeastwards and reached very close to Odisha coast, about 50 km southeast of Puri in the afternoon (1430 hours IST/0900 UTC) of 5th December and 30 km southeast of Paradip in the evening (1730 hours IST/1200 UTC) of 5th December as a depression.
- Thereafter, it moved northeastwards and weakened into a well marked low pressure area over northwest BoB and adjoining West Bengal & Bangladesh coasts in the morning (0530 hours IST/0000 UTC) and into a low pressure area over the same region in the forenoon (0830 hours IST/0300 UTC) of 6th December, 2021.
- The observed track of the system is presented in Fig.1 (a) and the best track parameters are presented in Table 1.

2. Salient features:

- JAWAD was the 5th cyclone over the north Indian Ocean (NIO) during the year 2021 and 1st cyclone during the post monsoon season (October-December).
- The tracks of cyclonic disturbances over the NIO in the month of December during the period 1891-2020 are presented in Fig.2. The figure shows that no cyclone crossed Odisha in the month of December in recorded history. There had been landfall over north Andhra Pradesh and West Bengal. Even if there was no landfall, there had been impact of cyclones over Odisha during past years in terms of heavy rainfall. Maximum genesis took place over south BoB & south Andaman Sea. Once the system crossed 15^0 N over BoB, it changed it's path and recurved north-northeastwards. The same has been observed with cyclone Jawad.
- JAWAD had a recurving track. It moved north-northwestwards initially and started recurving from 4th morning (0530 hours IST/0000 UTC).

- It had a track length of about 940 km.
- The peak maximum sustained wind speed (MSW) of the cyclone was 70-80 kmph (40 knots) gusting to 90 kmph during 3rd/1200 UTC to 4th/0000 UTC. Dhamra Port reported south-southeasterly winds of intensity 32 knots gusting to 35 knots at 4th/0600 UTC. Thereafter, the system started weakening under unfavourable conditions (enhanced wind shear, dry air incursion into the core of system, lower ocean thermal energy, land interactions and unfavourable Madden Julian Oscillation index).
- The lowest estimated central pressure (ECP) was 1000 hPa during the period with a pressure drop of about 8 hPa at the centre as compared to the surroundings (Fig.2a).
- The life period (D to D) of the system was 84 hours (3 days & 12 hours) against long period average (LPA) (1990-2013) of about 88 hours (3 days & 16 hrs) for CS category over the BoB during post-monsoon season.
- It moved with a 12-hour average translational speed of 14.6 kmph against LPA (1990-2013) of 12.9 kmph for CS category over BoB during post-monsoon season (Fig.2 b).
- The Velocity Flux, Accumulated Cyclone Energy (a measure of damage potential) and Power Dissipation Index (a measure of loss) were 4.4 $X10^2$ knots, 1.4 X 10^4 $knots^2$ and 0.48 $X10^6$ $knots^3$ respectively.
- The operational track forecast errors for 24, 48 and 60 hrs lead period were 79, 82 and 78 km respectively against the long period average (LPA) track forecast errors of 77, 117 and 137 km during last five years (2016-20) respectively.
- The operational absolute error (AE) of intensity (wind) forecast for 24, 48 and 60 hrs lead period were 6.7, 13.3 and 11.7 knots against the LPA of 7.9, 11.4 and 12.7 knots respectively.
- While recurving north-northeastwards, the cyclone came very close to Odisha caost. It was about 90 km east-southeast of Gopalpur at 0830 hrs IST, 70 km south-southeast of Puri at 1130 hrs IST, 50 km southeast of Puri at 1430 hrs IST, 30 km southeast of Paradip at 1730 hrs IST and 65 km east-southeast of Chandbali & 140 km south-southwest of Digha (West Bengal) at 2330 hrs IST of 5th December.
- As the cyclone moved very close to Odisha coast on 5th December, it caused heavy to extremely heavy rainfall activity affecting Odisha coast on 5th and 6th December and Gangetic West Bengal coast on 6th December. Very heavy rainfall (maximum 9 cm) was reported in Ganjam district on 5th December and extremely heavy rainfall (maximum 23 cm) was reported in Jagatsinghpur district of Odisha on 6th December. Very heavy rainfall (maximum 18 cm) was reported in Hooghly district of Gangetic West Bengal on 6th December.
- It also caused strong winds over Odisha coast. Meteorological Office at Puri reported MSW of 18 knots during 1030-1130 hrs IST (0500 to 0600 UTC) of 5th December, high wind speed recorder at Paradeep reported MSW of 26 knots at 1530 hrs IST (0995 UTC) of 5th December. Dhamra Port reported south-southeasterly winds of intensity 32 knots gusting to 35 knots at 4th/0600 UTC (1130 IST).
- A total of 23 national bulletins, 3 Special Messages, 28 RSMC bulletins to WMO/ESCAP Panel member countries, 4 Press Releases, 7 bulletins for International Civil Aviation, 72 lakhs SMS to fishermen, farmers & coastal population, frequent updates on social networking sites were sent to trigger mass response and sensitize masses about the impending disaster in association with the system.

- Director General of Meteorology gave a presentation on the status of cyclone JAWAD during the two National Crisis Management Committee Meetings chaired by Cabinet Secretary and special review meetings chaired by Hon'ble Prime Minister of India and Hon'ble Minister for Railways on 2nd December. A joint press conference was addressed by DGM IMD and DG NDRF on 3rd December to sensitize masses

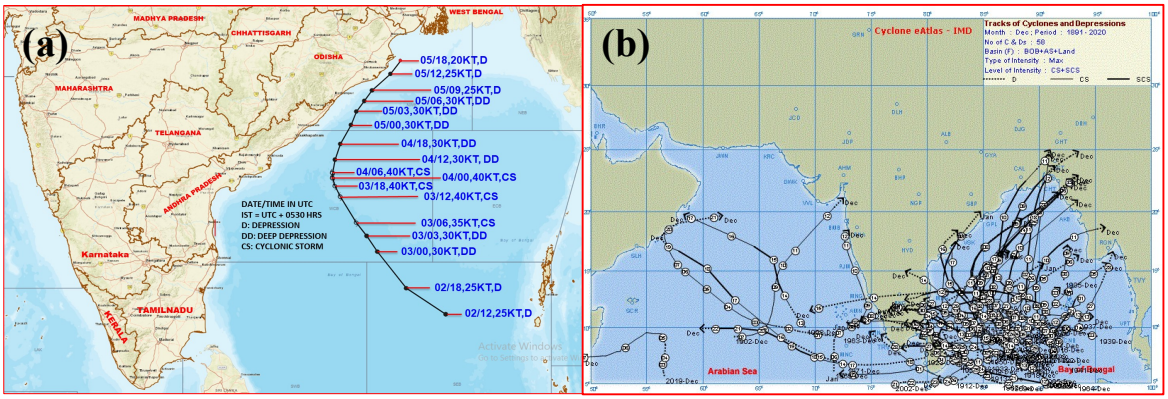


Fig.1: (a) Observed track of cyclonic storm JAWAD and (b) tracks of cyclonic disturbances over the NIO in the month of December during 1891-2019

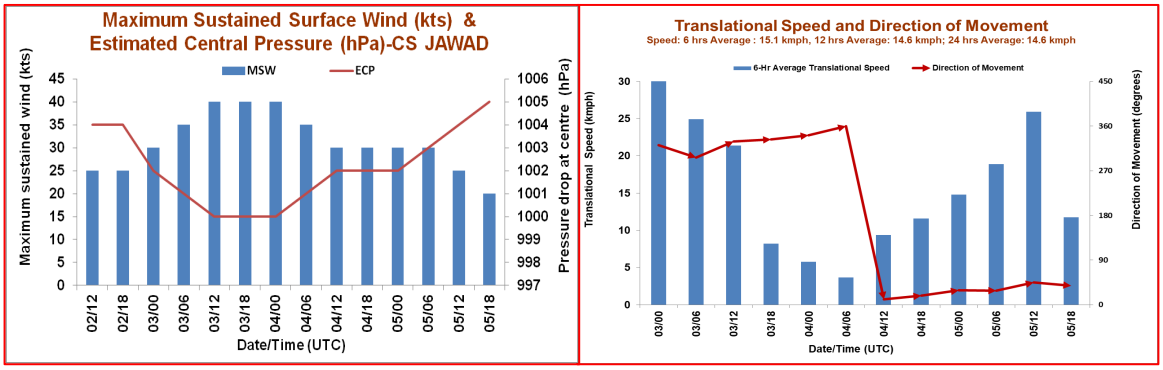


Fig.2: (a) 6 hourly Maximum sustained surface wind & estimated central pressure and (b) 6 hourly translational speed during life cycle of cyclonic storm JAWAD

Table1: Best track positions and other parameters of the Cyclonic Storm, "JAWAD" over the Bay of Bengal during 02 December- 06 December, 2021

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
02.12.21	1200	11.0	89.0	1.5	1004	25	4	**D**
	1800	12.0	87.5	1.5	1004	25	4	D
03.12.21	0000	13.4	86.4	2.0	1002	30	5	**DD**
	0300	14.0	86.0	2.0	1002	30	6	DD
	0600	14.5	85.6	2.5	1001	35	7	**CS**
	0900	15.0	85.3	2.5	1001	35	7	CS
	1200	15.5	85.0	2.5	1000	40	8	CS

	1500	15.7	85.0	2.5	1000	40	8	CS
	1800	15.9	84.8	2.5	1000	40	8	CS
	2100	16.0	84.9	2.5	1000	40	8	CS
04.12.21	0000	16.2	84.7	2.5	1000	40	8	CS
	0300	16.3	84.7	2.5	1000	40	8	CS
	0600	16.4	84.7	2.5	1001	35	7	CS
	0900	16.5	84.7	2.5	1001	35	7	CS
	1200	16.9	84.8	2.0	1002	30	6	**DD**
	1800	17.5	85.0	2.0	1002	30	6	DD
05.12.21	0000	18.2	85.4	2.0	1002	30	6	DD
	0300	18.7	85.6	2.0	1003	30	5	DD
	0600	19.1	85.9	2.0	1003	30	5	DD
	0900	19..5	86.2	1.5	1004	25	4	**D**
	1200	20.1	86.9	1.5	1004	25	4	D
	1800	20.6	87.3	1.5	1005	20	3	D
06.12.21	0000	Weakened into a well marked low pressure area over northwest Bay of Bengal off West Bengal-Bangladesh coasts						

3. Brief life history

3.1. Genesis

Under the influence of a cyclonic circulation over Gulf of Thailand, a low pressure area formed over South Thailand & neighbourhood in the morning (0830 hours IST/0300 UTC) of 30th November. At 0300 UTC of 30th, the sea surface temperature (SST) was 29-31^{0}C over Andaman Sea. Tropical cyclone heat potential (TCHP) was 100-120 KJ/cm^2 over Gulf of Thailand, south Andaman Sea & adjoining eastern Equatorial Indian Ocean (EIO) and southeast BOB. Depth of 26^{0}C isotherm was 100-120 m over the Gulf of Thailand, Andaman Sea and adjoining eastcentral BOB. The Madden Julian Oscillation index (MJO) was in phase 5 with amplitude more than 1. It was forecast to remain in same phase for next 1 day with amplitude remaining more than 1. Thereafter, it was expected to propagate eastwards into phase 6 from 2nd December onwards. Wind shear was moderate (10-20 knots) over Gulf of Thailand, becoming high over south Andaman sea. However, it was becoming low to moderate (05-15) over north Andaman sea, central BOB and adjoining north BOB. The positive low level vorticity was 50x10^{-6}s^{-1} over Gulf of Thailand to the west of system centre. Positive low level convergence was 20x10^{-6}s^{-1} over south Thailand to the northwest of system centre. Positive upper level divergence was 20x10^{-5}s^{-1} over Gulf of Thailand to the northwest of system centre. Upper tropospheric ridge ran along 15^{0}N. A trough in westerlies ran along 58^{0}E upto 18^{0}N. Under these favourable conditions, the cyclonic circulation over Gulf of Thailand concentrated into a low pressure area over South Thailand.

The east-southeasterly winds prevailing in the upper levels steered the system west-northwestwards and it emerged into central parts of Andaman Sea in the same evening (1730 hrs IST). Similar environmental conditions prevailed & the system moved west-northwestwards and lay as a well marked low pressure area over southeast Bay of Bengal (BoB) & adjoining Andaman Sea in the early morning (0530 hrs IST) of 2nd December.

At 1200 UTC of 2nd December, similar sea conditions prevailed. The environmental conditions further consolidated. Wind shear was moderate 15-20 knots over the system area over southeast BOB. Positive low level vorticity increased and was around $100x10^{-6}$ s^{-1} to the northwest of system area. Positive low level convergence was $20x10^{-6}s^{-1}$ to the northwest of the system centre. Positive Upper level divergence increased and was about $30x10^{-5}s^{-1}$ to the northwest of system centre. Continuing to move further west-northwestwards, it concentrated into a depression over southeast Bay of Bengal in the evening (1730 hours IST) of 2nd December.

3.2. Intensification and movement

At 0000 UTC of 3rd December, similar sea conditions prevailed over southeast BoB. Wind shear was moderate (20-25 knots) over the system area over southeast and adjoining westcentral BOB. It was becoming slightly higher towards westcentral & northwest BOB. Positive low level vorticity increased and was $150x10^{-6}s^{-1}$ around the system center. Low level convergence increased significantly and was $50x10^{-5}s^{-1}$ to the northwest of the system centre. Upper level divergence also increased and was 50×10^{-5} s^{-1} to the northwest of system centre. Both divergence and convergence lay over the same area. The system was steered north-northwestwards as it lay in the southern periphery of sub-tropical ridge at 18^0N. Under these conditions, the system intensified into a deep depression at 0000 UTC of 3rd December.

At 0600 UTC of 03rd December, similar sea conditions prevailed. However, MJO entered phase 6. Wind shear was moderate (15-20 knots) over the system area. Positive low level vorticity further increased and was about $180x10^{-6}s^{-1}$ around the system center with vertical extension upto 500 hpa level. Low level convergence was $20\text{-}30x10^{-6}s^{-1}$ to the northeast of the system centre. Upper level divergence was $40x10^{-5}s^{-1}$ to the north of system centre. The sub-tropical ridge lay near 18^0N. Under these conditions, the system moved north-northwestwards and intensified slightly into the cyclonic storm “JAWAD”.

The system moved north-northwestwards, followed by subsequent northwards movement from 0300 UTC of 4th as it lay in the western periphery of the anticyclone over Myanmar region. Thereafter, from 1200 UTC onwards, it recurved north-northeastwards along the western periphery of anticyclone over Myanmar region.

At 1200 UTC of 04th December, the sea conditions became slightly unfavourable with decrease in tropical cyclone heat potential (60-80 KJ/cm^2) and unfavourable MJO conditions. Wind shear was moderate (about 10-15 knots) over the system area, becoming high (20-30 knots) over northwest BoB and along the forecast track. Positive low level vorticity decreased and was about $100x10^{-6}s^{-1}$ around the system centre with vertical extension upto 500 hpa level. The Low level convergence decreased (about $20x10^{-6}s^{-1}$) and was located to the north-northeast of system centre. Upper level divergence also decreased and was about $10x10^{-5}s^{-1}$ around the system centre. Warm moist air incursion decreased. Upper tropospheric ridge ran along 18^0N. Under these conditions, the system re-curved north-northeastwards along Odisha coast and weakened into a deep depression over westcentral BoB.

At 0900 UTC of 5th December, sea conditions further weakened. Wind shear was moderate (about 15-20 knots) over the system area with an increasing tendency becoming high (20-25 knots) over northwest BoB. Positive low level vorticity further decreased and was about 60-80x$10^{-6}s^{-1}$ to the south of system centre with vertical extension upto 500 hpa level. Low level convergence decreased (05x$10^{-5}s^{-1}$) to the northeast of system centre. Upper level divergence also decreased (10x$10^{-5}s^{-1}$) over northwest BoB and was east-west oriented. Upper tropospheric ridge ran along 18.5^0N. The system lay close to the western periphery of anticyclone over Myanmar region. Due to unfavourable environmental features including enhanced vertical wind shear, land interactions, decreased ocean thermal energy over northwest BoB and unfavourable MJO phase, the system further weakened into a depression at 0900 UTC of 5th December over northwest BoB near Odisha coast.

Similar unfavourable conditions continued and the system weakened into a well marked low pressure area over northwest Bay of Bengal off West Bengal-Bangladesh coasts at 0000 UTC and into a low pressure area over the same region at 0300 UTC of 6th December.

The maximum wind speed increased gradually till 0300 UTC of 4th reaching maximum of 40 kts during 1200 UTC of 3rd to 0300 UTC of 4th with lowest pressure drop of 1000 hPa during this period (Fig. 2a). Thereafter, the system encountered unfavourable environmental and sea conditions leading to gradual decrease in intensity and rise in central pressure. It moved with 12 hourly average translational speed of 14.6 kmph against LPA (1990-2013) of 12.9 kmph for CS category over the Bay of Bengal during post monsoon season (Fig.2b). During initial stages of it's development (0000 UTC of 3rd to 1200 UTC of 3rd December), JAWAD moved faster than the average speed. Thereafter it slowed down during recurvature, becoming almost stationary around 0600 UTC of 4th December. Thereafter, the speed gradually increased becoming more than the long period average speed from 5th morning (0000 UTC) onwards. It again decreased just before weakening.

The total precipitable water (TPW) imageries (Source: TC Forecaster Website: https://rammb-data.cira.colostate.edu/tc_realtime/index.asp) during life cycle of CS JAWAD are presented in Fig. 3. These imageries indicate increase in warm moist air around the system centre on 0150 UTC of 3rd December. The warm moist air incursion gradually decreased from 1340 UTC of 4th December and was mainly confined to northeast sector

The mean wind speed and wind shear in middle and deep layer are presented in Fig. 4. The mean wind direction in the middle layer (850-500 hPa) represented the north-northwest movement till 4th/0000 UTC followed by gradual north-northeastward movement of the system. It also indicated that the mean wind speed decreased till 4th/0000 UTC, increased till 5th/1200 UTC and decreased thereafter. However, the deep layer mean wind speed indicated decrease in mean wind speed till 4th/0000 UTC and increase thereafter Thus the system was steered by mean wind in the middle layer.

The mean wind shear direction in the deep layer (between 200-850 hPa levels) indicated that the system was under the influence of low to moderate shear (<20 kts) till 4th/1200 UTC. Thereafter, the shear gradually increased. The direction of mean wind

shear was west-northwestwards till 4th/0600 UTC gradually becoming northwards. However, the mean wind shear in middle layer (850-500 hPa) indicated that moderate wind shear prevailed throughout the life cycle of the system. The wind shear in the deep layer better explained the wind shear speed and direction prevailing over the region during life cycle of the system

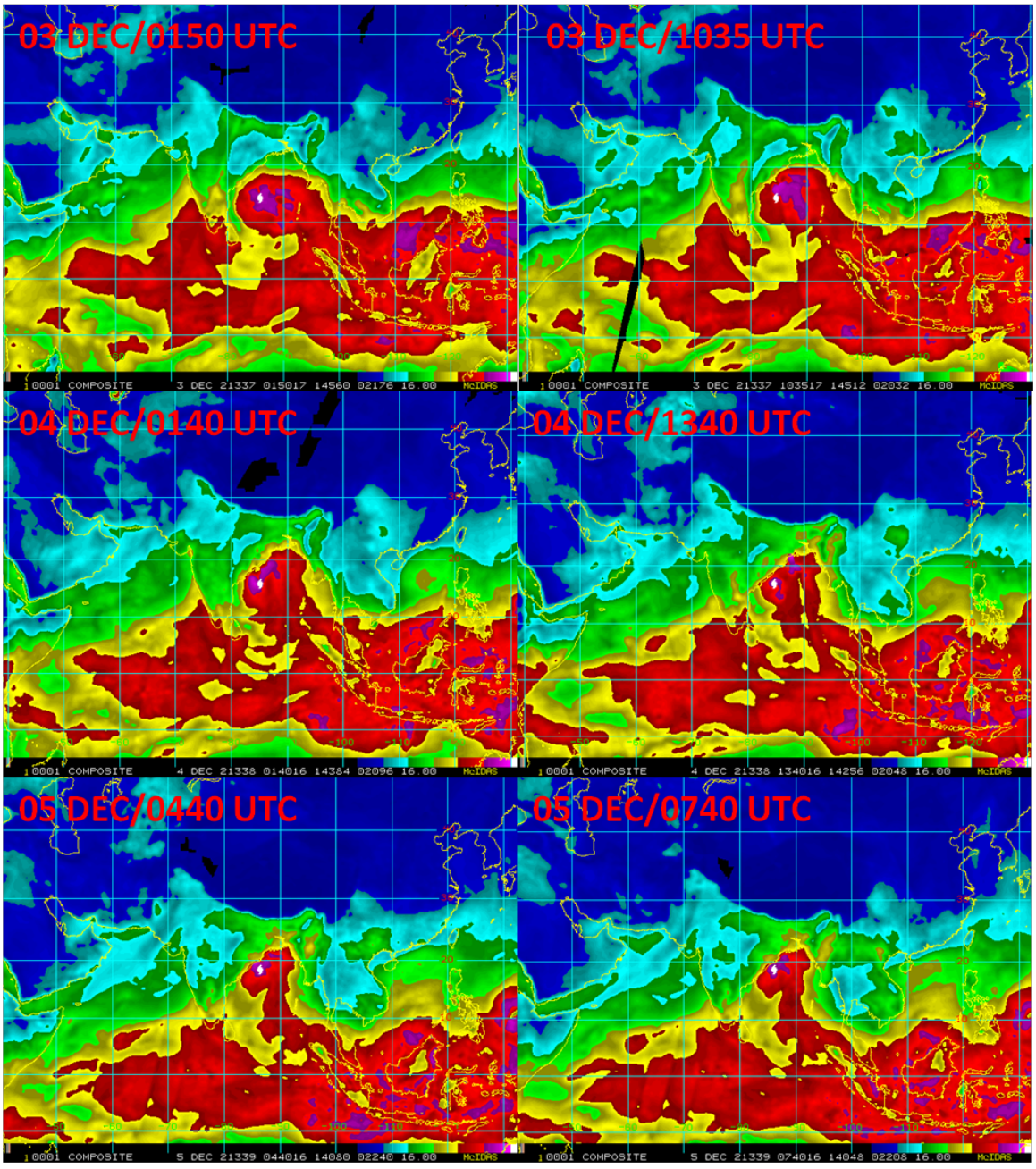


Fig. 3: Typical total precipitable water vapour imageries in case of CS JAWAD during 02 Dec-05 Dec, 2021

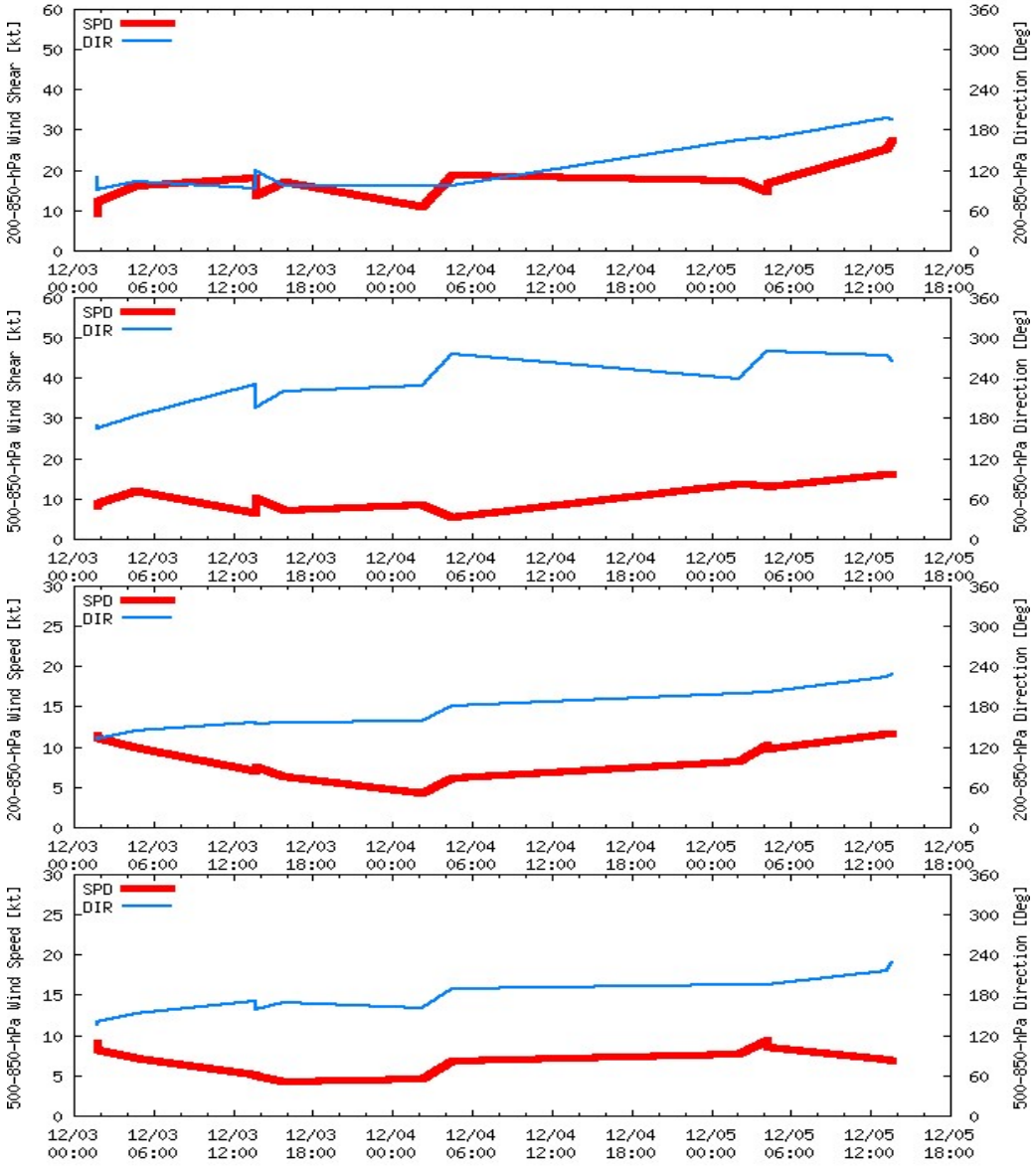


Fig.4: Mean Wind shear and mean wind speed in the middle (500-850 hPa) and deep layer (200-850 hPa) over the system during CS JAWAD (02-05 Dec.) 2021

4. Monitoring

India Meteorological Department (IMD) maintained round the clock watch over the north Indian Ocean and the cyclone was monitored since 18th November, about 12 days prior to the formation of low pressure area over south Thailand and neighborhood on 30th November and 14 days prior to formation of depression over southeast BoB on 2nd December. The cyclone was monitored with the help of all available satellite observations including geostationary satellites (INSAT 3D & 3DR) & various polar orbiting satellites and available ships & buoy observations in the region. The system was also monitored by Doppler Weather RADARs (DWR) Visakhapatnam and Gopalpur. Various numerical weather prediction models run by Ministry of Earth Sciences (MoES) institutions, 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 during CS JAWAD are presented in Fig. 5.

4.1. Features observed through satellite

At 1200 UTC of 2nd December, the convective clouds organised into shear pattern. The intensity of the system was characterized as T 1.5. The convective cloud clusters are sheared to northwest sector. Associated scattered to broken low & medium clouds with embedded intense to very intense convection lay over southeast & adjoining southwest BOB and central BOB between latitude 9.5^0N & 17.5^0N and longitude 81.5^0E & 92.5^0E, Andaman Islands and adjoining Andaman Sea.

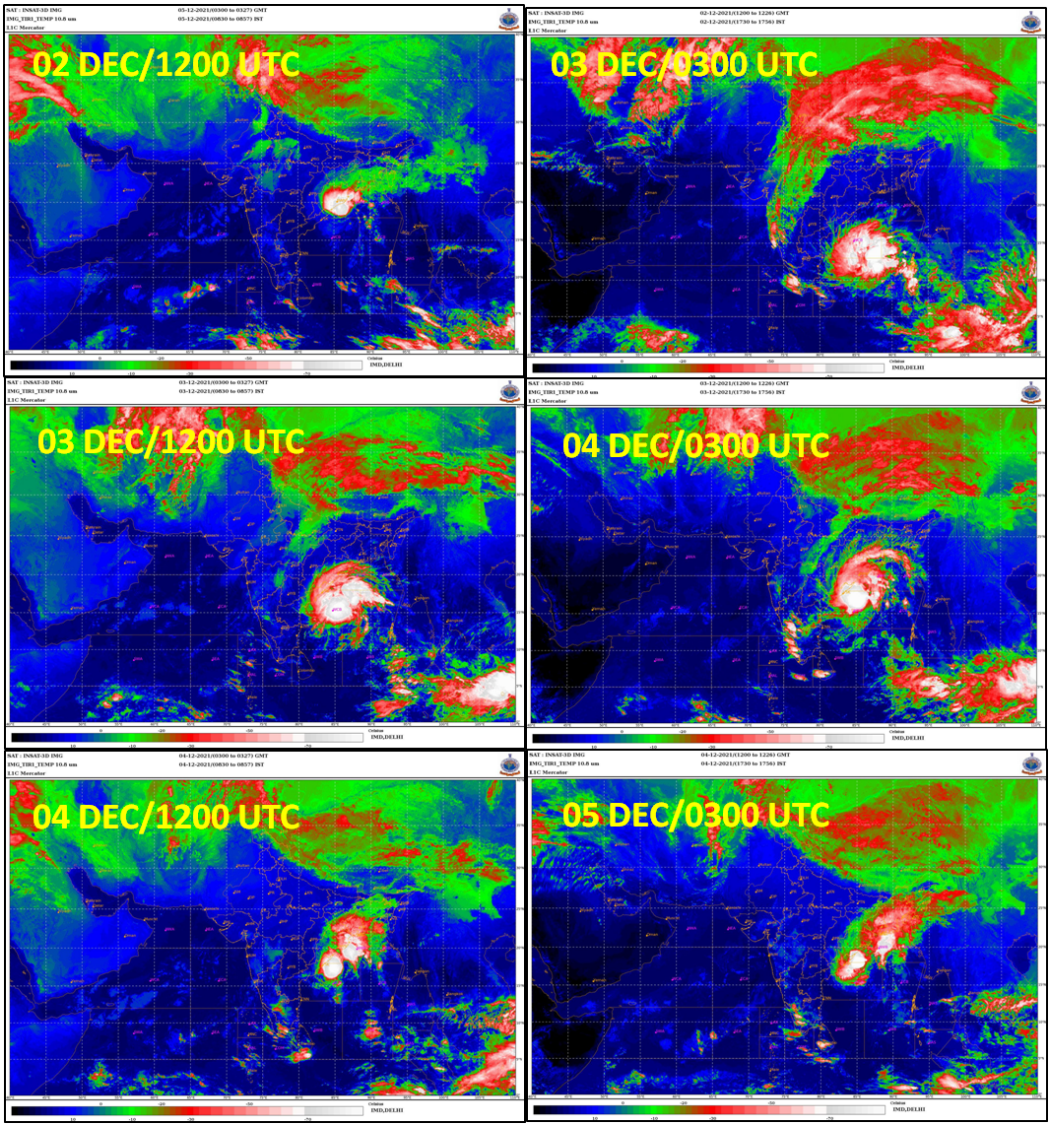


Fig. 5(a): INSAT-3D enhanced colored imageries during life cycle of CS JAWAD during 02 Dec-05 Dec, 2021

At 0000 UTC of 3rd December, the intensity of the system was characterized as T 2.0. The cloud mass was organized in shear pattern. The convective cloud clusters were

sheared to northwest sector. Associated scattered to broken low & medium clouds with embedded intense to very intense convection lay over central & adjoining northwest BOB between latitude 13.0^0N & 20.0^0N and longitude 81.0^0E & 92.0^0E, north coastal Andhra Pradesh and east Odisha.

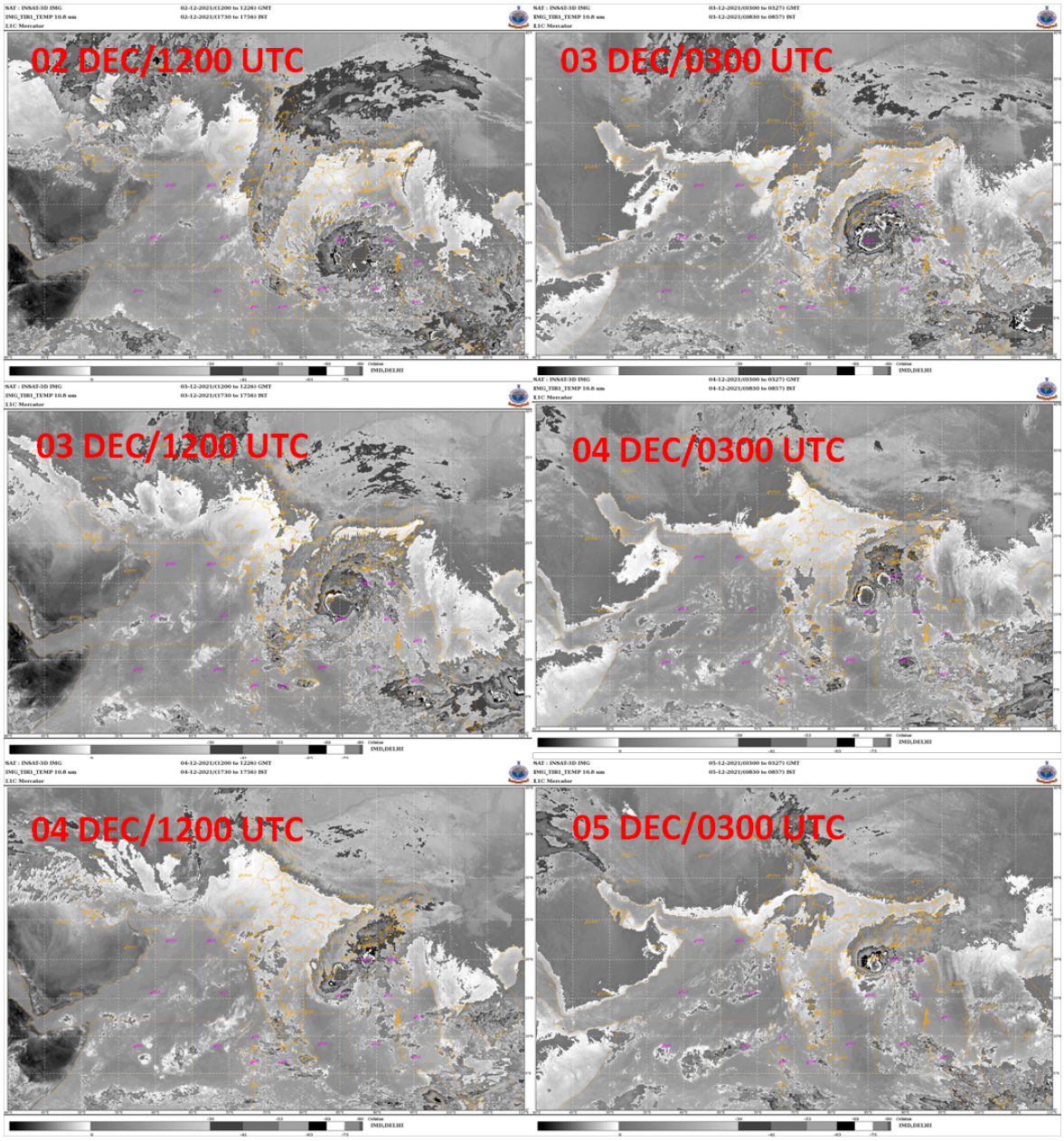


Fig. 5(b): INSAT-3D BD imageries during life cycle of CS JAWAD during 02 Dec-05 Dec, 2021

At 0600 UTC of 3rd December , the intensity of the system was characterized as T 2.5. The cloud mass was organized in shear pattern. The system moved west north-westwards and consolidated further. The convective cloud clusters were sheared to northwest sector. Area of intense convection lay in the northern sector. Secondary cloud bands were observed over north Andhra Pradesh and south Odisha coasts. Associated broken low & medium clouds with embedded intense to very intense convection lay over

central & adjoining northwest BOB between latitude 14.0^{0}N & 22.0^{0}N and longitude 81.0^{0}E & 92.0^{0}E, north coastal Andhra Pradesh and east Odisha.

At 1200 UTC of 4th December, the system entered moderately unfavourable environment. Wind shear increased and the system gradually started weakening. The intensity of the system was characterized as T 2.0. Associated cloud mass with embedded moderate to intense convection was seen over north coastal Andhra Pradesh and adjoining south Odisha, and moderate to intense convection lay over Jharkhand, Gangetic West Bengal and southeast Bihar. Associated broken low to medium clouds with embedded intense to very intense convection lay over westcentral and north Bay of Bengal between latitude 15.5^{0}N & 22.0^{0}N and longitude 82.5^{0}E & 92.0^{0}E. The maximum cloud top temperature was - 93^{0}C.

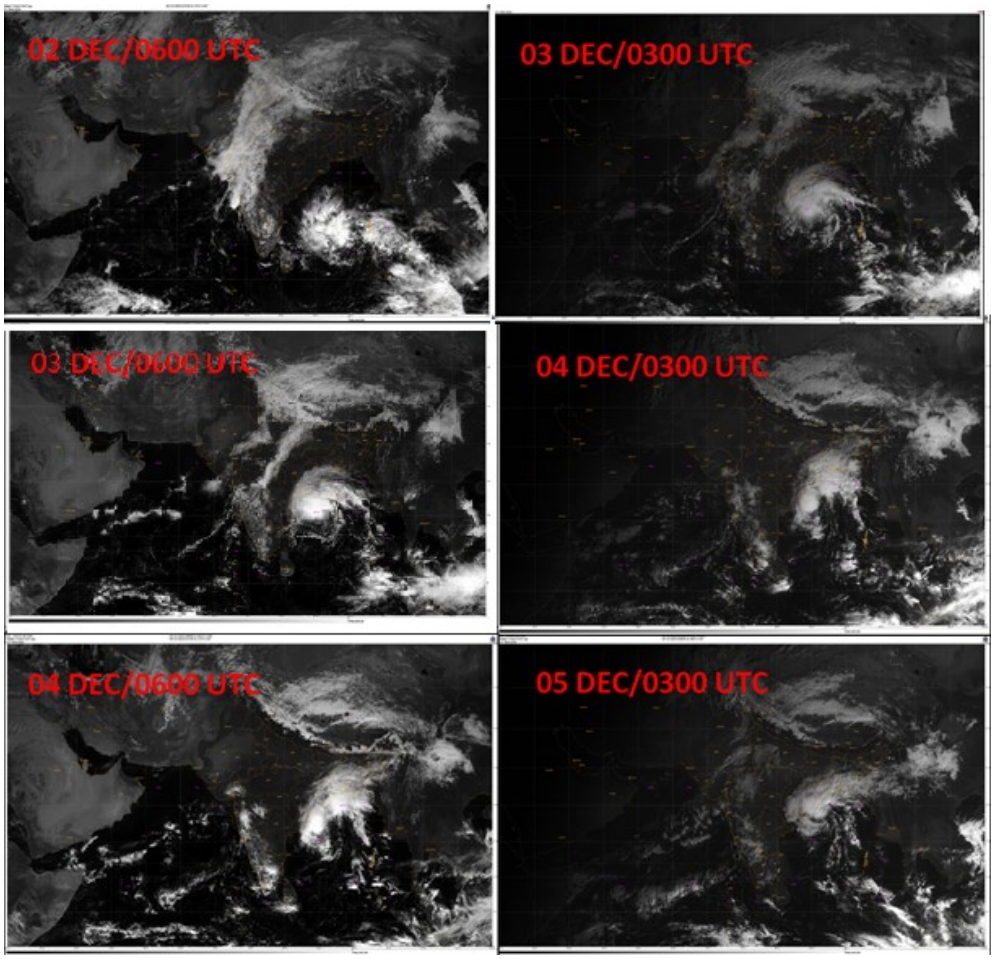


Fig. 5(c): INSAT-3D Visible imageries during life cycle of CS JAWAD during 02 Dec-05 Dec, 2021

At 0900 UTC of 5th December, further weakening of system was witnessed due to decreased ocean thermal energy, increased vertical wind shear and land interactions. The intensity of the system was characterized as T1.5/C.I.1.5. Associated cloud mass with embedded intense to very intense convection was seen over east Odisha and moderate to intense convection was seen over west Odisha, Jharkhand & Gangetic West Bengal. Associated scattered to broken low to medium clouds with embedded intense to

very intense convection lay over westcentral & northwest BoB, north of latitude 17.5^{0}N and west of longitude 89.0^{0}E. The minimum cloud top temperature was minus 93^{0}C.

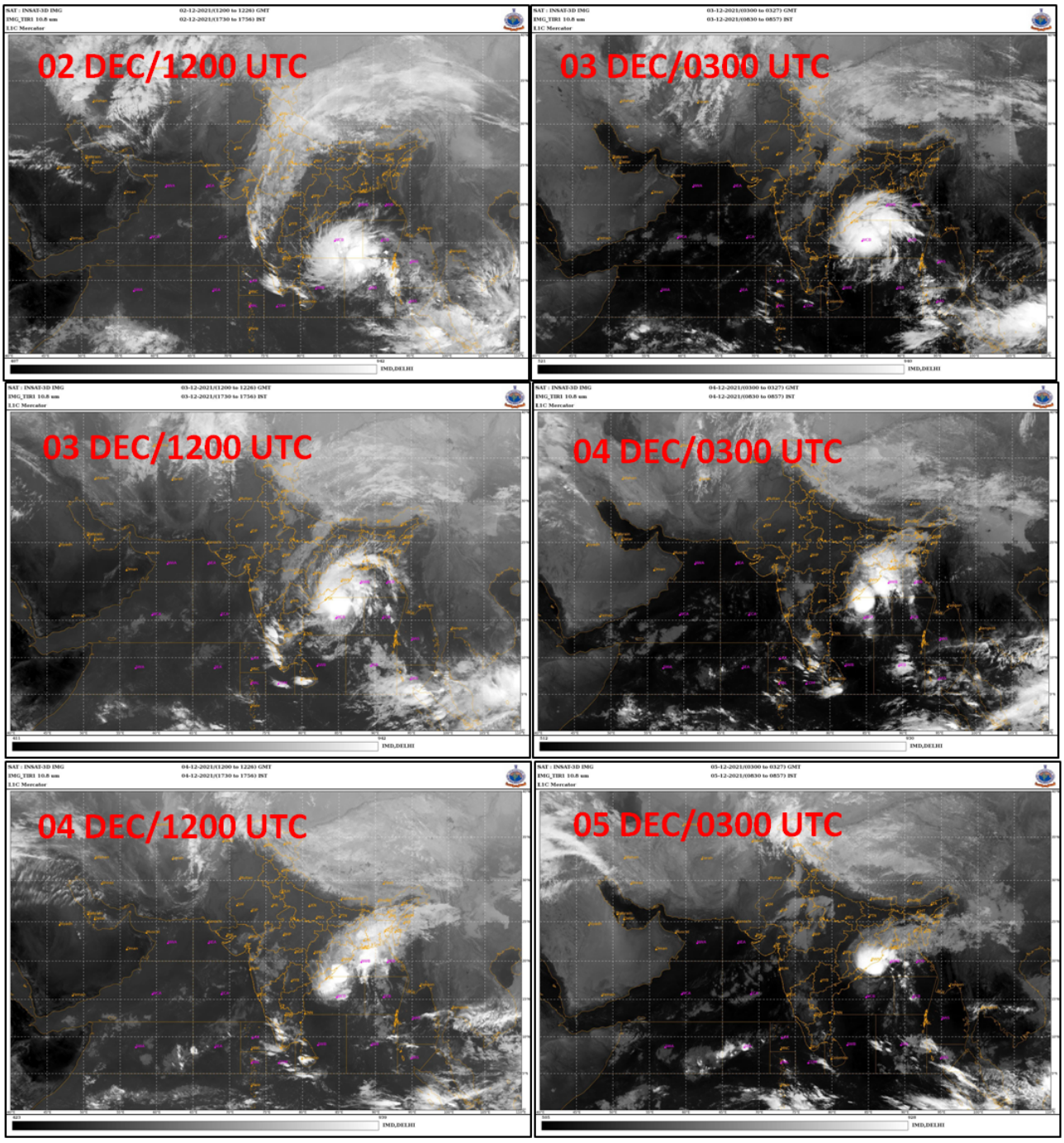


Fig. 5(d) : INSAT-3D IR imageries during life cycle of CS JAWAD during 02 Dec-05 Dec, 2021

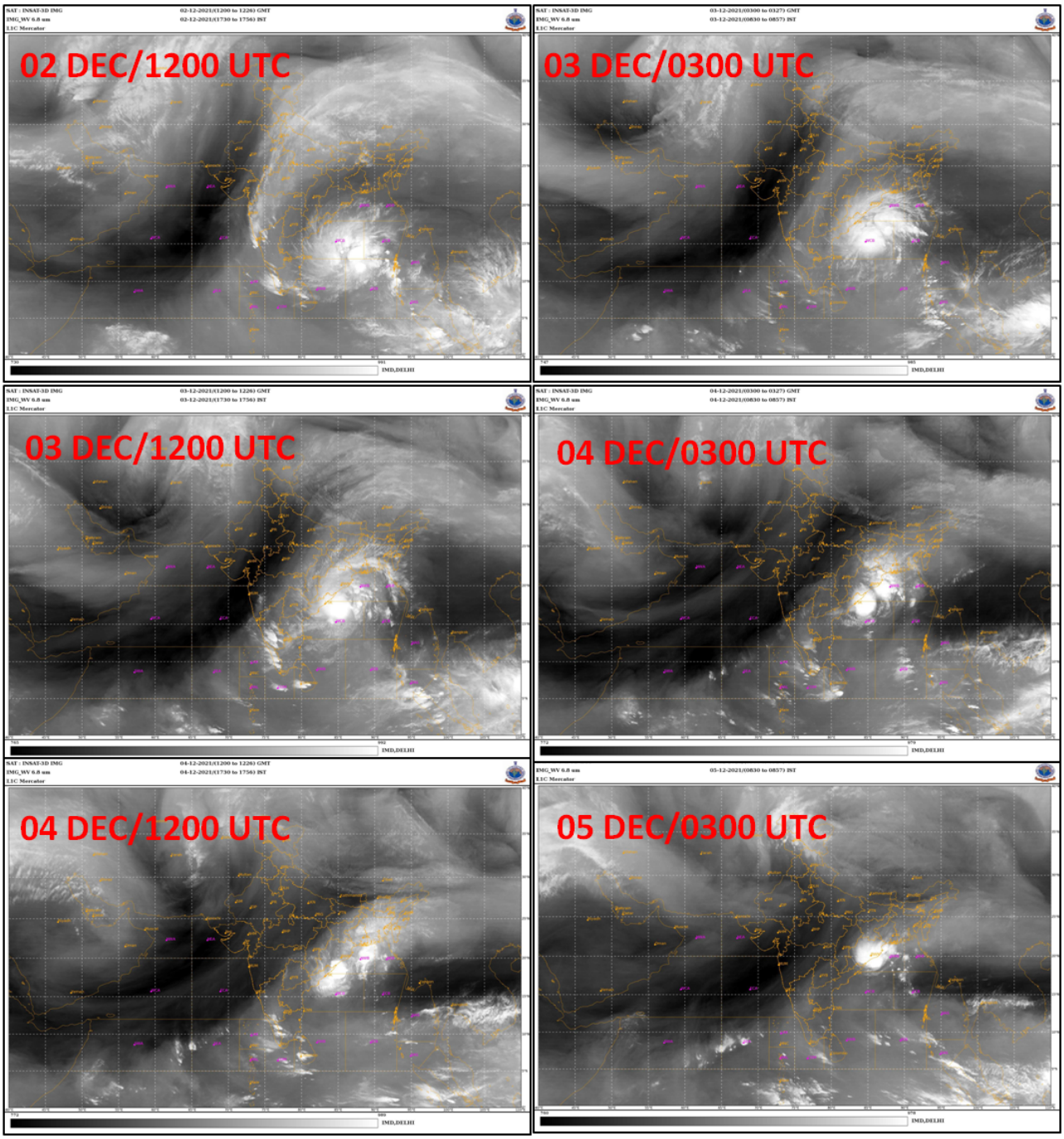


Fig. 5(e): INSAT-3D WATER VAPOUR imageries during life cycle of CS JAWAD during 02 Dec-04 Dec, 2021

Typical imageries from GCOM-W1, AMSR2 (89 GHz) imageries are presented in Fig.5 (f). At 1800 UTC of 2nd December, the intense convection was sheared in the northwest sector. Gradually from 4th morning onwards, the intense convection area shifted northeastwards. At 1800 UTC, area of intense convection extended over north BoB off north Odisha, Gangetic West Bengal & south Bangladesh coasts.

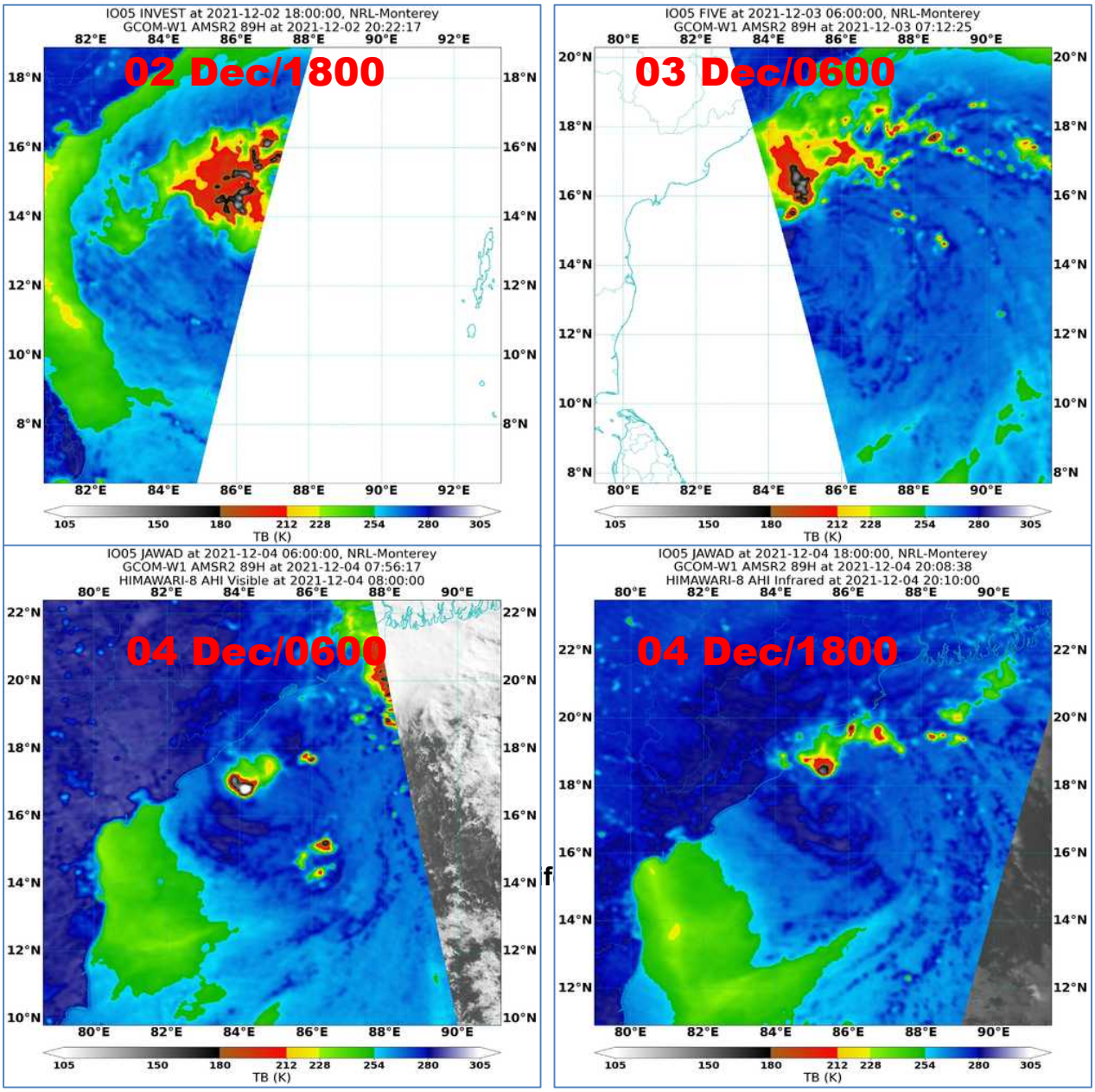


Fig. 5(f): Typical microwave imageries during life cycle of CS JAWAD during 02 Dec-04 Dec, 2021

Typical ASCAT imageries during life cycle of CS JAWAD during 02-06 December, 2021 are presented in Fig.5 (g). At 0438 UTC of 3rd December, ASCAT indicated maximum sustained wind speed of 35 kts. However, the centre was not clearly seen in the ASCAT pass. At 0417 UTC of 4th December, ASCAT indicated wind speed of 35 kts and centre was around 16^0N/84.5^0E. The operational location and intensity at 0300 UTC of 4th was 16.3^0N/84.7^0E with wind speed of 40 kts. The imagery at 0417 UTC indicated weakening trends in the intensity of system.

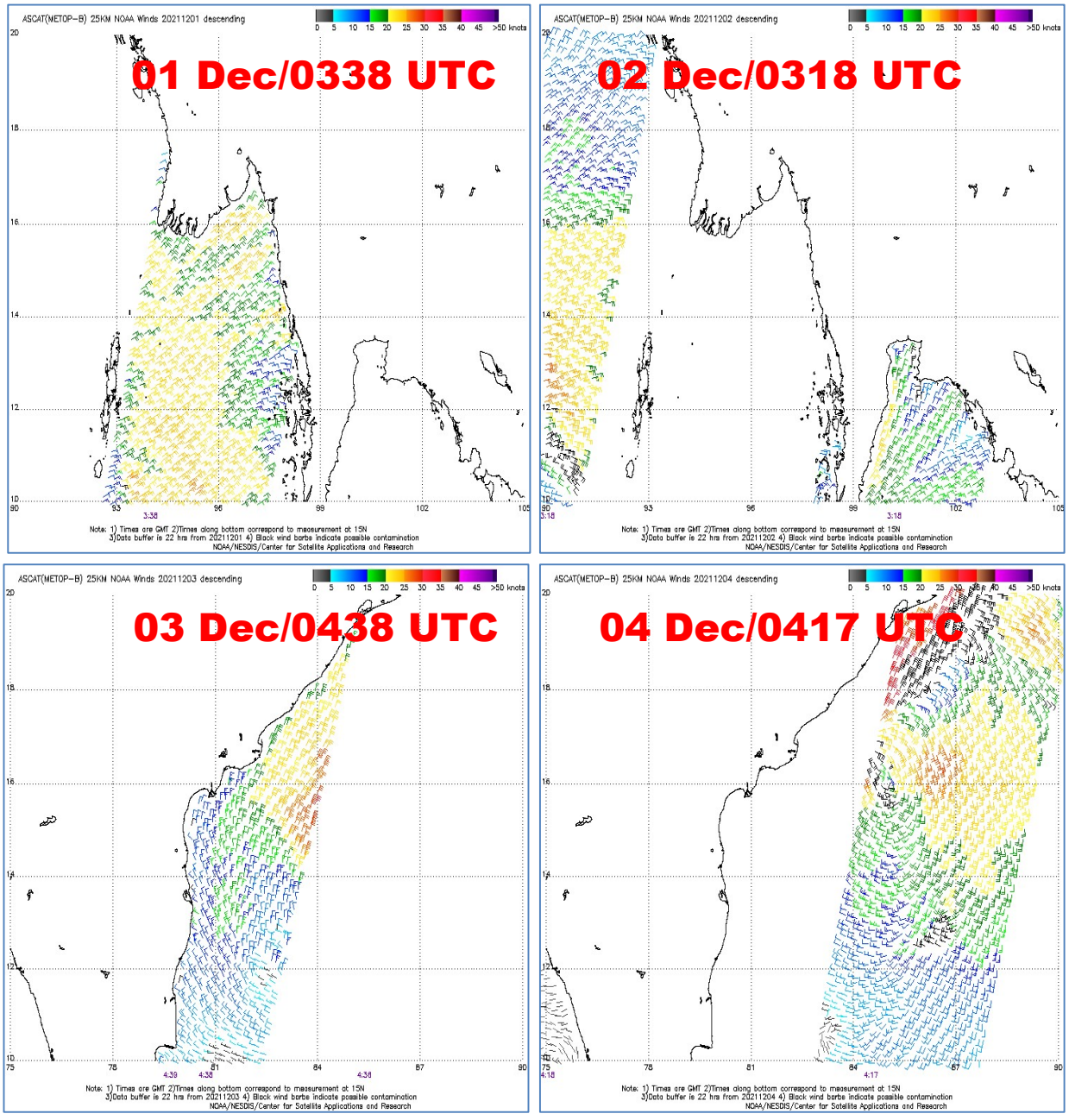


Fig. 5(g): Typical imageries from ASCAT during life cycle of CS JAWAD during 02 Dec-04 Dec, 2021

CS JAWAD was continuously monitored by IMD's Doppler Weather Radars (DWR) at Visakhapatnam, Gopalpur and Paradeep while moving north-northeastwards along the east coast of India close towards north BoB. Typical imageries from these Radars during 3rd to 6th December are presented in (Fig. 6).

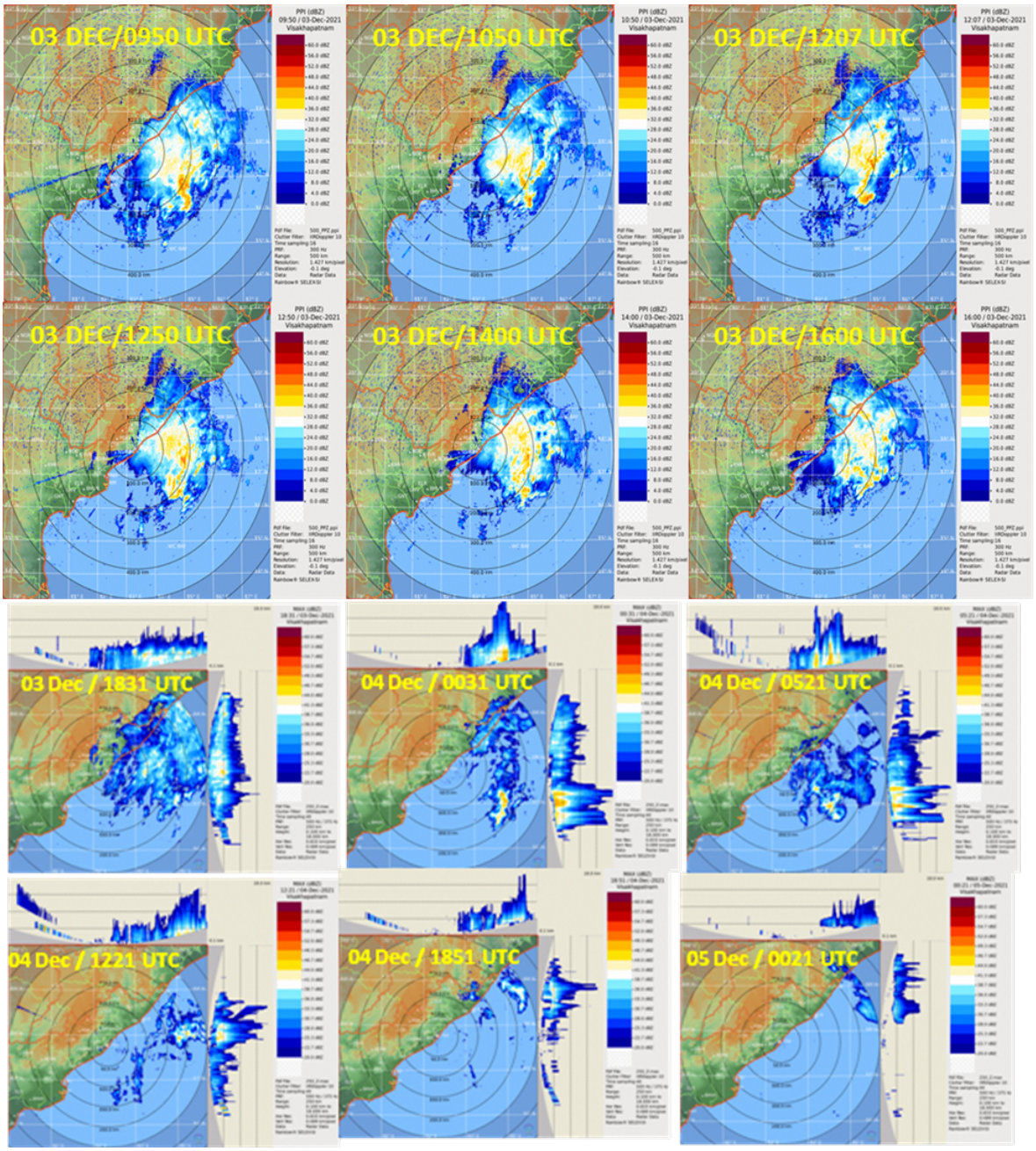


Fig. 6 (a): Maximum reflectivity (dBz) imageries from DWR Visakhapatnam during 03 Dec-06 Dec, 2021 in association with CS Jawad

Maximum reflectivity imageries from DWR Gopalpur during 3rd to 5th December are presented in Fig. 6 (b).

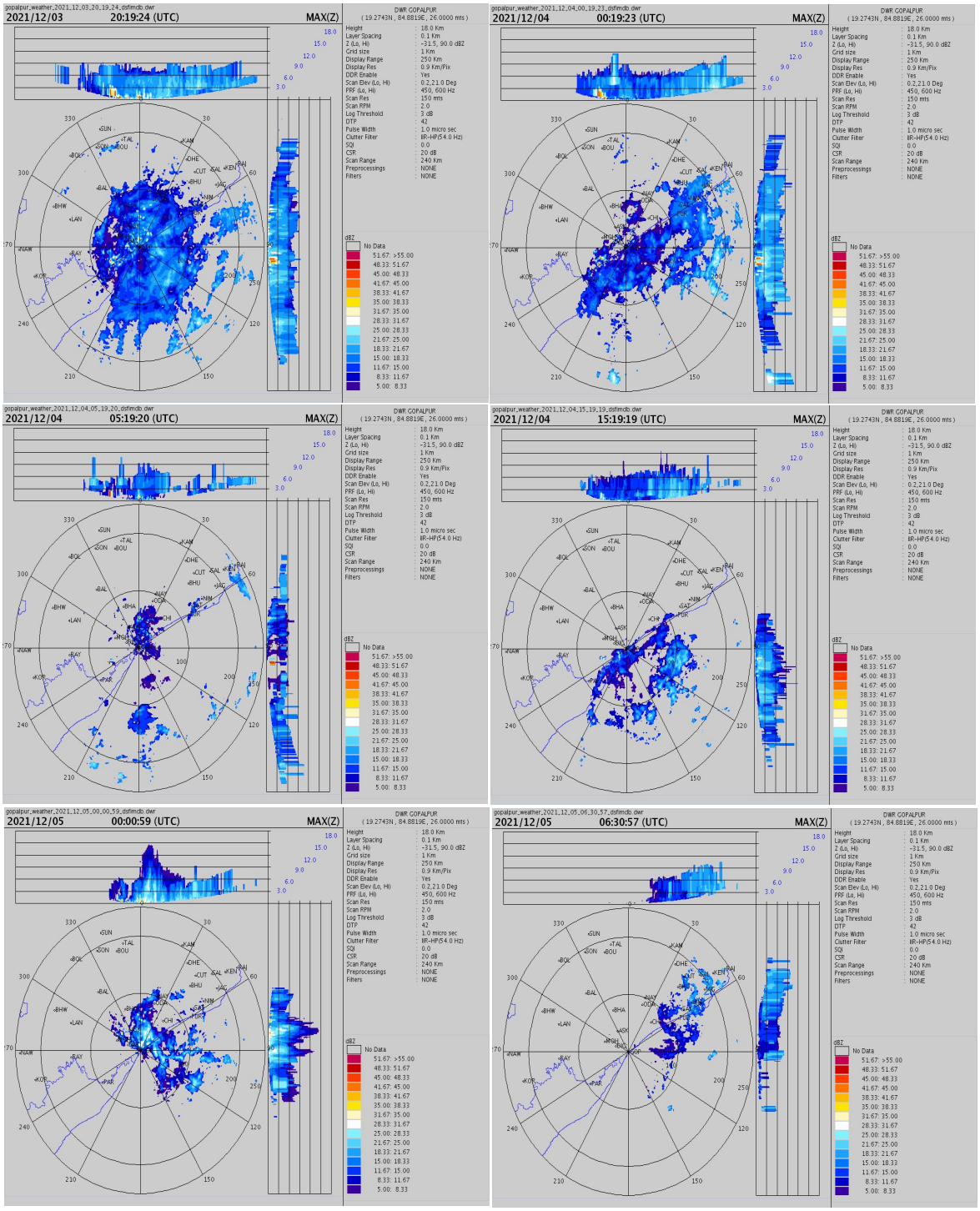


Fig. 6 (b): Maximum reflectivity (Z) imageries from DWR Gopalpur during 03 Dec-05 Dec, 2021 in association with CS Jawad

Volume Velocity Processing (VVP (V)) imageries presenting the horizontal wind speed and direction in a vertical column from DWR Gopalpur during 3rd to 5th are presented in Fig. 6(c).

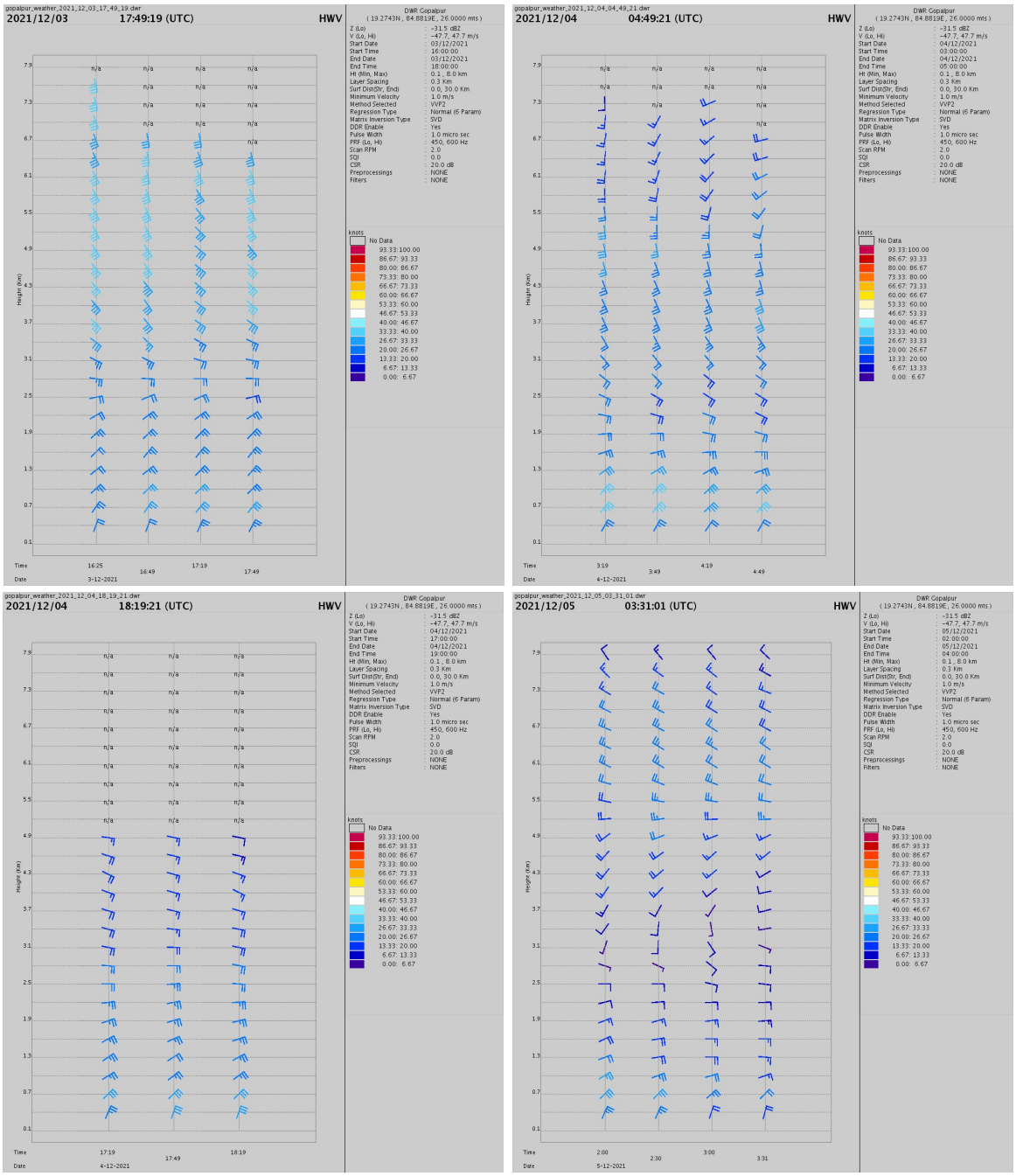


Fig. 6 (c): Volume Velocity Processing (VVP(V)) imageries from DWR Visakhapatnam during 03 Dec-05 Dec, 2021 in association with CS Jawad

Maximum reflectivity imageries from DWR Paradeep during 3rd to 5th December are presented in Fig. 6 (d).

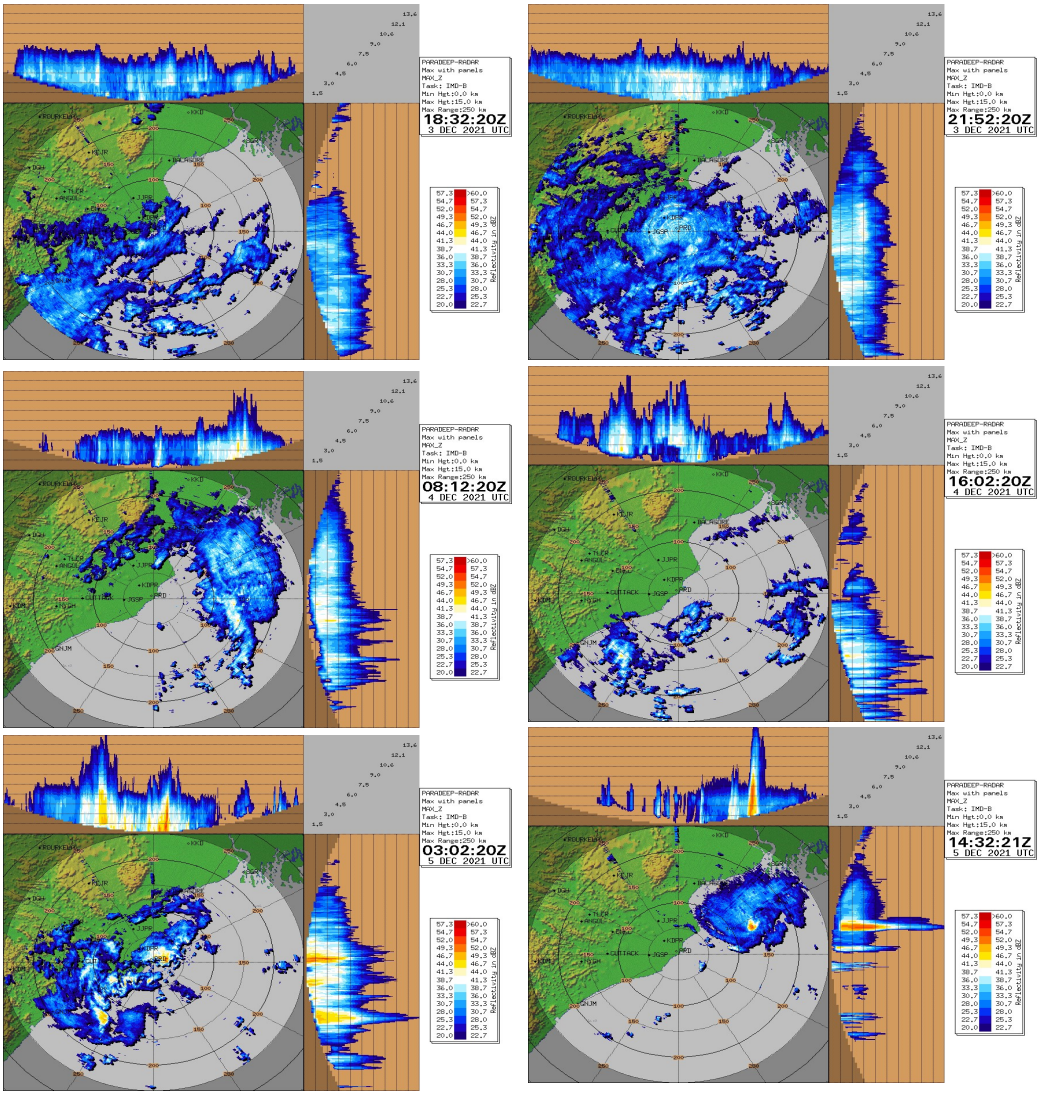


Fig. 6 (d): Maximum reflectivity (Z) imageries from DWR Paradeep during 03 Dec-05 Dec, 2021 in association with CS Jawad

Volume Velocity Processing (VVP (V)) imageries presenting the horizontal wind speed and direction in a vertical column from DWR Paradeep during 3rd to 5th are presented in Fig. 6(f).

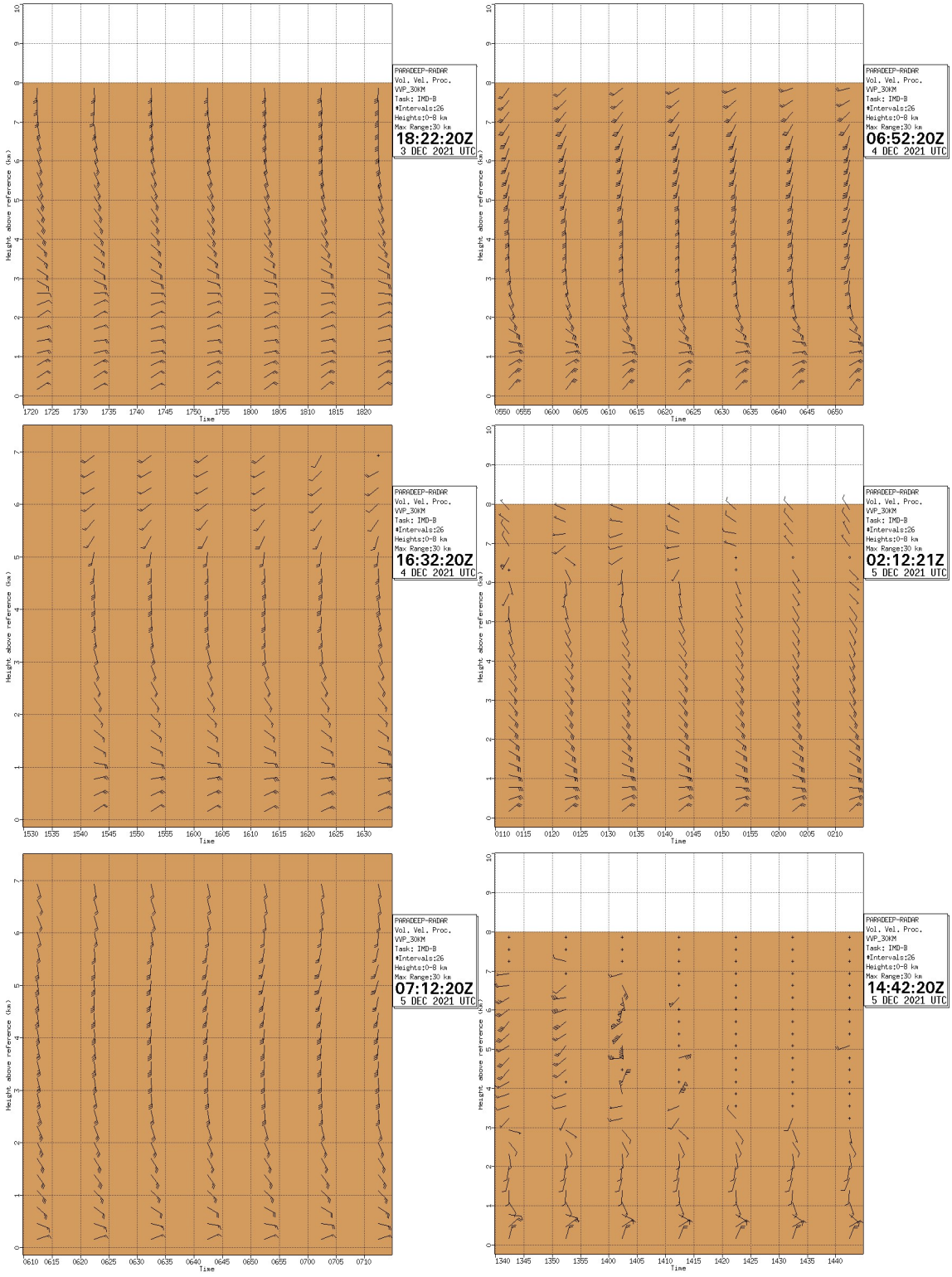


Fig. 6 (e): Volume Velocity Processing (VVP(V)) imageries from DWR Paradeep during 03 Dec-05 Dec, 2021 in association with CS Jawad

5. Dynamical features

IMD GFS analysis of mean sea level pressure, winds at 10m, 850 hPa, 500 hPa and 200 hPa levels based on 0000 UTC during 2nd to 6th December, 2021 are presented in Fig.7. On 2nd December, IMD GFS indicated a depression over southeast BOB with vertical extension of the cyclonic circulation upto 500 hPa level. The upper tropospheric ridge was seen near 15^0N. The model could capture the west-northwestwards movement of system. However, at 0000 UTC of 2nd December, the model slightly over-estimated the intensity of the system. At that time, it lay as a well marked low pressure area over southeast BoB and adjoining areas.

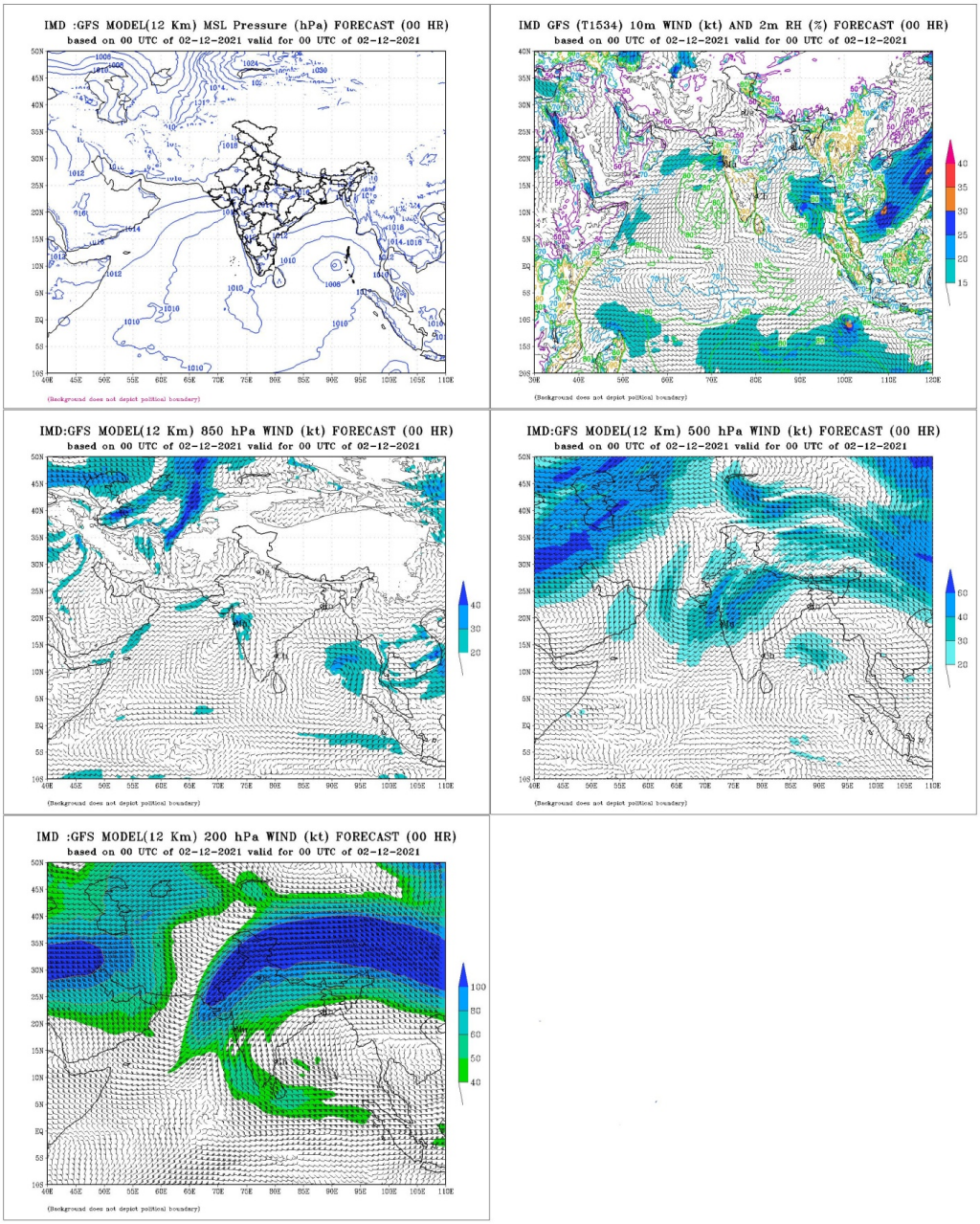


Fig. 7 (a): IMD GFS (T574) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 02nd December, 2021

On 3rd December, IMD GFS indicated a severe cyclonic storm over westcentral BOB with vertical extension upto 500 hPa level. The upper tropospheric ridge was seen near 15^0N. The approaching westerly trough was also picked by the model. The forecast field indicated further intensification of system and also crossing over south Odisha coast close to Puri around 1700 UTC of 4th. However, at 0000 UTC of 3rd, it lay as a deep depression over westcentral BoB. Thus, the model picked up the movement & location correctly, but over-estimated the intensity of the system.

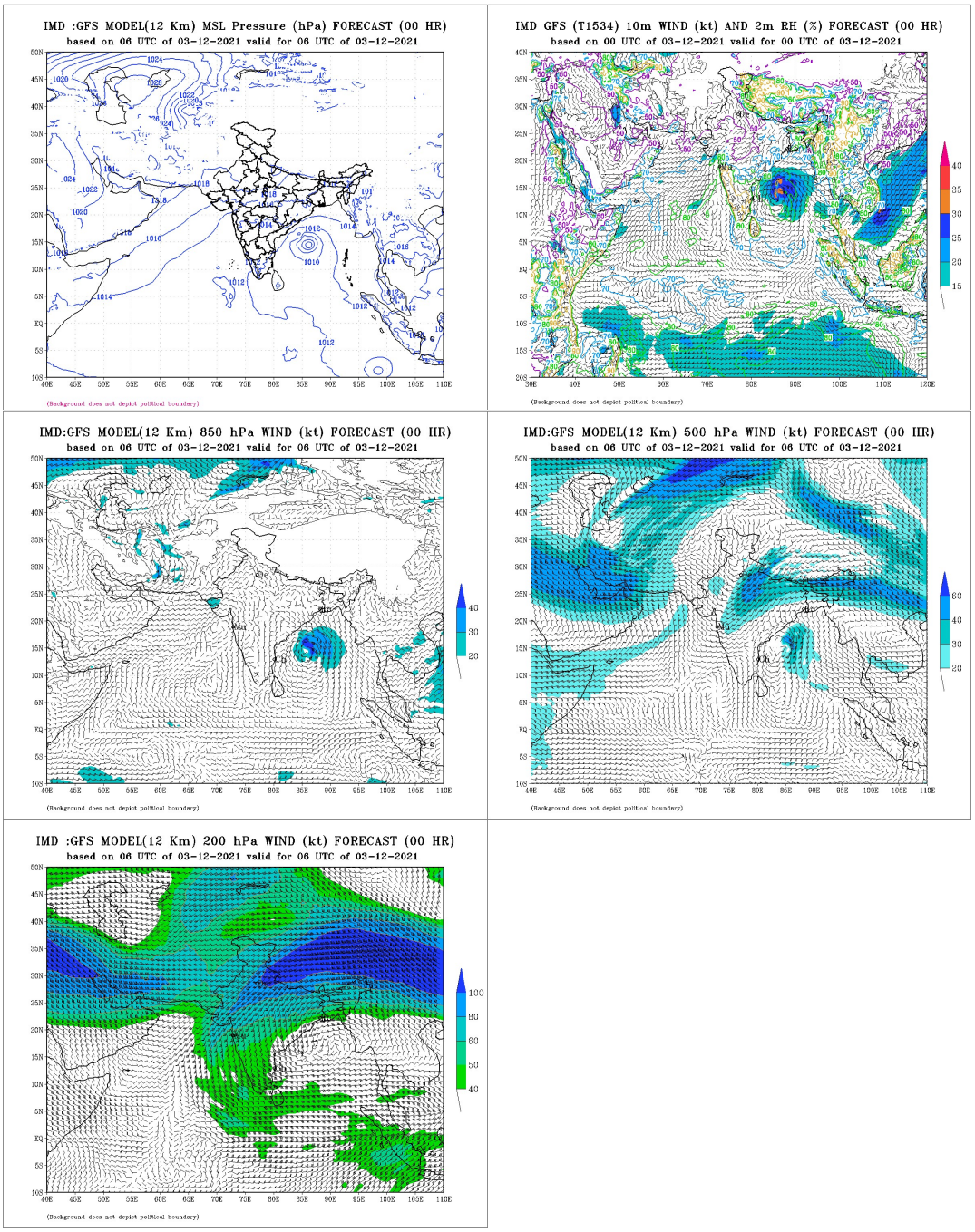


Fig. 7 (b): IMD GFS (T574) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 03rd December, 2021

On 4th December, IMD GFS indicated slight weakening into a cyclonic storm over westcentral BOB with vertical extension upto 500 hPa level. The anticyclone over eastcentral BoB near Myanmar and the approaching trough was captured by the model. The forecast field indicated northeastwards movement of system and it's weakening over northwest BoB off Odisha coast on 5th evening. However, at 0000 UTC of 4th, it lay as a cyclonic storm over westcentral BoB. Thus, the model picked up the movement, location and intensity of the system correctly on 4th December.

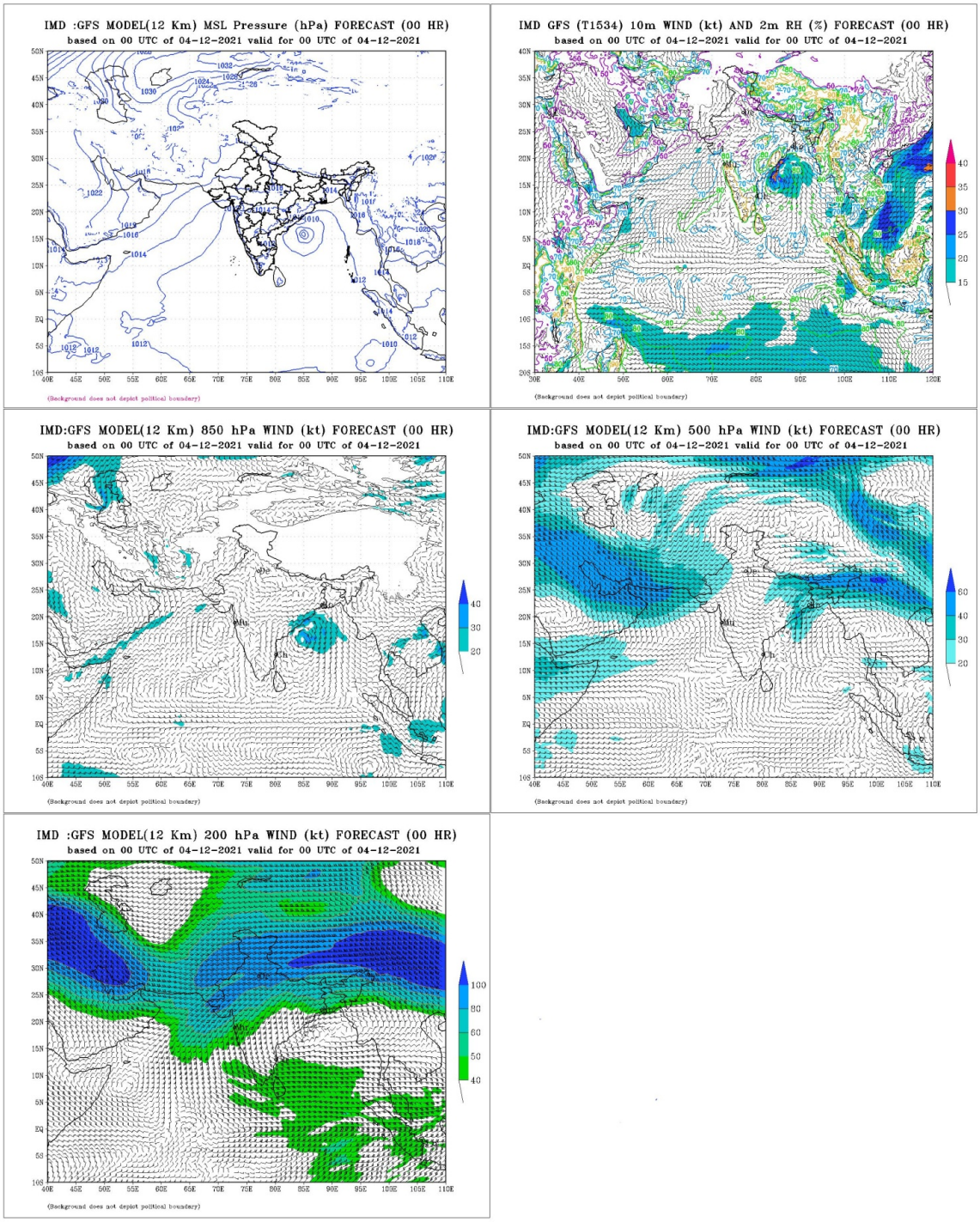


Fig. 7 (c): IMD GFS (T574) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 04th December, 2021

On 5th December, IMD GFS indicated further weakening into a deep depression over westcentral BOB (close to Odisha coast) with vertical extension upto 500 hPa level. The anticyclone over eastcentral BoB near Myanmar and the approaching trough was captured by the model. However, at 0000 UTC of 5th, it lay as a deep depression over westcentral BoB. Thus, the model picked up the movement, location and intensity of the system correctly on 5th December.

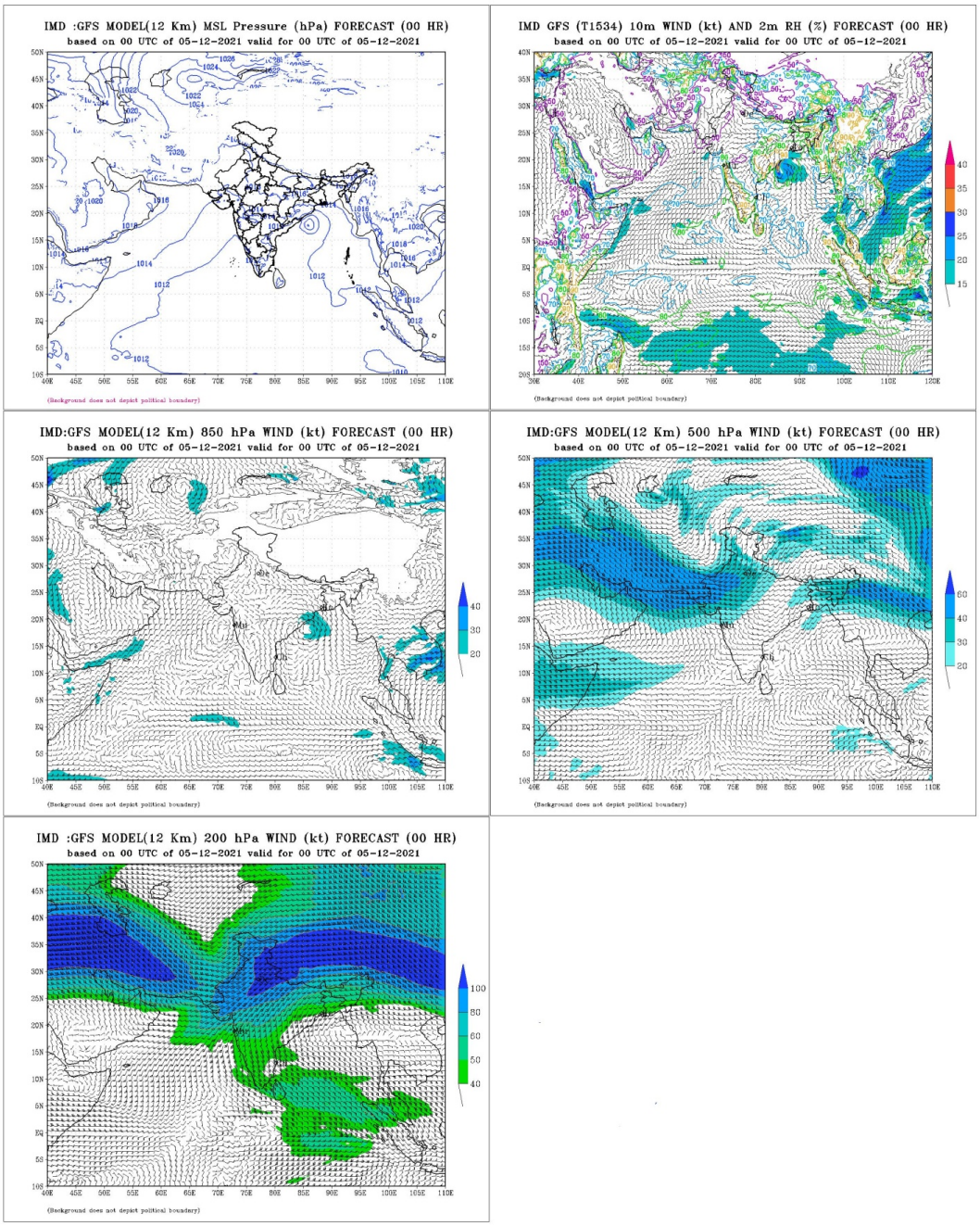


Fig. 7 (d): IMD GFS (T574) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 05th December, 2021

Hence to conclude, IMD GFS initially over-estimated the intensity of the system. But from 4th onwards, it correctly picked the location, intensity and movement. It could also capture the impact of approaching westerly trough and the anticyclone over eastcentral BoB and predicted northeastwards recurvature of the system from 4th onwards correctly.

6. Realized Weather:

6.1. Realised rainfall

The rainfall associated with CS Jawad based on IMD-NCMRWF GPM merged gauge 24 hours cumulative rainfall ending at 0830 IST of date is depicted in **Fig 8**. The plots show that the system caused heavy over south Andaman Sea on 29th November. The rainfall belt gradually moved west-northwestwards, causing heavy to very heavy rainfall at few places over south Andaman Sea on 30th November and at many places over Andaman Islands on 1st December. It caused widespread heavy to very rainfall at a few places with extremely heavy falls at isolated places over westcentral BoB on 2nd December. On 3rd, it caused scattered heavy to very rainfall with isolated extremely falls over westcentral BoB off north Andhra Pradesh & south Odisha coasts. On 4th decrease in rainfall activity is seen with isolated heavy to extremely heavy rainfall over westcentral BoB off Odisha-Gangetic West Bengal coasts. On 5th December, heavy to very heavy rainfall at few places over north Odisha, Gangetic West Bengal and south Bangladesh coasts is seen.

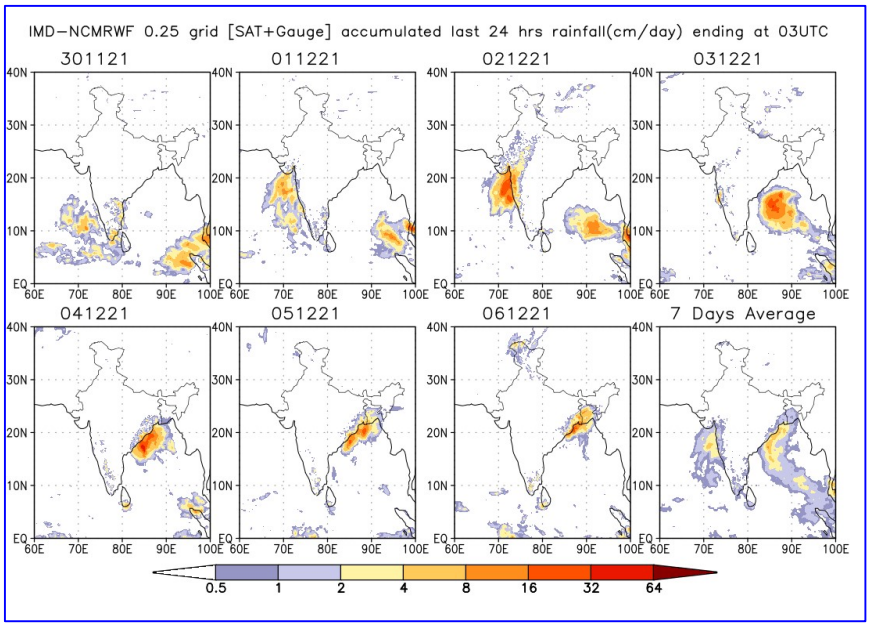


Fig.8: IMD-NCMRWF GPM merged gauge 24 hr cumulative rainfall (cm) ending at 0830 IST of date during 30th Nov. – 6th December and 7 days average rainfall (cm/day)

24 hours realized heavy to extremely rainfall (≥7cm) ending at 0830 hrs IST of date during the life cycle of the system is presented below:

5th December 2021:

Odisha: Ganjam district: Chhattarpur-9, Purushottampur-8, Behrampur, Digapahandi, Gopalpur-6 each; **Khurda district**: Banpur-8; Jagatsinghpur district: Paradip CWR-6, Balikuda-5; **Nayagarh district**: Nayagarh-6; **Puri district**: Astaranga-5; **Kendrapada district:** Garadapur5; **Cuttack district**: Kantapada-5; **Jajpur district**: Chandikhol-5

6th December 2021:

Odisha: Jagatsinghpur district: Erasama-23, Paradip-20, Balikuda-15, Kujanga-14, Nuagaon-13, Tirtol-12, Raghunathpur-9, Jagatsinghpur-7; **Kendrapara district**: Marshaghai, Garadpur13 each, Rajnagar-12, Mohakalpara-10, Derabis-9, Kendrapara,

Patamundai-8 each; **Puri district**: Kakatpur12, Astaranga-11, Delang, Kanas-8 each, Nimapara-7; **Cuttack district**: Niali-10, Tangi-Choudwar-7**.**

Gangetic West Bengal: Hooghly district: Tarakeshwar-18, Bagati-13, Harinkhola-8; Burdwan district: Burdwan - 13, Manteswar-7; **Nadia district**: Kalyani -12; **North 24 Parganas district**: Barrackpur-12, Dum Dum-10, Salt lake-9; **West Midnapore district**: Mohanpur, Kharagpur-11 each, Midnapore, Kalaikunda -9 each, Jhargram, Lalgarh-7 each; **Howrah district**: Uluberia -9; **Kolkata district**: Alipore-7; **South 24 Parganas district:** Canning-7**.**

Cumulative realised rainfall (cm) during 29th November to 6th December over Visakhapatnam, Odisha and Gangetic West Bengal in association with CS JAWAD is presented in Fig. 9.

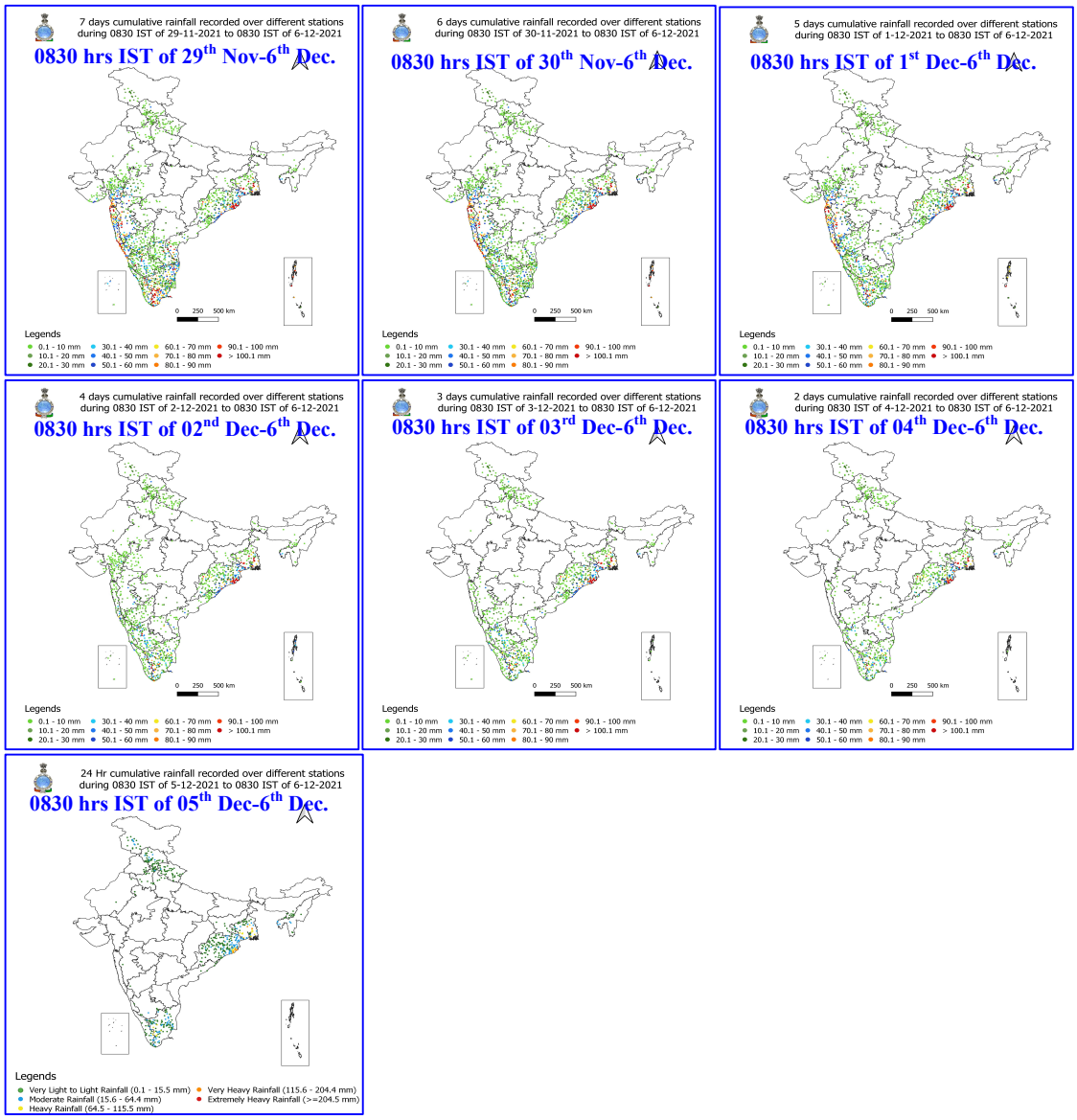


Fig.9: Cumulative realised rainfall (cm) during 29th November to 6th December over Visakhapatnam, Odisha and Gangetic West Bengal in association with CS JAWAD

6.2. Peak wind speed (kmph) recorded by various Meteorological Observatories in association with the passage of JAWAD

Meteorological Office at Puri reported MSW of 18 knots during 1030-1130 hrs IST (0500 to 0600 UTC) of 5th December, high wind speed recorder at Paradeep reported MSW of 26 knots at 1530 hrs IST (0995 UTC) of 5th December. Dhamra Port reported south-southeasterly winds of intensity 32 knots gusting to 35 knots at 4th/0600 UTC.

6.3. Storm Surge

No surge was forecast and observed in association with this system.

7. Damage due to CS JAWAD

Two persons lost their lives in Srikakulam district of Andhra Pradesh due to falling of coconut tree. 1 farmer in Odisha (Ganjam district) committed suicide due to damage caused to his paddy crops. Typical damage photographs from various media reports are presented in Fig. 10.

River Barrage at Mousuni Island broken due to impact of Cyclone JAWAD (Anandabazar Patrika dated 06-12-2021)

Boat drowned in Muri Ganga river at Kachuberia, South 24 Parganas, West Bengal (Chhapte Chhapte Hindi Newspaper dated 06-12-2021)

Fig. 10: Ravaged fields in Odisha due to incessant rains (Source: left- Pragativadi News dated 7th December, 2021 and right- News 18 Odisha dated 7th Dec., 2021)

9 Performance of operational NWP models

IMD operationally runs a regional model, a Global model T1534 for medium range prediction (10 days), a regional Weather Research & Forecast Model (WRF) for short-range prediction (3 days) and a cyclone specific ocean atmosphere coupled Hurricane Weather Research & Forecast (HWRF) model for short to medium range prediction (5 days). The GFS T1534 is run at 12 km resolution in horizontal over the tropics with ENKF based Grid point Statistical Interpolation (GSI) scheme as the global data assimilation scheme for the forecast up to 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 45^0N long 40^0E to 120^0E. 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. The HWRF is run at horizontal resolution of 18 km for parent domain and 6km & 2 km for intermediate and innermost nested domains following the center of cyclonic storm. The model is run with 61 vertical levels with parent domain, intermediate and innermost domain covering area of 80^ox80^o, 24^ox24^o and 7^o x7^o respectively.

In addition to the above NWP models, IMD also runs 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 (T 3.0) and forecast for potential cyclogenesis zone. The multi-model ensemble (MME) for predicting the track (at 12h interval up to 120h) of tropical cyclones for the Indian Seas is developed applying multiple linear regression technique using the member models IMD-GFS, IMD-WRF, GFS (NCEP), ECMWF and JMA. 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.

National Centre for Medium Range weather Forecasting (NCMRWF) Centre also runs global (NCUM-G), regional (NCUM-R) Unified Model adapted from UK Meteorological Office. NCUM-G has a horizontal grid resolution of ~12 km and 70 vertical levels. NCUM-R has a horizontal grid resolution of ~4 km and 80 vertical levels.

In addition, the Ministry of Earth Sciences (MoES) has commissioned two very high resolution (12 km grid scale) state-of-the-art global Ensemble Prediction Systems (EPS) for generating operational 10-days probabilistic forecasts of weather. The EPS involves the generation of multiple forecasts by slightly varying initial conditions. The Global Ensemble Forecast System (GEFS) model is run at Indian Institute of Tropical Meteorology (IITM) Pune and NCMRWF EPS (NEPS) is run at NCMRWF. These models are run twice a day based on 00 & 12 UTC initial conditions. The frameworks of the EPSs are among the best weather prediction systems in the world at present. Very few forecasting centres in the world use such high resolution for short-medium range probabilistic weather forecasts. The performance of these individual models is presented in following sections.

9.1 Prediction of cyclogenesis (Genesis Potential Parameter (GPP)) for JAWAD

Fig. 11 (a-i) indicates that the GPP could predict the potential zone for cyclogenesis on 2nd December since 25th Nov (about 168 hours in advance) over eastcentral BoB. However, the location of genesis was predicted slightly northwards.

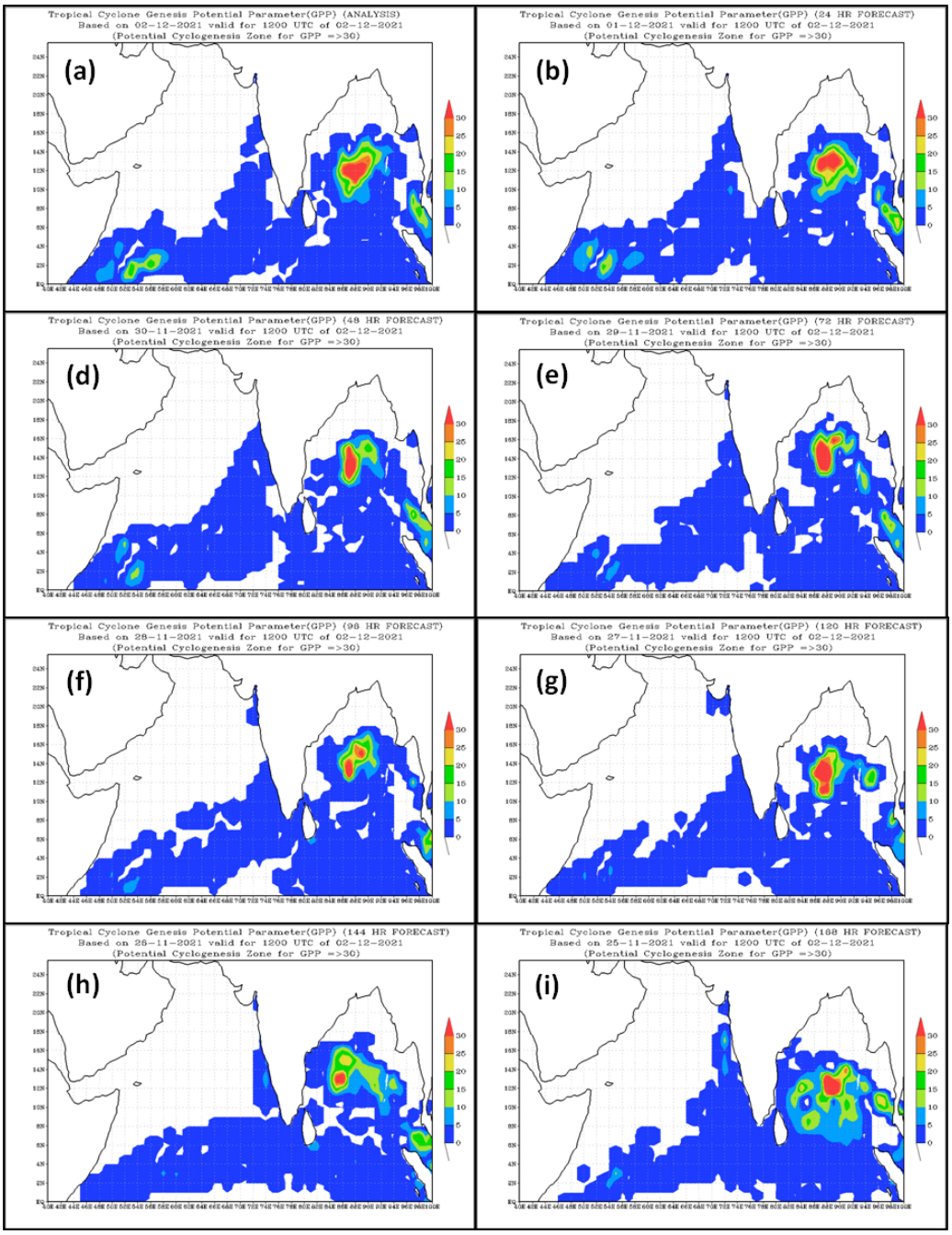


Fig.10 (a-i): Predicted zone of cyclogenesis over the Bay of Bengal (168 hrs before its formation at 1200 UTC of 02nd December) based on 1200 UTC of 25th Nov -02nd Dec 2021.

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. Average GPP ≥ 8.0 is the threshold value for system likely to develop into a cyclonic storm and average GPP < 8.0 indicates a non-developing system. The area average analysis of GPP on 02nd December is presented in Fig. 12. The area average analysis based on 00 & 12 UTC of 1st & 2nd December predicted the system to maintain cyclonic storm intensity from 0000 UTC of 1st upto 5th December. However, the analysis based on 0000 UTC of 3rd December predicted cyclonic storm intensity upto 1200 UTC of 3rd only. Thus. On 3rd, it indicated early weakening of system. The system actually maintained the intensity of cyclonic storm till 1200 UTC of 4th December.

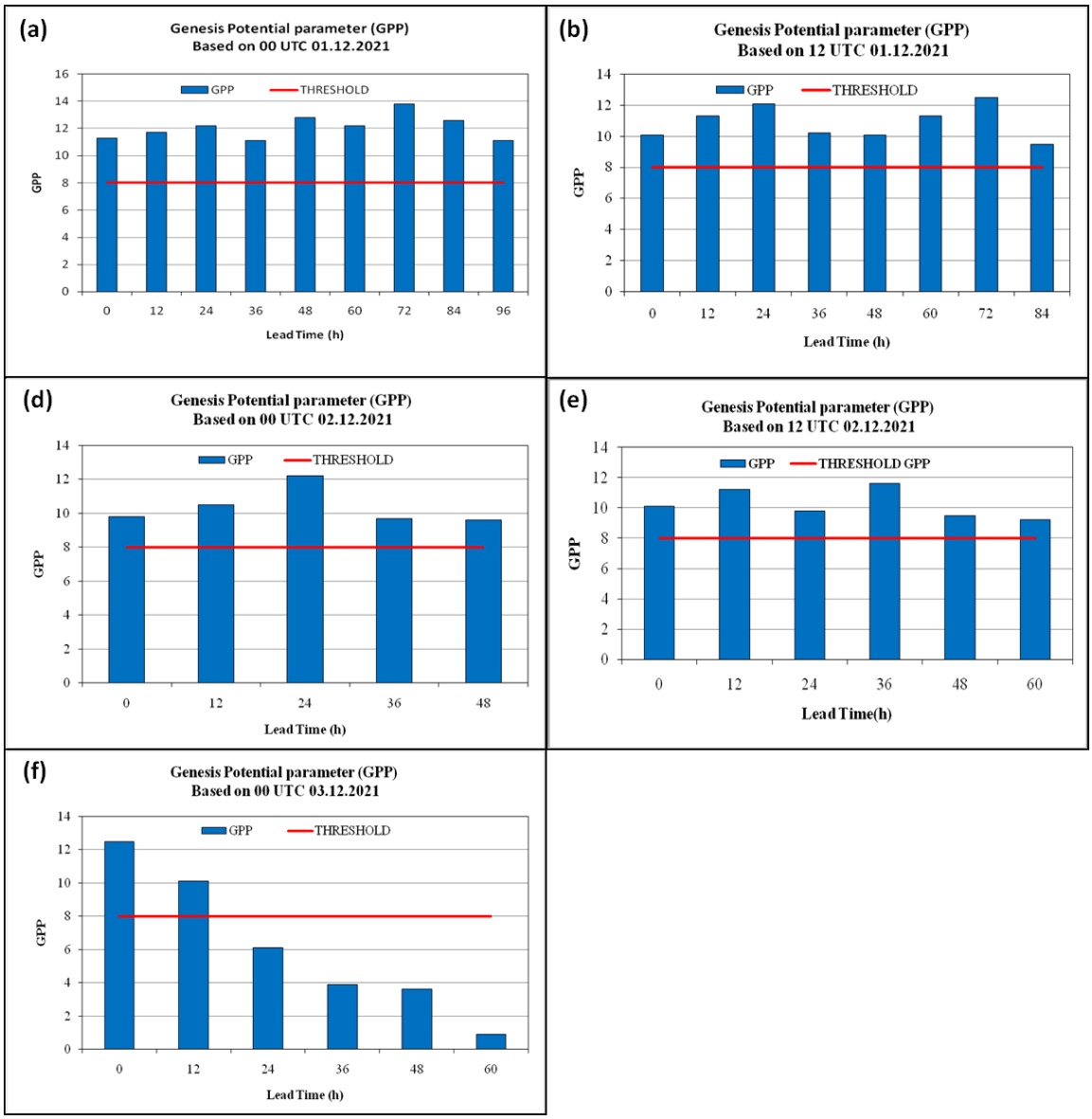


Fig.11(a-f) Area average analysis and forecasts of GPP based on (a) 0000 UTC of 01ST Dec (b) 1200 UTC of 01st Dec (c) 0000 of 02nd Dec (d) 1200 UTC of 02nd Dec (e) 0000 UTC of 03rd Dec 2021

9.2 Track prediction by NWP models

Tracks predicted by various NWP models including ECMWF, NCEP GFS, IMD GFS, UKMO, JMA, IMD MME, IMD HWRF and GEFS during 02nd to 04th Dec are presented in Fig.12. Based on initial conditions of 1200 UTC of 02nd Dec, most of the models indicated initial northwest movement followed by gradual north-northeastwards recurvature towards north BoB. However, models like ECMWF, JMA, IMD GFS, HWRF and GEFS (control and mean) predicted landfall over south Odisha-north Andhra Pradesh coast. NCEP GFS, UKMO predicted weakening over northwest BoB. MME indicated that the system would cross Odisha coast marginally on 5th December. There was large spread among various ensemble members of GEFS. The model mean was biased towards east. Peak intensity predicted by HWRF was about 50 kts and that by SCIP was 45 kts. Thus in the 1200 UTC run of 2nd December, about 5 out of 8 models were indicating the system to cross south Odisha-north Andhra Pradesh coast during 1200 to 2100 UTC of 4th December.

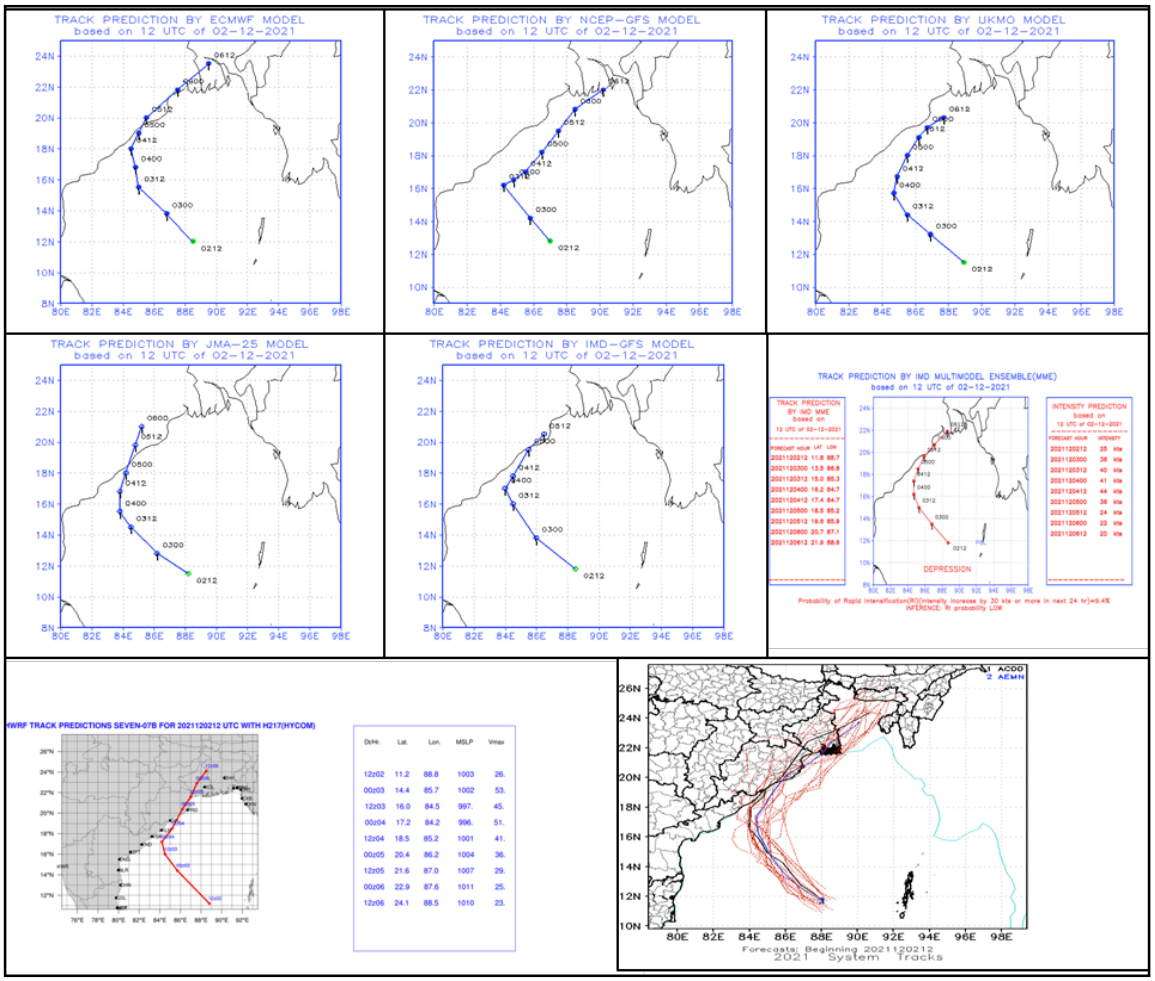


Fig.12 (a) NWP model for tropical cyclone "JAWAD" based on 1200 UTC of 02nd Dec 2021

Based on initial conditions of 0000 UTC of 03rd Dec, a few more models like NCEP-GFS indicated weakening over sea. However, the forecasts by ECMWF, JMA, IMD GFS, HWRF and GEFS (control and mean) predicted landfall over south Odisha coast. MME indicated that the system would move touching Odisha coast on 5th December. There was large spread among various ensemble members of GEFS. The model mean was biased towards east. Peak intensity predicted by HWRF was about 50 kts and SCIP was about 45 kts. Thus, in the 0000 UTC run of 3rd December, about 5 out of 8 models were indicating the system to cross south Odisha coast during 1800 of 4th to 0600 UTC of 5th December.

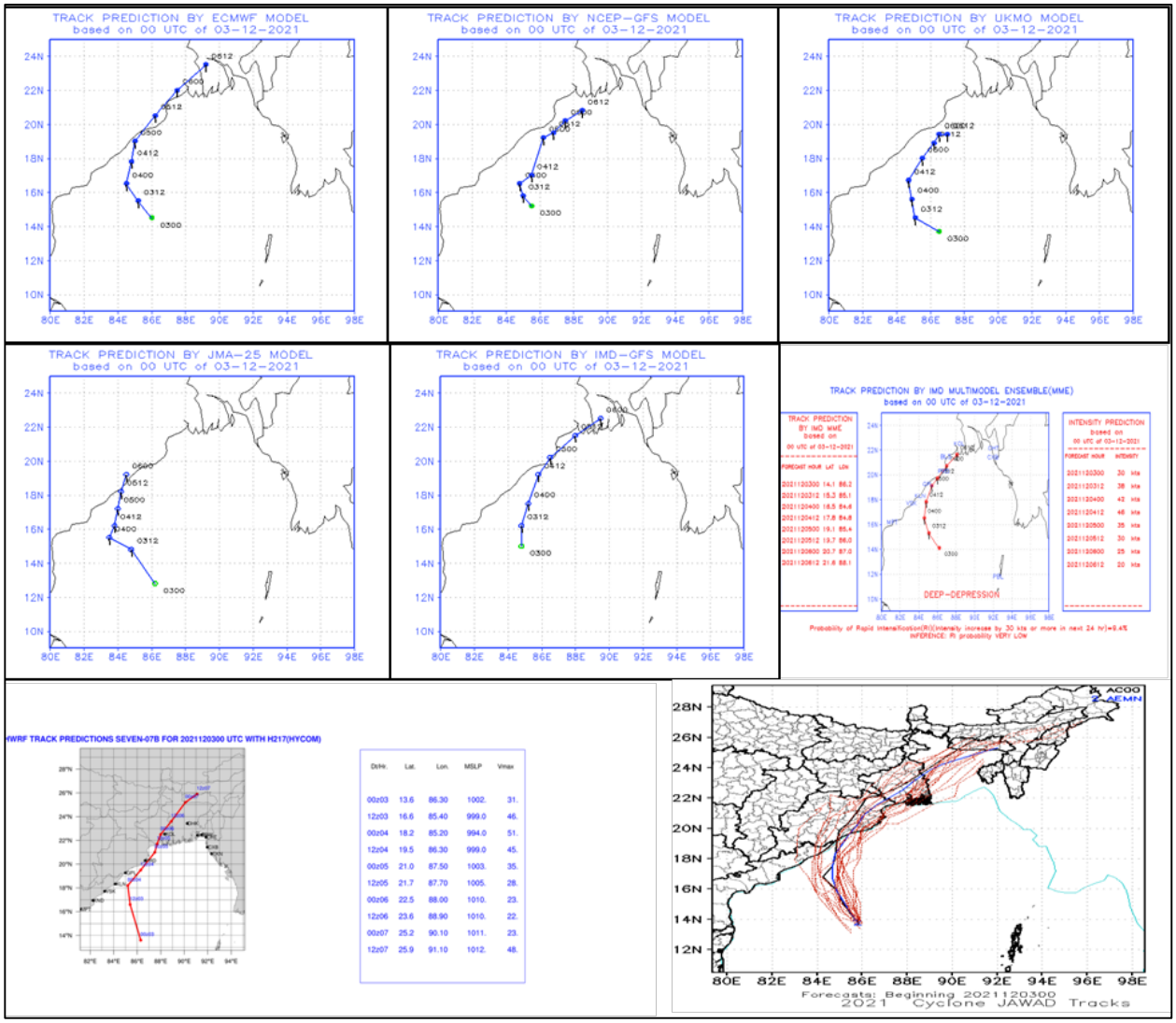


Fig.12(b) NWP model for tropical cyclone "JAWAD" based on 0000 UTC of 03RD Dec 2021

Based on initial conditions of 1200 UTC of 03rd Dec, NCEP-GFS indicated movement parallel to Odisha coast but slightly away and weakening over sea. All other models including ECMWF, UKMO, JMA, IMD GFS, HWRF and GEFS (control and mean) predicted landfall over Odisha coast. However, MME indicated that the system would touch Odisha coast near Puri-Paradip at 0000-0600 UTC of 5th December and recurve north-northeastwards thereafter. There was large spread among various ensemble members of GEFS. However, all members indicated crossing over Odisha coast except NCEP-GFS. Peak intensity predicted by HWRF was about 52 kts and SCIP was about 40 kts.

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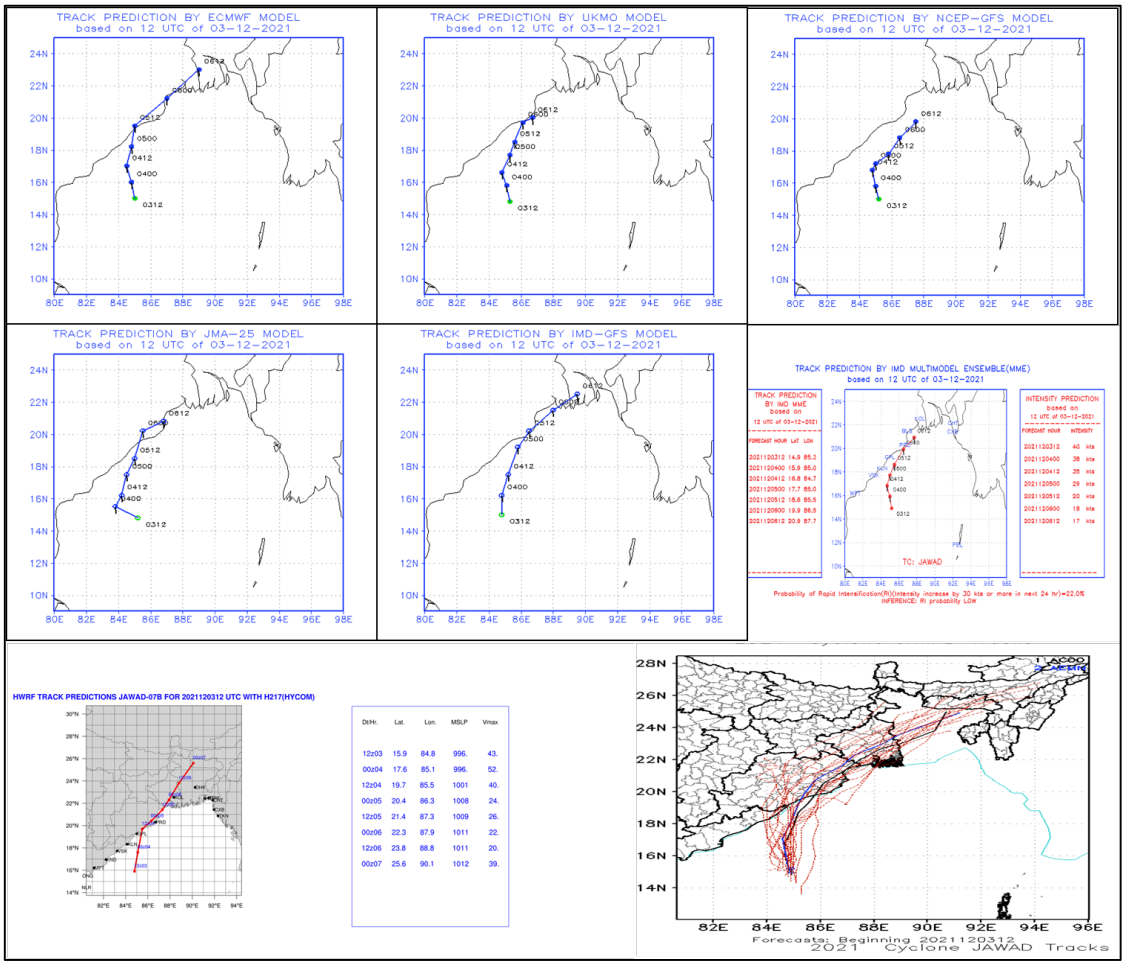

Fig.12(c) NWP model for tropical cyclone "JAWAD" based on 1200 UTC of 03rd Dec 2021

Based on initial conditions of 0000 UTC of 4th Dec, ECMWF, JMA and HWRF predicted landfall over Odisha coast near 20^0N around 1800 UTC of 5th. Rest of the models including UKMO, NCEP GFS, IMD GFS, MME indicated north-northeastwards recurvature with weakening over northwest BoB. There was large spread among various ensemble members of GEFS. However, all members indicated movement very close to Odisha coast except ECMWF, JMA, HWRF and GEFS which prected landfall over Odisha and movement along the coast. Both SCIP and HWRF indicated peak intensity of 40 kts.

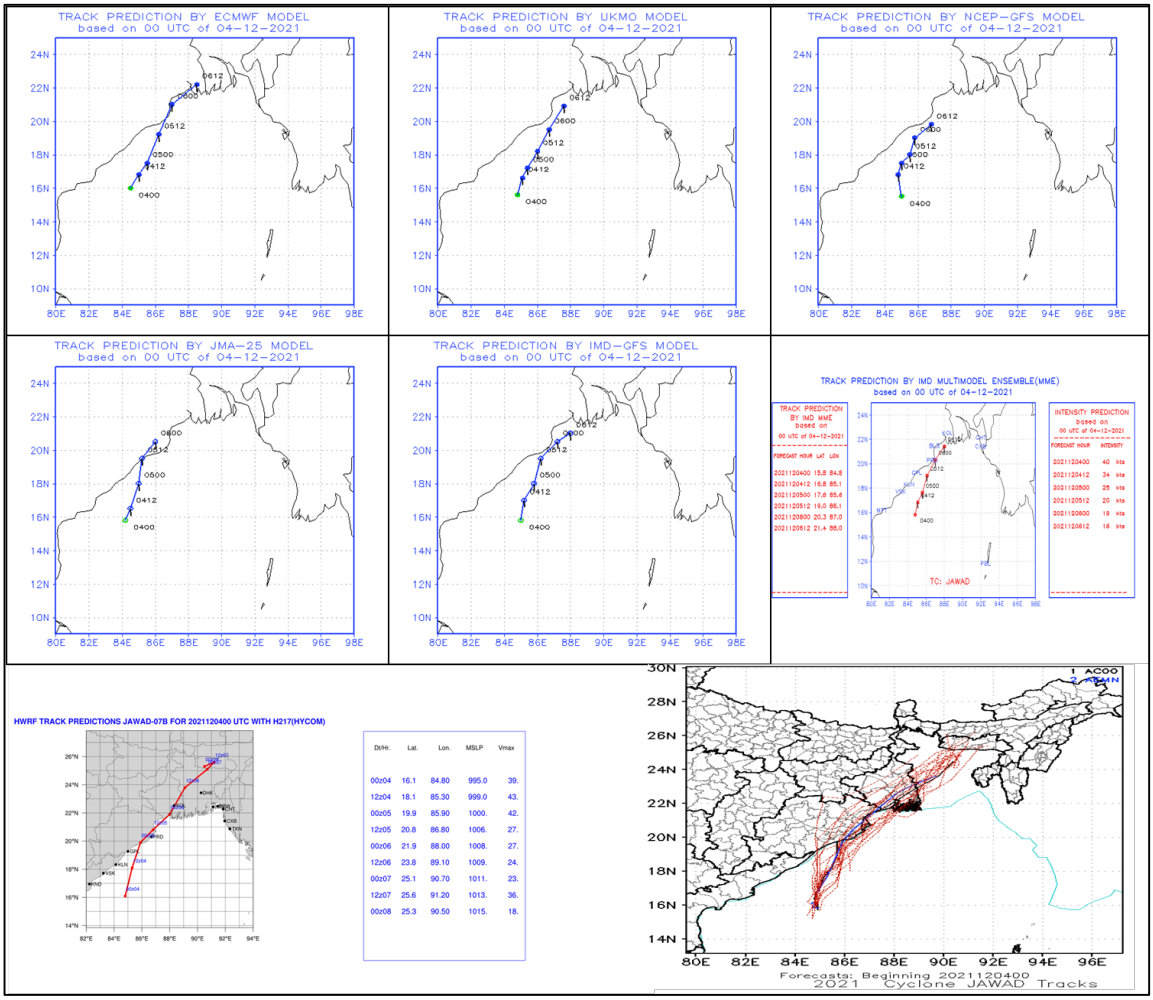

Fig.12(d) NWP model for tropical cyclone "JAWAD" based on 0000 UTC of 04th Dec 2021

Based on initial conditions of 1200 UTC of 4th Dec, all the models shifted the track north-northeastwards. Only HWRF indicated that the system would cross Odish and then West Bengal coast and JMA indicated the system to cross Odisha coast while ECMWF predicted it to touch Odisha coast while moving northeastwards. Ensemble member tracks also shifted north-northeastwards. Both SCIP and HWRF indicated peak intensity of 30 kts. Thus, in the 0200 UTC run of 4th December, most of the models (excluding ECMWF, HWRF and JMA) indicated north-northeastwards movement close to Odisha coast and weakening over sea

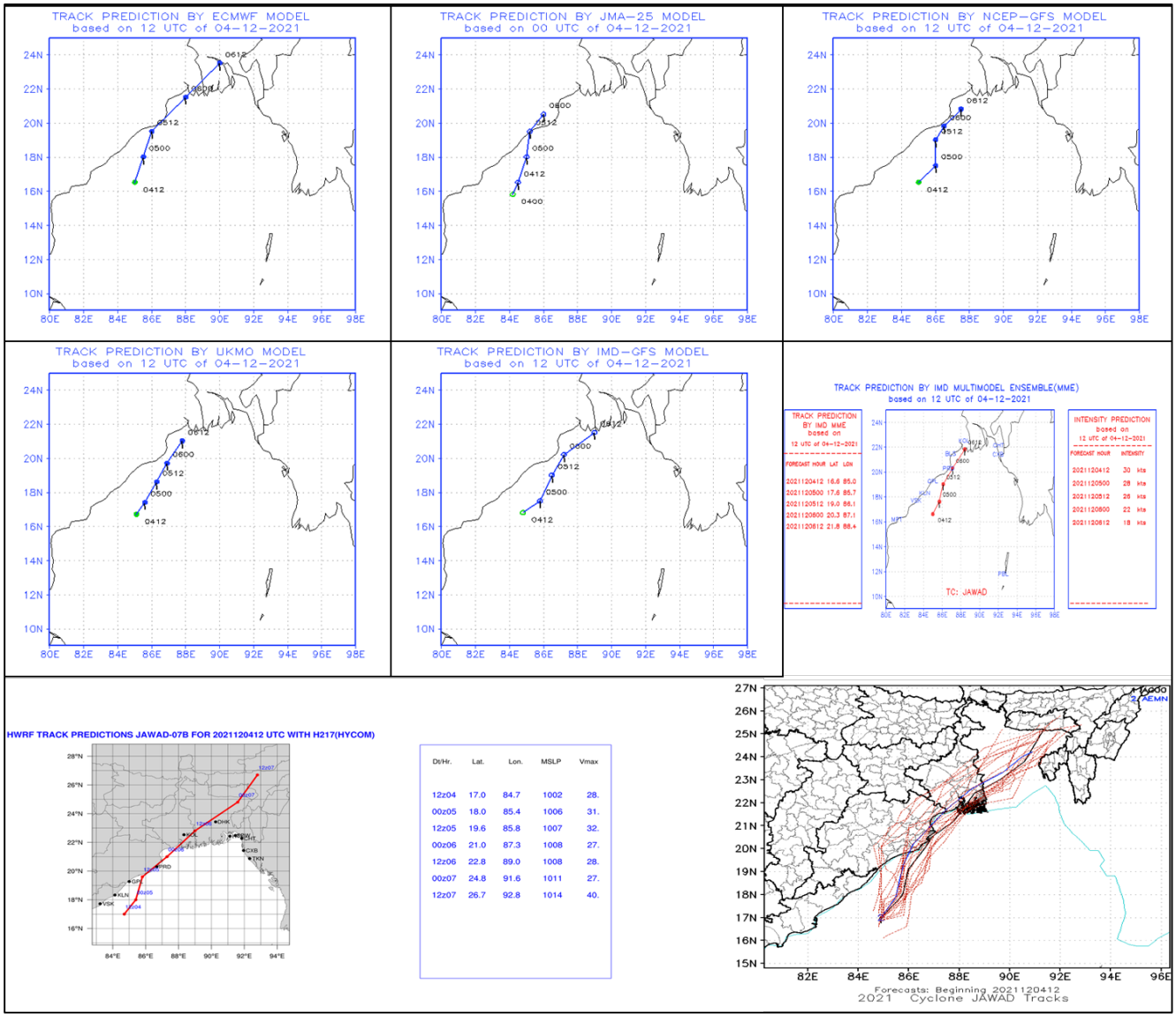

Fig.12(e) NWP model for tropical cyclone "JAWAD" based on 1200 UTC of 04th Dec 2021

9.3 Track forecast errors

Average track forecast errors by various NWP models is presented in Table 2a. For 24 hrs lead period track forecast error was the least i.r.o. ECMWF followed by NCUM (Global) and MME. For 48 hrs lead period, the track forecast error was the least i.r.o. NCUM (Global) followed by UKMO and NEPS. For 72 hours lead period, the error was the least i.r.o. IMD GFS followed by GEFS (Mean) and NCEP GFS. Thus, for longer lead period GFS group of models error was the least.

Table-2a: 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
IMD-MME	45(5)	67(5)	80(4)	126(3)	72(2)	118(1)
ECMWF	31(5)	54(5)	89(4)	145(3)	92(2)	147(1)
NCEP-GFS	62(5)	81(5)	126(4)	165(3)	92(2)	92(1)
UKMO	74(5)	105(5)	92(4)	91(3)	88(2)	133(1)
JMA	75(5)	118(5)	142(4)	186(3)	241(2)	222(1)
IMD-GFS	57(5)	97(5)	153(4)	133(3)	169(2)	61(1)
NCUM(R)	100(6)	86(6)	154(6)	158(5)	196(4)	286(2)
NCUM (G)	58(6)	61(5)	93(6)	87(5)	82(4)	140(3)
NEPS	66(5)	85(6)	108(7)	102(6)	149(5)	185(4)
GEFS (CNTL)	65(6)	95(5)	147(4)	158(3)	173(2)	113(1)
GEFS (ENS_MEAN)	53(6)	84(5)	132(4)	154(3)	118(2)	89(1)

** The numbers within the parentheses against DP Errors for indicate the number of forecasts issued corresponding to the lead-time. The number of forecasts, corresponding to a particular lead-time, is the same for all the models*

9.4. Intensity forecast errors by various NWP Models

The intensity forecasts errors of various models are presented in Table 3. It is seen that intensity prediction errors were the least in case of GEFS followed by SCIP for different lead periods.

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

Lead time →	12H	24H	36H	48H	60H	72H	84H
SCIP (AAE)	3.6(5)	2.6(5)	5.0(5)	6.3(4)	4.3(3)	3.0(2)	2.0(1)
SCIP (RMSE)	3.9	3.3	7.6	7.9	4.7	3.6	2.0
NCUMR (AAE)	8.9	11.6	9.8	13.8	18.3	21.5	
NUCMG (AAE)	4.7	4.4	6.5	7	6.3	9.7	15.5
GEFS CNTL (AAE)	-2(6)	1(5)	-4(4)	-2(3)	-7(2)	-5(1)	
GEFS ENS_MEAN (AAE)	-1(6)	-1(5)	-3(4)	-4(3)	-6(2)	-3(1)	
GEFS CNTL (RMSE)	3(6)	4(5)	4(4)	6(3)	7(2)	5(1)	
GEFS ENS_MEAN (RMSE)	1(6)	1(5)	2(4)	2(3)	4(2)	3(1)	

Intensity forecast by IMD Statistical Cyclone Intensity Prediction (SCIP) model is presented in Fig. 13(a). It is seen that for longer lead period (beyond 24 hours), there was over estimation of the intensity of system.

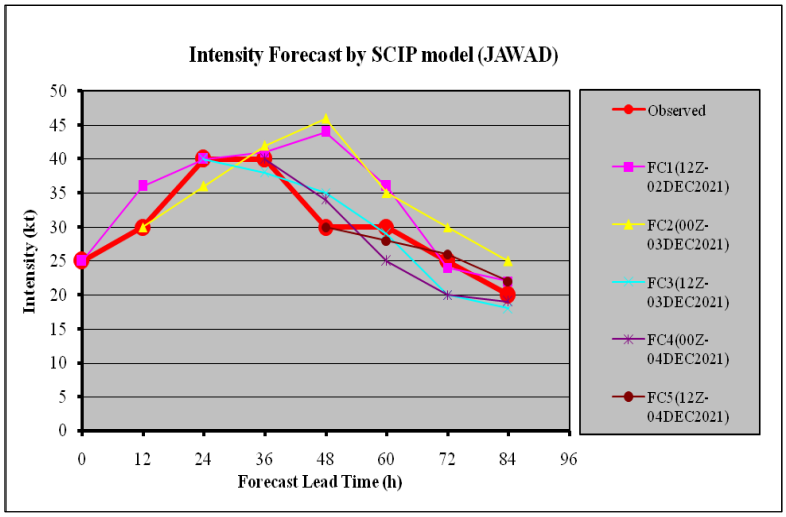

Fig.13: Intensity forecast based on 0000 and 1200 UTC during 2nd to 4th December

10. Operational Forecast Performance

10.1 Genesis, track, landfall and intensity forecast performance:

- First information about likely cyclogenesis (low probability: 1-33%) over southeast BoB was given in the extended range outlook issued on 18th November, about 12 days prior to the formation of low pressure area over south Thailand and neighbourhood on 30th November and 14 days prior to formation of depression over southeast BoB on 2nd December. Subsequent extended range outlooks issued on 25th November and 2nd December indicated initial northwestwards movement and then north-northeastwards recurvature of the system while moving parallel to east coast of India close to Andhra Pradesh-Odisha coasts (Fig.14 a-c).
- Since 25th November, fishermen warnings were issued for Andaman Sea area for 30th November (even before the emergence of low pressure area over south Andaman Sea on 30th) in graphical form and also in the six hourly bulletins issued by National Weather Forecasting Centre, New Delhi. Fishermen warnings were subsequently issued for entire BoB region in association with cyclone Jawad.
- First special message for the disaster managers was issued at 1400 hours IST of 30th November on formation of low pressure area over south Thailand and neighbourhood at 0830 hours IST of 30th November indicating that the system would emerge into Andaman Sea and subsequently intensify intro a cyclonic storm around 3rd December. It was also indicated that the system would reach near north Andhra Pradesh-Odisha coasts around 4th December morning. On 30th November, heavy rainfall warnings were issued for Andaman & Nicobar Islands.
- Typical observed and forecast tracks of cyclone JAWAD based 0530 hours IST of 3rd December demonstrating accuracy in track, landfall and intensity prediction are presented in Fig.15.

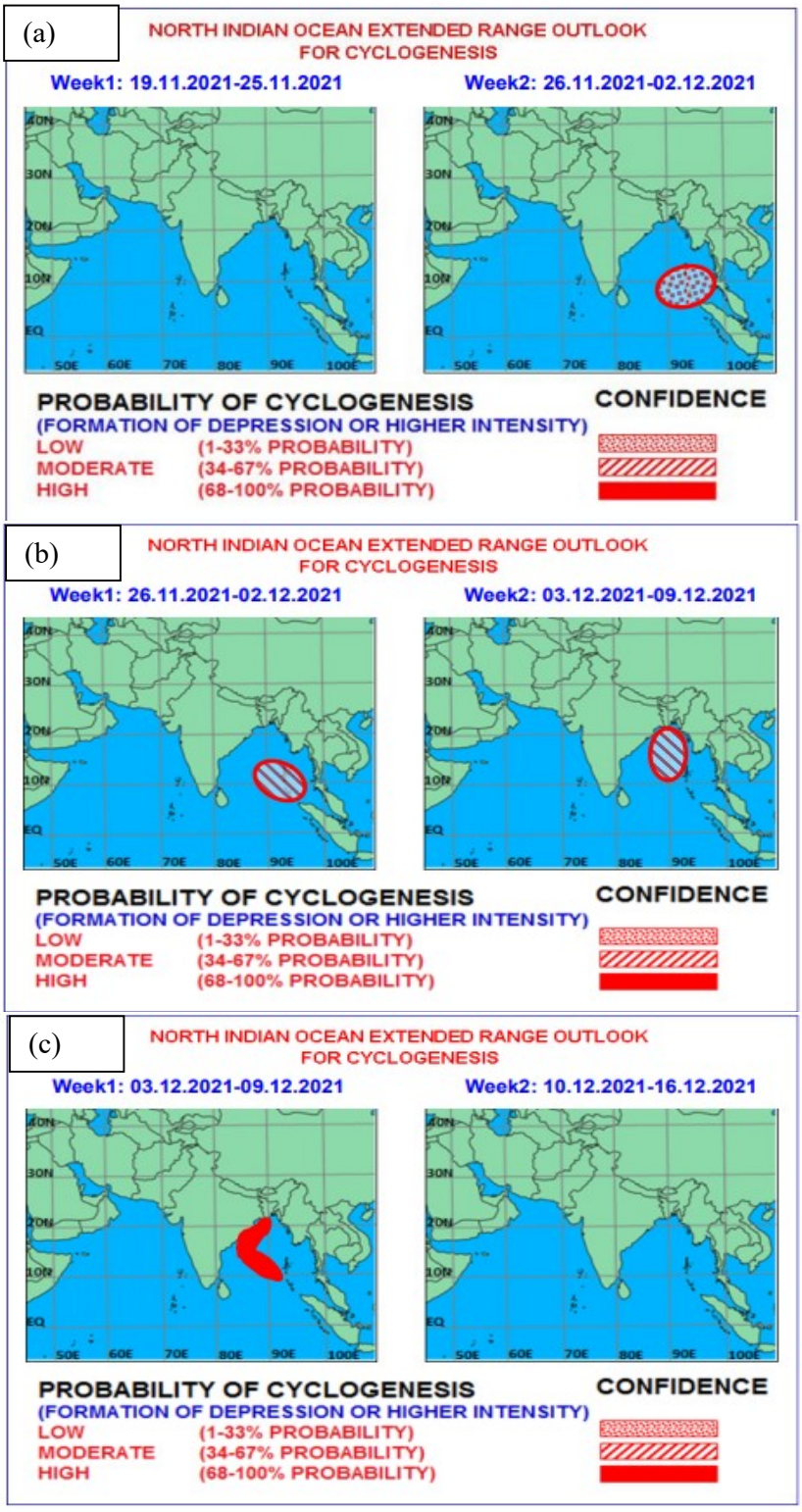

Fig. 13 (a - c): Extended range outlook issued on (a) 18th November, (b) 25th November and (c) 2nd December

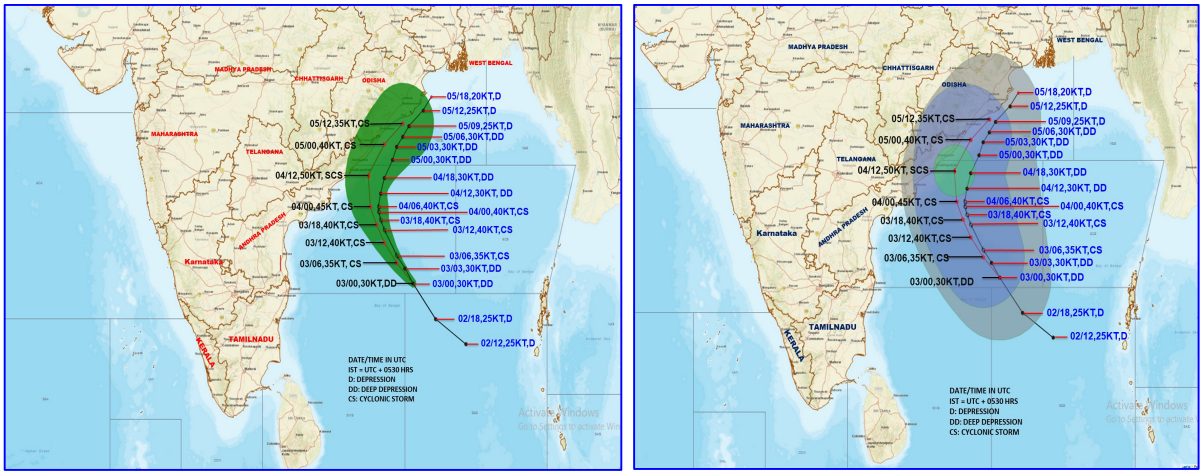

Fig.14: Typical observed and forecast track of cyclonic storm JAWAD at 0530 hours IST (0000 UTC) of 03rd Dec. demonstrating accuracy in track, intensity and landfall of system

10.2. 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.15(a-b) and Table 4. The track forecast errors for 24, 48 and 60 hrs lead period were 78.8, 82.2, and 77.5 km respectively against the LPA errors (2016-20) of 77.5, 116.8, and 137 km respectively (Fig.15 a). The track forecast skill was about 66%, 88%, and 92% against the LPA skill of 64%, 76%, and 76% for 24, 48 and 60 hrs lead period respectively (Fig.15b). The track forecast error for all lead periods were comparable or significantly less than the LPA errors. Skill in track forecasting was comparable or better than LPA skill for all lead periods.

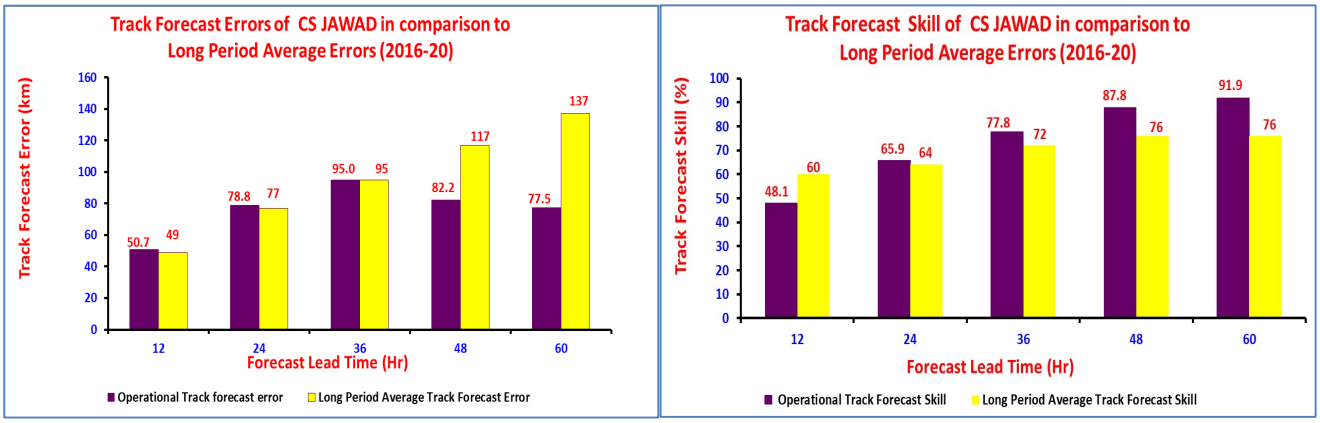

Fig.15: Operational Track forecast (a) errors and (b) skill of SCS 'JAWAD" as compared to long period average (2016-20)

Table 4: Operational Track forecast errors and skill of SCS 'JAWAD" as compared to long period average (2016-20)

Lead Period (hrs)	N	Operational Track forecast error (km)	Operational Track Forecast Skill (%)	Long Period Average (2016-20)	
				Track Forecast Error (km)	Track Forecast Skill (%)
12	11	50.7	48.1	49	60
24	9	78.8	65.9	77	64
36	8	95.0	77.8	95	72
48	6	82.2	87.8	117	76
60	3	77.5	91.9	137	76

N: no. of observations verified

10.3. 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.16 & and Table 5 respectively. The absolute error (AE) of intensity (wind) forecast for 24, 48 and 60 hrs lead period were 6.7, 13.3 and 11.7 knots against the LPA errors of 7.9, 11.4, and 12.7 knots during 2016-20 respectively (Fig. 16 a). The root mean square error (RMSE) of intensity (wind) forecast for 24, 48 and 60 hrs lead period were 9.4, 14.1 and 11.9 knots against the LPA errors of 9.9, 13.8, and 14.9 knots respectively (Fig. 16b). The skill (%) in intensity forecast as compared to persistence forecast based on AE for 24, 48 and 60 hrs lead period was 56%, 65% and 77% against the LPA of 52%, 72% and 73% respectively (Fig.17a). The skill (%) in intensity forecast based on RMSE for 24, 48 and 60 hrs lead period was 63%, 68% & 78% against the LPA of 52%, 64% and 70% respectively (Fig.17b).

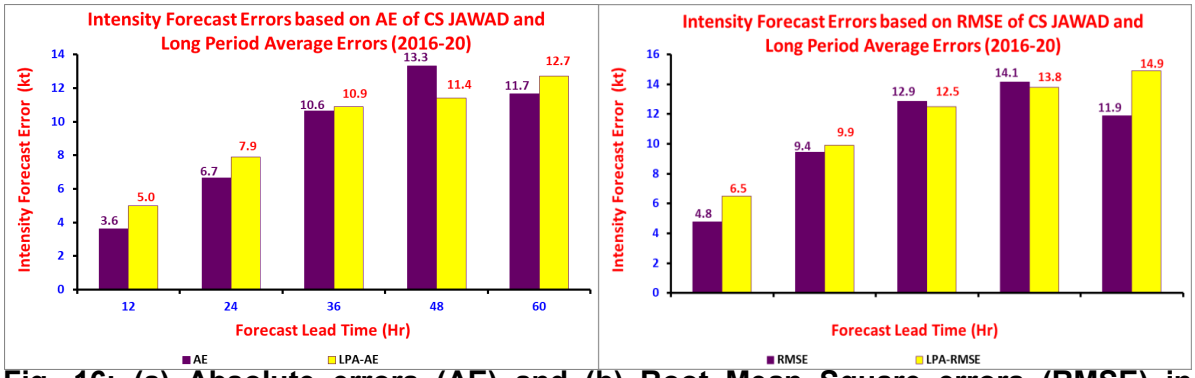

Fig. 16: (a) Absolute errors (AE) and (b) Root Mean Square errors (RMSE) in intensity forecast (winds in knots) of SCS "JAWAD" as compared to long period average (2016-20)

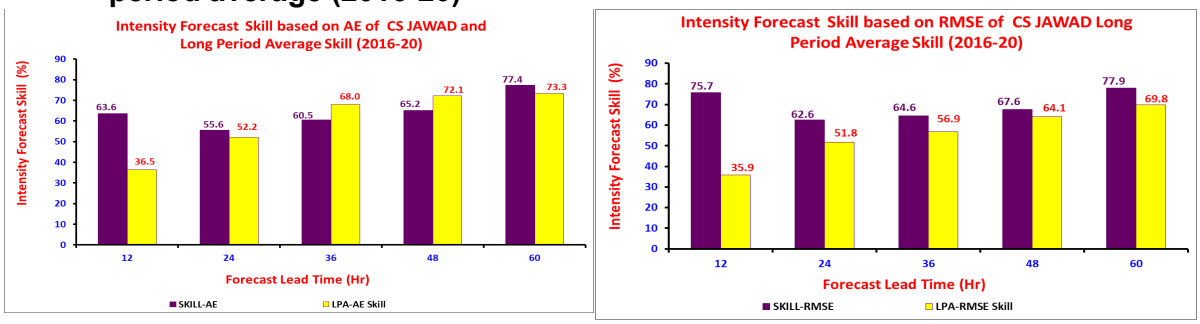

Fig.17: Skill (%) in intensity forecast based on (a) Absolute errors (AE) and (b) Root Mean Square errors (RMSE) of SCS "JAWAD" as compared to long period average (2016-20)

Table 5: Operational Absolute errors (AE) and Root Mean Square errors (RMSE) and corresponding skill in intensity forecast of SCS "JAWAD" as compared to long period average (2016-20)

Lead Period	N	AE	RMSE	Skill-AE	Skill-RMSE	Long Period Average (2016-20)			
						AE	RMSE	Skill-AE	Skill-RMSE
12	11	3.6	4.8	63.6	75.7	5.0	6.5	36.5	35.9
24	9	6.7	9.4	55.6	62.6	7.9	9.9	52.2	51.8
36	8	10.6	12.9	60.5	64.6	10.9	12.5	68.0	56.9
48	6	13.3	14.1	65.2	67.6	11.4	13.8	72.1	64.1
60	3	11.7	11.9	77.4	77.9	12.7	14.9	73.3	69.8

N: No. of observations verified, AE: Absolute error, RMSE: Root Mean Square Error, LPA: Long Period Average

10.4. Adverse weather forecast verification

The verifications of adverse weather like heavy rainfall and gale wind forecast issued by IMD are presented in Tables 6-7. It is found that both types of adverse weather were predicted accurately and well in advance.

Table 6: Verification of Heavy Rainfall Forecast

Date/Base Time of observation (UTC)	24 hr Heavy rainfall warning ending at 0830 hrs IST of next day	Realised 24-hour heavy rainfall ending at 0300 UTC of date
30/11/2021 0300 UTC	**30th Nov.:** H**eavy to very heavy rainfall falls** at isolated places very likely over Andaman & Nicobar Islands. **1st Dec.:** H**eavy to very heavy rainfall at a few places & extremely heavy falls at isolated places** very likely over Andaman & Nicobar Islands. **2nd Dec.:** H**eavy rainfall** at isolated places very likely over Andaman & Nicobar Islands. **3rd Dec.:** H**eavy rainfall** at isolated places very likely to commence over north coastal Andhra Pradesh and south coastal Odisha from evening / night. **4th Dec.:** H**eavy to very heavy rainfall** & **extremely heavy falls** at isolated places very likely over **coastal Odisha** and heavy to very heavy rainfall at isolated places over adjoining interior districts of Odisha, coastal districts of West Bengal and north coastal Andhra Pradesh. **5th Dec.:** H**eavy to very heavy rainfall** at isolated places likely over West Bengal and adjoining north coastal Odisha. It is likely that the north eastern states would also experience enhanced rainfall activity on 5th & 6th December, with isolated heavy to very heavy rainfall owing to the likely northeastward movement of the remnant of the system during the same period.	**5th December 2021:** **Odisha:** Ganjam district: Chhattarpur-9, Purushottampur-8, Behrampur, Digapahandi, Gopalpur-6 each; Khurda district: Banpur-8; Jagatsinghpur district: Paradip CWR-6, Balikuda-5; Nayagarh district: Nayagarh6; Puri district: Astaranga-5; Kendrapada district: Garadapur5; Cuttack district: Kantapada-5; Jajpur district: Chandikhol-5 **6th December 2021:** **Odisha:** Jagatsinghpur district: Erasama-23, Paradip-20, Balikuda-15, Kujanga-14, Nuagaon-13, Tirtol-12, Raghunathpur-9,
01/12/2021	**1st Dec.:** Light to moderate rainfall at most places with	

0300 UTC	**heavy to very heavy rainfall at isolated places** very likely over Andaman & Nicobar Islands. **2nd Dec.:** Light to moderate rainfall at most places **with heavy rainfall** at isolated places very likely over Andaman & Nicobar Islands. **3rd Dec.:** Light to moderate rainfall at many places with **heavy rainfall** at isolated places very likely to commence over north coastal Andhra Pradesh and south coastal Odisha from evening. **4th Dec.:** Light to moderate rainfall at most places **with heavy to very heavy rainfall** at a few places & **extremely heavy falls** at isolated places very likely over **north coastal Andhra Pradesh and coastal Odisha,** heavy to very heavy rainfall at isolated places over adjoining interior districts of Odisha and heavy falls at isolated places over Gangetic west Bengal. **5th Dec.:** Light to moderate rainfall at most places with **heavy to very heavy rainfall** at isolated places likely over West Bengal and adjoining north coastal Odisha and heavy rainfall at isolated places over Assam & Meghalaya and Tripura.	Jagatsinghpur-7; Kendrapara district: Marshaghai, Garadpur13 each, Rajnagar-12, Mohakalpara-10, Derabis-9, Kendrapara, Patamundai-8 each; Puri district: Kakatpur12, Astaranga-11, Delang, Kanas-8 each, Nimapara-7; Cuttack district: Niali-10, Tangi-Choudwar-7. **Gangetic West Bengal:** Hooghly district: Tarakeshwar-18, Bagati-13, Harinkhola-8; Burdwan district: Burdwan - 13, Manteswar-7; Nadia district: Kalyani -12; North 24 Parganas district: Barrackpur-12, Dum dum-10, Salt lake-9; West Midnapore district: Mohanpur, Kharagpur-11 each, Midnapore, Kalaikunda -9 each, Jhargram, Lalgarh-7 each; Howrah district: Uluberia -9; Kolkata district: Alipore-7; South 24 Parganas district: Canning-7.
02/12/2021 0300 UTC	**2nd Dec.:** H**eavy rainfall** at isolated places likely over Andaman & Nicobar Islands. **3rd Dec.:** H**eavy to very heavy rainfall** at isolated places over south coastal Odisha and heavy rainfall at isolated places over north coastal Andhra Pradesh. **4th Dec.:** H**eavy to very heavy rainfall** & **extremely heavy falls** at isolated places very likely over **south Odisha and north coastal Andhra Pradesh** and **heavy to very heavy rainfall** at isolated places over **north coastal Andhra Pradesh,** north & interior districts of Odisha and also over **Gangetic west Bengal**. **5th Dec.:** H**eavy to very heavy rainfall** at isolated places likely over West Bengal & Odisha and heavy rainfall at isolated places over Assam & Meghalaya and Tripura. **6th Dec.:** H**eavy to very heavy rainfall** at isolated places likely over Assam & Meghalaya, Mizoram and Tripura.	
03/12/2021 0300 UTC	**3rd Dec.:** Heavy to very heavy rainfall at isolated places over north coastal Andhra Pradesh and south coastal Odisha. **4th Dec.:** Heavy to very heavy rainfall & extremely heavy falls at isolated places very likely over south coastal Odisha and north coastal Andhra Pradesh and heavy to very heavy rainfall at isolated places over north coastal Odisha & adjoining interior districts and also over coastal districts of Gangetic west Bengal. **5th Dec.:** Heavy to very heavy rainfall at isolated places likely over Gangetic West Bengal & north Odisha and heavy rainfall at isolated places over Assam & Meghalaya, Mizoram and Tripura.	

	6th Dec.: Heavy to very heavy rainfall at isolated places likely over Assam & Meghalaya, Mizoram and Tripura and heavy rainfall at isolated places over west Bengal.	
04/12/2021 0300 UTC	**4th Dec.:** H**eavy to very heavy rainfall & extremely heavy falls** at isolated places very likely over coastal Odisha; **heavy to very heavy rainfall** at isolated places over north Coastal Andhra Pradesh, interior Odisha and coastal districts of Gangetic West Bengal. **5th Dec.:** H**eavy to very heavy rainfall at isolated places** likely over Gangetic West Bengal & north Odisha and **heavy rainfall at** isolated places over south Assam & Meghalaya, Mizoram and Tripura. **6th Dec.:** H**eavy rainfall at isolated places** likely over Assam & Meghalaya, Mizoram and Tripura.	
05/12/2021 0300 UTC	**5th Dec.:** H**eavy to very heavy rainfall at isolated places** likely over north coastal & adjoining areas of Odisha & Gangetic West Bengal. **Heavy rainfall at** isolated places is also likely over south coastal Odisha during next 12 hours. **6th Dec.:** H**eavy to very heavy rainfall at isolated places** likely over south Assam & Meghalaya, Mizoram and Tripura and **heavy rainfall at** isolated places over eastern districts of Gangetic West Bengal.	

Table 6: Verification of Squally/Gale wind forecast (2-6 Dec)

Date/Base Time of observation (UTC)	24 hr wind warning ending at 0830 hrs IST of next day	Realised 24-hour wind ending at 0300 UTC of date
30/11/2021 0300 UTC	• Squally wind speed reaching 40-50 kmph gusting to 60 kmph likely to prevail over Andaman Sea, today 30th November. It would increase gradually becoming 45-55 kmph gusting to 65 kmph over Andaman Sea, Andaman & Nicobar Islands and adjoining southeast Bay of Bengal, tomorrow, the 1st December. • It would further increase to wind speed reaching 50-60 kmph gusting to 70 kmph over southeast & adjoining east-central Bay of Bengal, Andaman & Nicobar Islands & Andaman Sea on 2nd December. • Gale winds speed reaching 65-75 kmph gusting to 85 kmph likely to prevail over central Bay of Bengal from the early morning of 3rd December and gradually increase becoming 90-100 kmph gusting to 110 kmph over northwest & adjoining west-central Bay of Bengal from the morning of 4th December for the subsequent 24 hours. • Squally wind speed reaching 45-55 kmph gusting to 65 kmph likely to commence along & off North Andhra Pradesh – Odisha coast from the mid-night of 3rd December and increase gradually becoming 70-80 kmph gusting to 90 kmph from 4th Afternoon, for the subsequent 12 hours.	Meteorological Office at Puri reported MSW of 18 knots during 1030-1130 hrs IST (0500 to 0600 UTC) of 5th December, high wind speed recorder at Paradeep reported MSW of 26 knots at 1530 hrs IST (0995 UTC) of 5th December.

	• Squally wind speed reaching 45-55 kmph gusting to 65 kmph also likely to commence along & off West Bengal coast from 4th December morning and become Gale wind speed reaching 60-70 kmph gusting to 80 kmph from the evening of 4th December for the subsequent 12 hours.	Dhamra Port reported south-southeasterly winds of intensity 32 knots gusting to 35 knots at 4th/0600 UTC.
01/12/2021 0300 UTC	• Squally wind speed reaching 45-55 kmph gusting to 65 kmph likely to prevail over Andaman Sea, today the 1st December. • It would further increase to wind speed reaching 50-60 kmph gusting to 70 kmph over southeast & adjoining east-central Bay of Bengal, Andaman & Nicobar Islands & Andaman Sea on 2nd December. • Gale winds speed reaching 65-75 kmph gusting to 85 kmph likely to prevail over central Bay of Bengal from the early morning of 3rd December and gradually increase becoming 90-100 kmph gusting to 110 kmph over northwest & adjoining west-central Bay of Bengal from the morning of 4th December for the subsequent 24 hours. • Squally wind speed reaching 45-55 kmph gusting to 65 kmph likely to commence along & off North Andhra Pradesh – Odisha coasts from the mid-night of 3rd December and increase gradually becoming 70-80 kmph gusting to 90 kmph from 4th morning, for the subsequent 12 hours. • Squally wind speed reaching 45-55 kmph gusting to 65 kmph also likely to commence along & off West Bengal coast from 4th December morning and become Gale wind speed reaching 60-70 kmph gusting to 80 kmph from the evening of 4th December for the subsequent 12 hours.	
02/12/2021 0300 UTC	• Squally wind speed reaching 45-55 kmph gusting to 65 kmph likely to prevail over southeast Bay of Bengal & adjoining Andaman Sea during next 6 hours. • It would further increase to wind speed reaching 50-60 kmph gusting to 70 kmph over southeast & adjoining east-central Bay of Bengal, from today, the 2nd December evening. • Gale winds speed reaching 65-75 kmph gusting to 85 kmph likely to prevail over central Bay of Bengal from the morning of 3rd December and gradually increase becoming 90-100 kmph gusting to 110 kmph over northwest & adjoining west-central Bay of Bengal from the morning of 4th December for the subsequent 24 hours. • Squally wind speed reaching 45-55 kmph gusting to 65 kmph likely to commence along & off North Andhra Pradesh – Odisha coasts from the mid-night of 3rd December and increase gradually becoming 70-80 kmph gusting to 90 kmph from 4th morning, for the subsequent 12 hours. • Squally wind speed reaching 45-55 kmph gusting to 65 kmph also likely to commence along & off West Bengal coast from 4th	

	December morning and become Gale wind speed reaching 60-70 kmph gusting to 80 kmph from the evening of 4th December for the subsequent 12 hours.	
03/12/2021 0300 UTC	• Squally wind speed reaching 55-65 kmph gusting to 75 kmph over westcentral and adjoining southeast & eastcentral Bay of Bengal during next 06 hours. • Gale winds speed reaching 70-80 kmph gusting to 90 kmph likely to prevail over westcentral & adjoining northwest Bay of Bengal from today evening and gradually increase becoming 90-100 kmph gusting to 110 kmph over northwest & adjoining west-central Bay of Bengal from the evening of 4th December for the subsequent 12 hours. • Squally wind speed reaching 45-55 kmph gusting to 65 kmph likely to commence along & off North Andhra Pradesh – Odisha coasts from the mid-night of today, the 3rd December and increase gradually becoming 80-90 kmph gusting to 100 kmph from 4th evening, for the subsequent 12 hours. • Squally wind speed reaching 45-55 kmph gusting to 65 kmph also likely to commence along & off West Bengal coast from 4th December evening and become Gale wind speed reaching 60-70 kmph gusting to 80 kmph from the morning of 5th December for the subsequent 12 hours.	
04/12/2021 0300 UTC	• Gale wind, speed reaching 70-80 kmph gusting to 90 kmph, prevails over westcentral Bay of Bengal. It would gradually decrease becoming 60-70 kmph gusting to 80 kmph over northwest and adjoining westcentral Bay of Bengal by mid-night of today, the 4th December. It would decrease further becoming 50-60 gusting to 70 kmph from the morning of 5th December over northwest Bay of Bengal. • Squally winds speed reaching 45-55 kmph gusting to 65 kmph likely to prevail along & off North Andhra Pradesh–Odisha coasts during next 12 hours. It will gradually increase becoming 55-65 gusting to 75 kmph till morning of 5th and squally winds speed reaching 50-60 kmph gusting to 70 kmph from 5th morning till afternoon. It would decrease thereafter gradually. • Squally wind speed reaching 45-55 kmph gusting to 65 kmph also likely to commence along & off West Bengal coast from 4th December evening till the evening of 5th December and gradually decrease thereafter.	
05/12/2021 0300 UTC	• Squally wind speed reaching 50-60 kmph gusting to 70 kmph prevails over northwest and adjoining westcentral Bay of Bengal. It would gradually decrease becoming 40-50 kmph gusting to 60 kmph over northwest and adjoining westcentral Bay of Bengal by evening of today, the 5th December. It would decrease further becoming 30-40 kmph gusting to 50 kmph over northwest Bay of Bengal by night of today, the 5th December. • Squally winds speed reaching 45-55 kmph gusting to 65 kmph likely to prevail along & off North Andhra Pradesh coast during next 06 hours and along & off Odisha – West Bengal coasts	

	during next 24 hours.	

11. Warning Services

Bulletins issued by Cyclone Warning Division, New Delhi

- **Track, intensity and landfall forecast:** IMD continuously monitored, predicted and issued bulletins containing track, intensity, and landfall forecast for +06, +12, +18, +24, +36 and +48… +72 hrs lead period commencing from 2nd December evening (1200 UTC) till the system weakened into a low pressure area. The above forecasts were issued from the stage of depression onwards along with the cone of uncertainty in the track forecast five times a day and every three hours during the cyclone period.
- **Cyclone structure forecast for shipping and coastal hazard management:** The radius of maximum wind and radii of MSW ≥28, ≥34 knots wind in four quadrants of cyclone was issued every six hourly, commencing from 2nd December evening (1200 UTC) giving forecast for +06, +12, +18, +24, +36 and +72 hrs lead period.

- **Four stage Warning:**
- **Considering the development of cyclonic** storm over central BoB, IMD issued first Special Message at 1400 hours IST of 30th November on detection of low pressure area over south Thailand and neighbourhood and it's likely emergene into Andaman Sea (**about 50 hours in advance of formation of depression over southeast BoB on 2nd December**). Heavy rainfall, strong wind and tidal waves warnings were issued alongwith advisories for fishermen, ports and off & along shore activities.
- First Press Release was issued at 1430 hours IST of 30th November (**about 50 hours in advance of formation of depression over southeast BoB on 2nd December**) indicated likely formation of a cyclonic storm over central BoB around 3rd December.
- **Considering the expected development of a cyclonic storm the Pre cyclone watch** was issued for north Andhra Pradesh and Odisha coasts in the Special Message issued at 1350 hrs IST of 1st December, when the low pressure area emerged into central Andaman Sea **(about 46 hours prior to formation of the cyclonic storm JAWAD at 1130 hrs IST of 3rd December)**.
- **Warnings were further upgraded and Cyclone alert** for north Andhra Pradesh and Odisha coasts was given in the national bulletin issued at 0230 hrs IST of 1st December, when the system lay as a depression over southeast BoB **(about 45 hours prior to formation of the cyclonic storm JAWAD at 1130 hrs IST of 3rd December)**
- **In the first national bulletin issued at 2030 hrs IST of 2nd December, it was indicated that** the system would reach close to south Odisha – north Andhra Pradesh coasts and would recurve north-northeastwards. However, due to close movement along the coast adverse weather over Andhra Pradesh, Odisha and

Gangetic West Bengal and disturbed sea conditions over BoB would be experienced.

- **Warnings were further upgraded and Cyclone Warning** north Andhra Pradesh and Odisha coasts was given in the national bulletin issued at 1630 hrs IST of 3rd December, on formation of cyclonic storm over westcentral BoB.
- **Weakening of system was indicated in the bulletin issued at 0830 hours IST of 4th December** when the system lay as a cyclonic storm over westcentral BoB about 230 km southeast of Visakhapatnam and 340 km south of Gopalpur.
- **Adverse weather warning bulletins:** The tropical cyclone forecasts alongwith expected adverse weather like heavy rain, gale wind and disturbed sea was issued with every three hourly update to central, state and district level disaster management agencies including MHA NDRF, NDMA for all concerned states along the east coast of India including West Bengal, Odisha, Andhra Pradesh, Tamil Nadu & Puducherry and Administrator Andaman & Nicobar Islands. The bulletins also contained the suggested action for disaster managers and general public in particular for fishermen, ports and off & along shore activities. These bulletins were also issued to Defence including Indian Navy & Indian Air Force, NDRF, Indian Cost Guard, ports, Shipping, fishery, Railways, surface transport and aviation authorities.
- **Warning graphics:** The graphical display of the observed and forecast track with cone of uncertainty and the wind forecast for different quadrants were disseminated by email and uploaded in the RSMC, New Delhi website (http://rsmcnewdelhi.imd.gov.in/) regularly. The adverse weather warnings related to heavy rain, gale wind & fishermen warnings were also presented in graphics alongwith colour codes in the website.
- **Warning and advisory through social media:** Daily updates (every three hourly or whenever there was any significant change in intensity/track/landfall) were uploaded on Facebook and Twitter during the life period of the system since the emergence of low pressure area into Andaman Sea.
- **Press Conference, Press release and Media briefing:** Press and electronic media were given daily updates since inception of system through press release, e-mail, website, video capsule by DGM and SMS.
- **Warning and advisory for marine community:** The three/six hourly Global Maritime Distress Safety System (GMDSS) bulletins were issued by the Marine Weather Services division at New Delhi and bulletins for maritime interest were issued by Area cyclone warning centres of IMD at Kolkata and Cyclone warning centres at Visakhapatnam and Bhubaneswar to ports, fishermen, coastal and high sea shipping community.
- **Fishermen Warning:** Regular warnings for fishermen for deep Sea of Bay of Bengal were issued since 25th November.
- **Advisory for international Civil Aviation:** The Tropical Cyclone Advisory Centre (TCAC) bulletin for International Civil Aviation were issued every six hourly to all meteorological watch offices in Asia Pacific region for issue of significant meteorological information (SIGMET). It was also sent to Aviation Disaster Risk Reduction (ADRR) centre of WMO at Hong Kong.

- **Diagnostic and prognostic features of cyclone:** The prognostics and diagnostics of the systems were described in the RSMC bulletins.
- **Director General of Meteorology** gave a presentation on the status of cyclone JAWAD during the National Crisis Management Committee Meeting chaired by Hon'ble Prime Minister of India on , Members of Parliament on . A joint press conference was addressed by DGM IMD and DG NDRF to sensitize masses

Statistics of bulletins issued by RSMC New Delhi, Area Cyclone Warning Centre Kolkata, CWCs Visakhapatnam and Bhubaneswar in association with the CS JAWAD are given in **Table 8-9.**

Table8: Bulletins issued by Cyclone Warning Division, New Delhi

S. No.	Bulletin type	No. Of Bulletins	Issued to
1	National Bulletin	23	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 West Bengal, Odisha, Andhra Pradesh, Tamil Nadu & Puducherry and Administrator Andaman & Nicobar Islands.
2.	Special Message	3	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 West Bengal, Odisha, Andhra Pradesh, Tamil Nadu & Puducherry and Administrator Andaman & Nicobar Islands.
3	Bulletin from DGM IMD	4	FAX and e-mail to Cabinet Secretary, Prime Minister office, Control Room Ministry of Home Affairs & National Disaster Management Authority, 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 West Bengal, Odisha, Andhra Pradesh, Tamil Nadu & Puducherry and Administrator Andaman

			& Nicobar Islands.
4	RSMC Bulletin	23	1. IMD's website 2. WMO/ESCAP member countries through GTS and E-mail.
5	GMDSS Bulletins	23	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)
6	Tropical Cyclone Advisory Centre Bulletin	7	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
7	Tropical Cyclone Vital Statistics	7	Modelling group of IMD, National Centre for Medium Range Weather Forecasting Centre (NCMRWF), Indian National Centre for Ocean Information Services (INCOIS), Indian Institute of Technology (IIT) Delhi, IIT Bhubaneswar etc.
8	Statistics of SMS	Around 71 lakh	71,23,154 SMS sent by Agromet Division IMD to farmers of Andhra Pradesh, Odisha and West Bengal 1273 messages were sent to Senior level Central & State Disaster Managers INCOIS issued messages to Fishermen through NaVIC (20)
9	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)
10	Press Release	4	Disaster Managers, Media persons by email and uploaded on website
11	Press Briefings	Daily	Regular briefing daily

Table 9: Statistics of bulletins issued by Area Cyclone Warning Centre Kolkata, CWC Bhubaneswar and Visakhapatnam.

S.No.	Type of Bulletin	No. of Bulletins issued		
		Kolkata	Bhubaneswar	Visakhapatnam
1.	Sea Area Bulletins	22	N/A	-
2.	Coastal Weather Bulletins	22	21	24
3.	Fishermen Warnings issued	WB – 28 A & N - 28	26	28
4.	Port Warnings	WB – 14 A & N -14	20	18

5.	Heavy Rainfall Warning	WB – 16 A & N - 6	24	14
6.	Gale Wind Warning/Gusty wind warning	WB - 16 A & N (Sea area)- 6	08	-
7.	Storm Surge Warning	-	04	-
8.	Information & Warning issued to State Government and other Agencies	WB – 17 A & N - 6	26	37
9.	SMS	-	--	-
10.	No. of Press releases/	23	06 (in English) and 04 (In local language Odia)	19
11.	Special Bulletin	WB – 17 A & N - 6	26	19
12.	No. of impact based warnings for a. District b. City	A. Dist. - 16 B. City - 1	 24 03	25 253
13.	No. of whatsapp messages	WB – 9500 A & N - 80	28650	115
14.	No. of updates on facebook	27(Both English & Bengali)	57	32
15.	No. of updates on tweeter	09	160	32
16.	No. of Forecast / Warning video released	06	04	3

12. Acknowledgement:

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