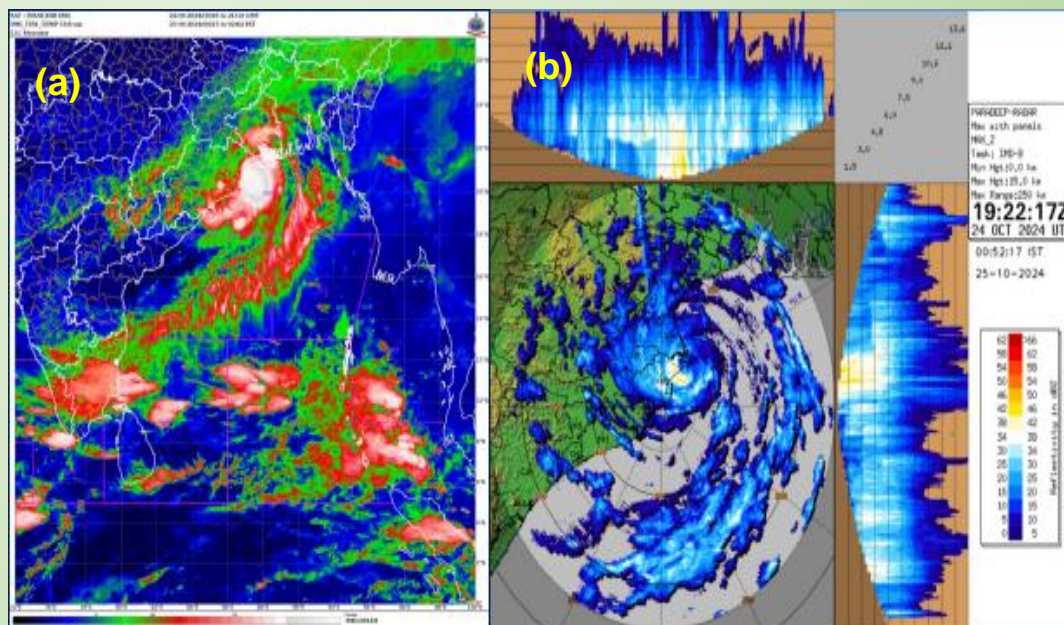




## Severe Cyclonic Storm “DANA” over the Bay of Bengal (22<sup>nd</sup>-26<sup>th</sup> October, 2024): A Report



Typical (a) INSAT 3D imagery at 0215 IST of 25<sup>th</sup> October and (b) Doppler Weather Radar Paradip imagery at 0052 IST of 25<sup>th</sup> during severe cyclonic storm “DANA”

Cyclone Warning Division  
India Meteorological Department

New Delhi  
October 2024

## **Severe Cyclonic Storm “DANA” over the Bay of Bengal (22<sup>nd</sup> – 26<sup>th</sup> October, 2024): A Report**

### **1. Life History of “DANA”:**

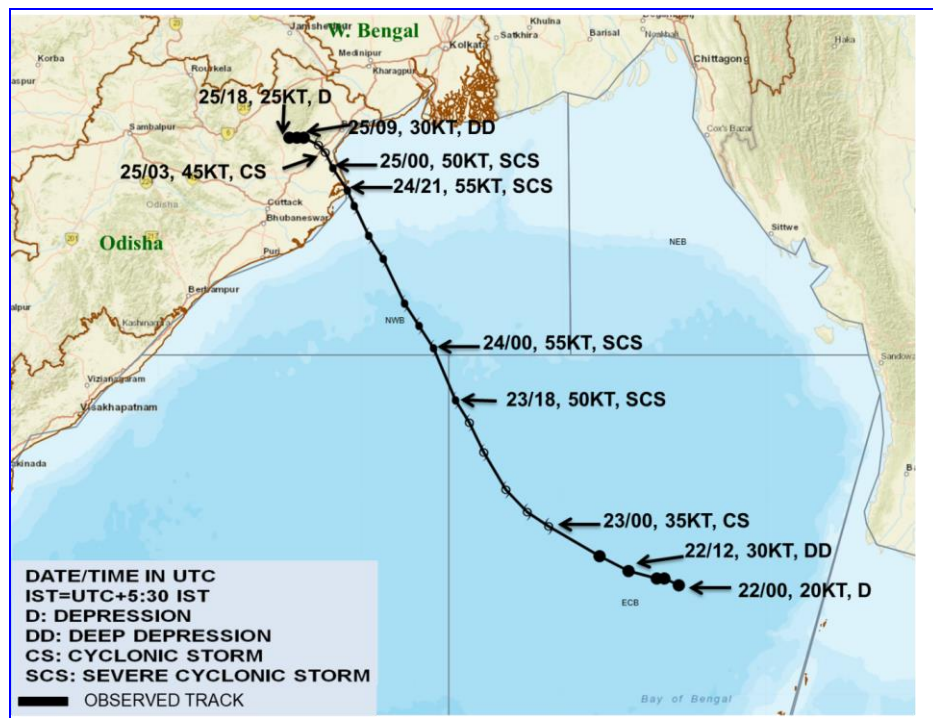
- A cyclonic circulation was seen over central Andaman Sea in the early morning (0530 hours IST/0000 UTC) of 19<sup>th</sup> October and it lay over North Andaman Sea in the early morning (0530 hours IST/0000 UTC) of 20<sup>th</sup> October 2024.
- Under its influence, a Low-Pressure Area formed over the Eastcentral Bay of Bengal (BoB) and adjoining north Andaman Sea in the evening (1730 hours IST/ 1200 UTC) of 20<sup>th</sup> October.
- Moving west-northwestwards, it concentrated into a well-marked low-pressure area over Eastcentral BoB in the noon (1130 hours IST) of 21<sup>st</sup> October.
- Continuing to move west-northwestwards, it intensified into a Depression over Eastcentral BoB in the early morning (0530 hours IST/0000 UTC) of 22<sup>nd</sup> October. It then moved northwestwards and intensified into a deep depression over Eastcentral BoB in the same evening (1730 hours IST/ 1200 UTC).
- Continuing to move further northwestwards, it intensified into a cyclonic storm (CS) “DANA” over eastcentral BoB in the early morning (0530 hours IST/ 0000 UTC) of 23<sup>rd</sup> October.
- It then moved north-northwestwards and intensified into a severe cyclonic storm (SCS) over central & adjoining northwest BoB in the mid-night (2330 hours IST/1800 UTC) of 23<sup>rd</sup> October, 2024.
- Continuing to move north-northwestwards, it crossed north Odisha coast close to Habalikhathi Nature Camp (Bhitarkanika) and Dhamara during 0130 hrs IST to 0330 hrs IST of 25<sup>th</sup> October (2000 to 2200 UTC of 24<sup>th</sup> October) as a severe cyclonic storm with a wind speed of 100-110 kmph gusting to 120 kmph.
- The landfall process commenced in the midnight (2330 hours IST/1800 UTC) of 24<sup>th</sup> October and continued for 9 hours till 0830 hours IST/ 0300 UTC of 25<sup>th</sup> October.
- Continuing to move further north-northwestwards slowly, it weakened into a CS over north coastal Odisha in the forenoon (0830 hours IST/0300 UTC) of 25<sup>th</sup> October, into a deep depression in the afternoon (1430 hours IST/0900 UTC). Thereafter, it gradually moved westwards, weakened into a depression over interior Odisha in the midnight (2330 hours IST/1800 UTC) of 25<sup>th</sup> October and into a well-marked low-pressure area over North Odisha in the early morning (0530 hours IST/ 0000 UTC) of 26<sup>th</sup> October.
- The best track parameters are presented in **Table 1**. The observed track of the severe cyclonic storm “DANA” is presented in **Fig.1**.

**Table 1: Best track positions and other parameters of the Severe Cyclonic Storm “DANA” over Eastcentral Bay of Bengal during 22<sup>nd</sup> – 26<sup>th</sup> October, 2024**

**D: Depression, DD: Deep Depression, CS: Cyclonic Storm, SCS: Severe Cyclonic Storm, kt: Knot (1 Knot=1.85 kmph)**

<b>Date</b>	<b>Time (UTC)</b>	<b>Lat.</b>	<b>Long.</b>	<b>CI No.</b>	<b>Estimated Central Pressure (hPa)</b>	<b>Estimated Maximum Sustained surface wind (kt)</b>	<b>Estimated Pressure drop at the Centre (hPa)</b>	<b>Grade</b>
22.10.24	0000	15.4	91.6	1.5	1003	20	3	D
22.10.24	0300	15.5	91.4	1.5	1002	20	3	D
22.10.24	0600	15.5	91.3	1.5	1000	25	4	D
22.10.24	1200	15.6	90.9	2.0	999	30	5	DD
22.10.24	1800	15.8	90.5	2.0	998	30	6	DD
23.10.24	0000	16.2	89.8	2.5	997	35	7	CS
23.10.24	0300	16.5	89.6	2.5	996	35	8	CS
23.10.24	0600	16.7	89.2	2.5	995	40	9	CS
23.10.24	0900	16.9	89.1	3.0	994	45	10	CS
23.10.24	1200	17.2	88.9	3.0	992	45	12	CS
23.10.24	1500	17.6	88.7	3.0	992	45	12	CS
23.10.24	1800	17.9	88.5	3.0	990	50	14	SCS
23.10.24	2100	18.3	88.3	3.0	990	50	14	SCS
24.10.24	0000	18.6	88.2	3.5	988	55	16	SCS
24.10.24	0300	18.9	88.0	3.5	988	55	16	SCS
24.10.24	0600	19.2	87.8	3.5	988	55	16	SCS
24.10.24	0900	19.4	87.6	3.5	986	60	18	SCS
24.10.24	1200	19.8	87.5	3.5	986	60	18	SCS

24.10.24	1500	20.1	87.3	3.5	986	60	18	SCS
24.10.24	1800	20.5	87.1	3.5	988	55	16	SCS
		Crossed North Odisha coast close to Habalikhati Nature Camp (Bhitarkanika) & Dhamara between 2000 to 2200 UTC of 24th October (0130 to 0230 hrs IST of 25 <sup>th</sup> October) as a Severe Cyclonic Storm with wind speed of 100-110 gusting to 120 kmph						
24.10.24	2100	20.7	87.0	-	988	55	16	SCS
25.10.24	0000	21.0	86.8	-	990	50	14	SCS
25.10.24	0300	21.2	86.7	-	994	45	10	CS
25.10.24	0600	21.3	86.6	-	997	35	7	CS
25.10.24	0900	21.4	86.4	-	998	30	6	DD
25.10.24	1200	21.4	86.3	-	999	30	5	DD
25.10.24	1800	21.4	86.2	-	1000	25	4	D
26.10.24	0000	Weakened into a Well-Marked Low-Pressure Area over North Odisha						



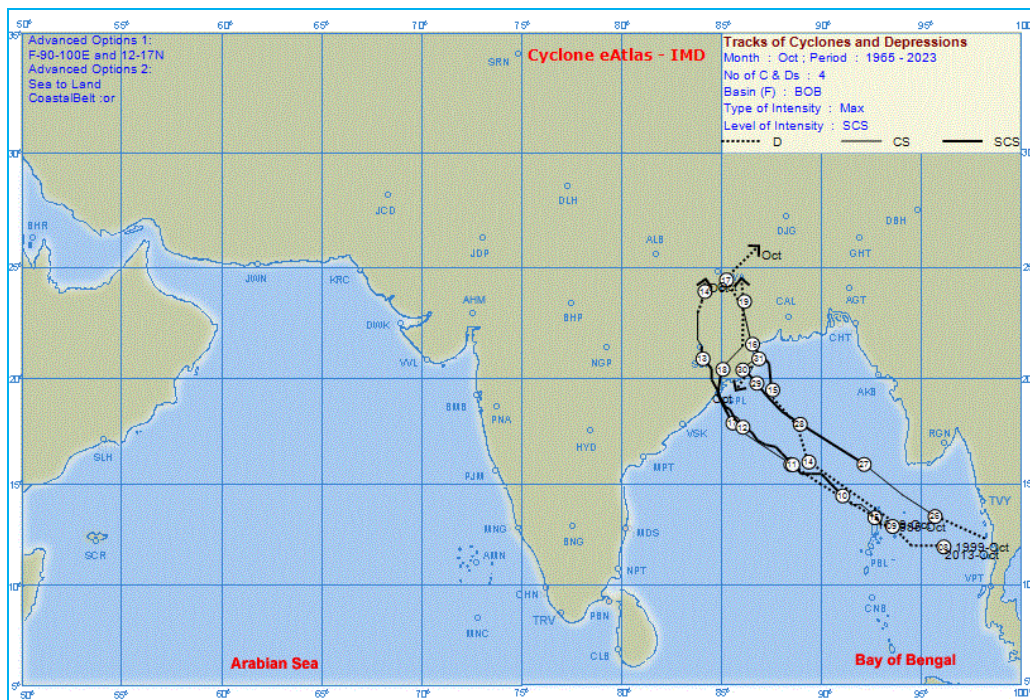
**Fig. 1: Observed track of severe cyclonic storm “DANA” over eastcentral Bay of Bengal during 22-26 October, 2024**



## 2. Salient Features:

### (a) Salient features compared to climatology:

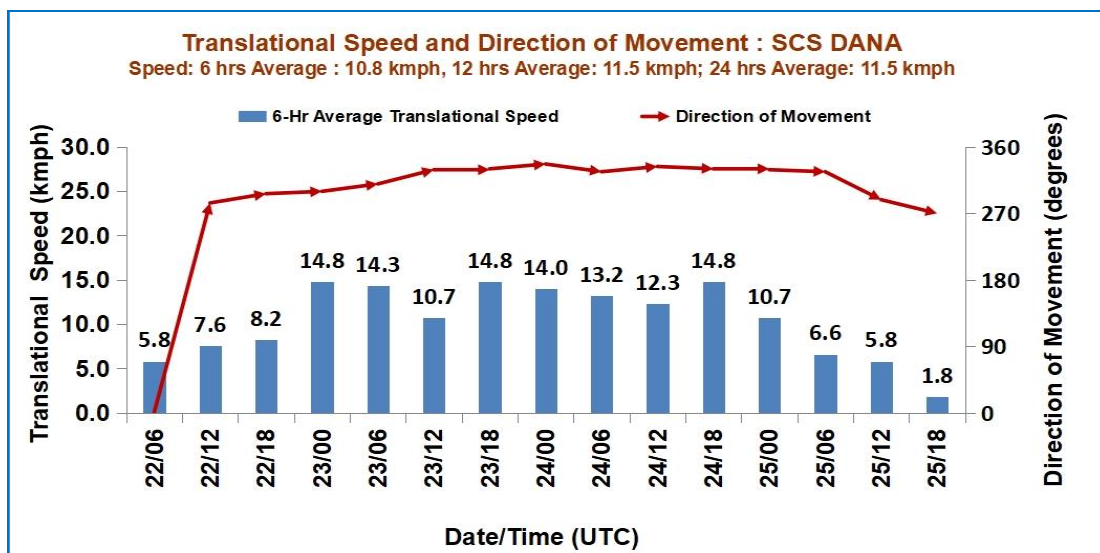
It was the 2<sup>nd</sup> cyclone of the year 2024 over the BoB after the SCS "REMAL" during 24 to 28 May. Climatologically, 4 SCSs & above category storms formed from the depressions that developed in the region 12<sup>o</sup>-17<sup>o</sup>N and 90<sup>o</sup>-100<sup>o</sup>E over the eastcentral BoB and North Andaman Sea which crossed Odisha coast in October during the period 1965-2023 (**Fig.2**). The SCS in 1985 formed over eastcentral BoB on 13<sup>th</sup> October and crossed North Odisha coast to the south of Balasore around 2300 UTC of 15<sup>th</sup> October as an SCS (50 kt). Other storm in 1999, developed over eastcentral BoB on 15<sup>th</sup> October and crossed Odisha coast near Gopalpur in the early morning of 18<sup>th</sup> October, (0230 hrs IST of 18<sup>th</sup> October/ 2100 UTC of 17<sup>th</sup> October) as an extremely severe cyclonic storm (90 kt). In 1999, the Super Cyclone of Odisha developed from a depression over North Andaman Sea. It moved northwestwards and crossed Odisha coast in the morning (0930-1200 hrs IST) of 29<sup>th</sup> October, 1999 (120 kt). It moved very slowly during & after landfall and remained almost stationary over the Odisha coast near Cuttack & Bhubaneswar for about 30 hours, moved southwestwards and dissipated over the Odisha coast after 45 hours. In 2013, extremely severe cyclonic storm "Phailin" developed from a depression over North Andaman Sea. It moved northwestwards initially and then north-northwestwards and crossed Odisha coast as VSCS (64-89 kt) in the night (2230 hrs IST/1700 UTC) of 12<sup>th</sup> October, 2013.



**Fig. 2: Tracks of cyclonic storms developing from a depression in the grid (12°-17°N and 90°-100°E) crossing Odisha coast in the month of October during the period 1965-2023**

**(b) Movement:**

The six hourly average translational speed of “DANA” was 10.8 kmph against the normal speed of 16.7 kmph for SCS category over the BoB during the post-monsoon season (October-December). It moved slower than the average translational speed during the entire life cycle (**Fig. 3**). However, during landfall and particularly after landfall, on 25<sup>th</sup> October, it moved further slowly. As a result, the landfall process which commenced in the midnight (2330 hours IST/1800 UTC) of 24<sup>th</sup> October, continued for 9 hours till morning (0830 hours IST/ 0300 UTC) of 25<sup>th</sup> October. The northward movement of the system was restricted mainly due to north-northwesterly to northerly winds prevailing over the system area in association with the anticyclonic circulation centred near Kachchh region. After landfall, it moved slowly west-northwestwards after landfall and weakened into a CS by 0830 IST, DD by 1730 IST, a depression by 2330 hrs IST and into a well marked low pressure area over North Odisha in the early morning (0000 UTC) of 26<sup>th</sup> October.

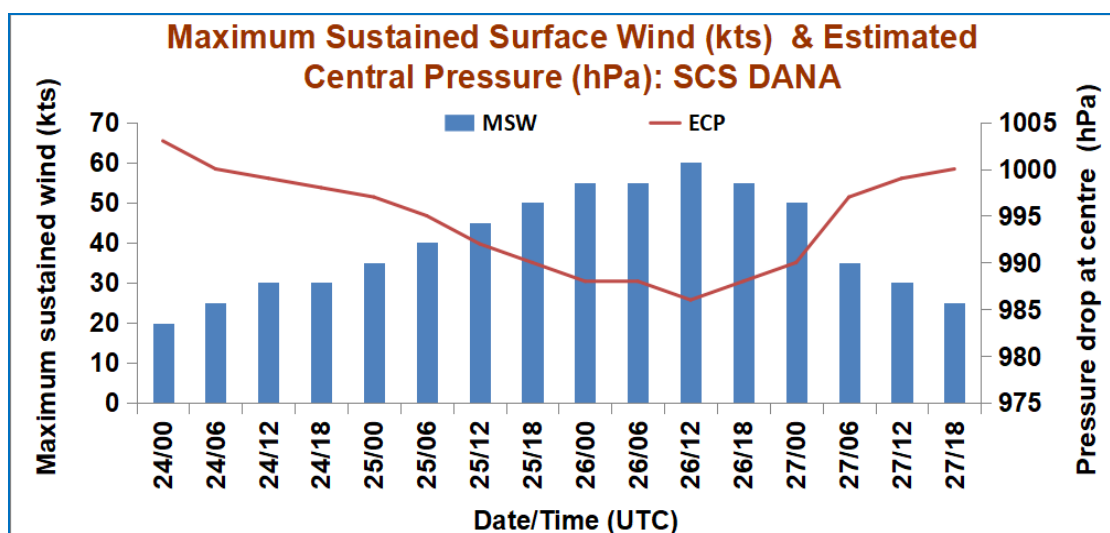


**Fig. 3: Six hourly average translational speed and direction of movement during life cycle of “SCS DANA”**

**(c) Maximum sustained wind speed (MSW) and estimated central pressure (ECP):**

The system intensified in the normal rate during early stages of its development i.e. from low pressure area stage (1730 hours IST of 20<sup>th</sup> October) to well-marked low-pressure area (1130 hours IST of 21<sup>st</sup> October) to depression (0530 hours IST of 22<sup>nd</sup> October), deep depression (1730 hours IST of 22<sup>nd</sup> October) and cyclonic storm (0530 hrs IST of 23<sup>rd</sup>). However, no rapid intensification (increase in intensity by at least 30 kt in 24 hours) was observed till landfall of the system. After landfall, the system weakened rapidly, mainly due to land interactions and cold dry air incursion from northwest into the core. The system attained peak intensity of 60 kts in

the evening of 24<sup>th</sup> October (1730 hours IST/ 1200 UTC) (**Fig. 4**) over northwest BoB when the system entered into an area of high sea surface temperature ( $\geq 30^{\circ}\text{C}$ ). Thereafter, due to land interactions and cold dry air incursion from northwest, it weakened gradually and crossed coast with wind speed of 55 knots (100-110 gusting to 120 kmph). After landfall, it rapidly weakened from the evening (1830 hours IST/ 1200 UTC) of 25<sup>th</sup> October to a well-marked low-pressure area in the early morning (0530 hours IST/ 0000 UTC) of 26<sup>th</sup> October (within 12 hours).



**Fig. 4: Six hourly Maximum sustained wind speed and estimated central pressure during life cycle of “SCS DANA”**

**(d) Track length:**

The total track length of severe cyclonic storm “DANA” was 1780 km against average track length of 930 km of SCS in post-monsoon season.

**(e) Life Period:**

The total life period (depression to depression) of “DANA” was 4 days against the normal of 4 days & 4 hours for SCS category over the BoB in post-monsoon season based on the data of 1990-2013.

**(f) Accumulated Cyclone Energy and Power Dissipation Index:**

The Velocity Flux, Accumulated Cyclone Energy (a measure of damage potential) and Power Dissipation Index (a measure of loss) were  $4.8 \times 10^2$  knots,  $2.36 \times 10^4$  knots<sup>2</sup> and  $1.21 \times 10^6$  knots<sup>3</sup> respectively against normal of  $3.88 \times 10^2$  knots,  $1.83 \times 10^4$  knots<sup>2</sup> and  $0.90 \times 10^6$  knots<sup>3</sup> respectively over the BoB.

### 3. Genesis, intensification, Landfall and Weakening

#### 3.1 Genesis

At 0000 UTC of 19<sup>th</sup> October, a **Cyclonic Circulation** lay over central Andaman Sea. It lay over North Andaman Sea in at 0000 UTC of 20<sup>th</sup> October 2024. Under its influence, a **Low-Pressure Area** formed over the Eastcentral BoB and

adjoining north Andaman Sea at 1200 UTC of 20<sup>th</sup> October. Moving west-northwestwards, it concentrated into a **Well-Marked Low-Pressure area** Eastcentral BoB at 0600 UTC of 21<sup>st</sup> October. Continuing to move west-northwestwards, it intensified into a **Depression** over Eastcentral BoB at **0000 UTC of 22<sup>nd</sup> October**. The madden-julian oscillation (MJO) was in phase 5, with amplitude more than 1, and expected to move across phase 5 during next 7 days with further increasing amplitude. Thus, MJO supported enhancement of convective activity over the BoB during next 5 days. The guidance from North Carolina Institute of Climate Studies (NCICS) based forecast over BoB indicated westerly winds (1-3 mps) over south BoB and adjoining Equatorial Indian Ocean and easterly winds (1-3 mps) over westcentral BoB. Eastward moving MJO & Kelvin waves along with Equatorial Rossby waves were likely over the central BoB during next 5-7 days. These features indicated highly favourable environment for cyclogenesis (formation of depression) over the central parts of the BoB. The sea surface temperature (SST) was 30°C over the central and northern BoB. The tropical cyclone heat potential (TCHP) was greater than 100 kJ/cm<sup>2</sup> over the west-central BoB and less than 80 kJ/cm<sup>2</sup> over the northwest BoB. A zone of positive relative vorticity, measuring  $100 \times 10^{-6} \text{ s}^{-1}$ , was present to the south of the system's center over the east-central BoB, extending vertically up to the 500 hPa level. The low-level convergence of  $10 \times 10^{-6} \text{ s}^{-1}$  was observed to the south of the system area, along with upper-level divergence of  $20 \times 10^{-6} \text{ s}^{-1}$  in the same region. The Vertical wind shear (VWS) was low to moderate over the central BoB and high over the northern BoB. Total precipitable water imagery indicated a warm, moist air incursion into the core of the system.

### 3.2 Intensification

The Depression then moved northwestwards and intensified into a **Deep Depression** over Eastcentral BoB at 1200 UTC of 22<sup>nd</sup> October. Continuing to move further northwestwards, it is intensified further into a CS **“DANA”** over eastcentral BoB in the early morning (0530 hours IST/ 0000 UTC) of 23<sup>rd</sup> October. It then moved north-northwestwards and intensified into an SCS over central & adjoining northwest BoB in the mid-night (2330 hours IST/1800 UTC) of 23<sup>rd</sup> October, 2024.

**At 1200 UTC of 22<sup>nd</sup> October** the MJO was in phase 5, with amplitude more than 1, and was expected to move across phase 5 during next 7 days with further increasing amplitude. Thus, MJO supported enhancement of convective activity over central and north BoB during next 5 days. The guidance from NCICS based forecast over BoB indicated eastward moving MJO & kelvin waves along with equatorial Rossby waves over the central BoB during next 5 days. These features indicated highly favourable environment for intensification of system over the central & north parts of the BoB. The SST was 30°C over central & north BoB. The TCHP was >100 KJ/cm<sup>2</sup> over westcentral BoB, <80 kJ/cm<sup>2</sup> over northwest. The relative vorticity at low level increased in past 6 hours and was



150x 10<sup>-6</sup>s<sup>-1</sup> around system centre over eastcentral BoB with vertical extension upto 500 hPa level. The low-level convergence increased and was 30 x10<sup>-6</sup> s<sup>-1</sup> to the north of system area. The upper-level divergence was 20x10<sup>-6</sup> s<sup>-1</sup> to the northeast of system area. The VWS was low to moderate (05-15 kt) over central BoB.

**At 0000 UTC of 23rd and 24<sup>th</sup> October** the similar MJO, equatorial Rossby wave and Kelvin waves prevailed along with similar SST and TCHP. The relative vorticity at low level increased and was 150x 10<sup>-6</sup>s<sup>-1</sup> around system centre over eastcentral BoB with vertical extension upto 500 hPa level. The low-level convergence increased and was 30 x10<sup>-6</sup>s<sup>-1</sup> to the northwest of system area at 00 UTC of 23<sup>rd</sup>. The upper-level divergence also increased and was 30x10<sup>-6</sup>s<sup>-1</sup> around the northeast of system area. The VWS was moderate to high (10-20 kt) over central BoB

The relative vorticity at low level has increased in **1800 UTC of 23<sup>rd</sup>** and was 200x 10<sup>-6</sup>s<sup>-1</sup> around system centre over eastcentral BoB with vertical extension upto 200 hPa level. The low-level convergence was 20 x10<sup>-6</sup>s<sup>-1</sup> to the southwest of system area. The upper-level divergence was also same and was 10x10<sup>-6</sup>s<sup>-1</sup> to the southwest of system area. The VWS was low-moderate (10-15kt) over central BoB. Enhanced poleward outflow was seen in midlatitude westerlies. High SST, poleward outflow, moderate wind shear supported further intensification of the system into SCS.

### 3.3 Landfall

Continuing to move north-northwestwards, the SCS “**DANA**” crossed **north Odisha coast close to Habalikhati Nature Camp (Bhitarkanika) and Dhamara** during **0130 hrs IST to 0330 hrs IST of 25<sup>th</sup> October** (2000 to 2200 UTC of 24<sup>th</sup> October) as a severe cyclonic storm with a wind speed of 100-110 kmph gusting to 120 kmph. The landfall process commenced in the midnight (2330 hours IST/1800 UTC) of 24<sup>th</sup> October and continued for 9 hours till 0830 hours IST/ 0300 UTC of 25<sup>th</sup> October.

**At 0015 UTC of 24<sup>th</sup> October**, the relative vorticity at low level was 250 x 10<sup>-6</sup>s<sup>-1</sup> around system area with vertical extension upto 200 hPa level. The low-level convergence was 10 x10<sup>-6</sup>s<sup>-1</sup> to the southwest of system area. The upper-level divergence was also same and was 10x 10<sup>-6</sup>s<sup>-1</sup> to the northeast of system area. The VWS was low (10-15 kt) over northwest BoB. The upper tropospheric ridge was around 20<sup>o</sup>N. The system was tracking north-northwesterly under the influence of south-southeasterly winds to the south of ridge.

**At 2100 UTC of 24<sup>th</sup> October**, the relative vorticity at low level decreased further to 150x 10<sup>-6</sup>s<sup>-1</sup> around system area with vertical extension upto 500 hPa level. Low-level convergence was 15 x10<sup>-6</sup>s<sup>-1</sup> to the southwest of system area. The upper-level divergence was also same and was 10x10<sup>-6</sup>s<sup>-1</sup> to the northeast of system

area. The VWS was increased to moderate (10 kt) over northwest BoB. The upper tropospheric ridge was around 20°N.

**At 0000 UTC of 25<sup>th</sup> October**, the relative vorticity at low level was  $200 \times 10^{-6} \text{s}^{-1}$  around system area with vertical extension upto 500 hPa level. Low-level convergence was  $20 \times 10^{-6} \text{s}^{-1}$  to the southwest of system area. The upper-level divergence was also same and was  $10 \times 10^{-6} \text{s}^{-1}$  to the east of system area and extending westwards upto eastcentral Bay of Bengal. Vertical wind shear (VWS) was moderate (10-20 kt) over system area and to its west. The upper tropospheric ridge was around 20° N and an anticyclonic circulation over Chhattisgarh (India).

### 3.4 Weakening

Continuing to move further north-north westwards slowly, the SCS “**DANA**” weakened into a CS over north coastal Odisha at 0300 of 25 October, into a **deep depression** at 0900 UTC of 25 October. Thereafter, it gradually moved westwards, weakened into a **depression** over interior Odisha in the midnight (2330 hours IST/1800 UTC) of 25<sup>th</sup> October and into a **well-marked low-pressure area** over North Odisha in the early morning (0530 hours IST/ 0000 UTC) of 26<sup>th</sup> October.

**At 0300 UTC of 25 October**, the relative vorticity at low level was  $200 \times 10^{-6} \text{s}^{-1}$  around system area with vertical extension upto 500 hPa level. Low-level convergence was  $15 \times 10^{-6} \text{s}^{-1}$  to the south of system area. The upper-level divergence was also same and was  $20 \times 10^{-6} \text{s}^{-1}$  to the south of system area and extending westwards upto eastcentral Bay of Bengal. The VWS was low (05-10 kt) over system area and to its west. The upper tropospheric ridge was around 20° N and an anticyclonic circulation over Chhattisgarh (India).

**At 0900 UTC of 25 October**, the relative vorticity at low level was  $200 \times 10^{-6} \text{s}^{-1}$  around system area with vertical extension upto 500 hPa level. Low-level convergence was around  $20 \times 10^{-6} \text{s}^{-1}$  to the system area. The upper-level divergence was also same and was  $30 \times 10^{-6} \text{s}^{-1}$  to the system area and extending westwards upto eastcentral BoB. The VWS was low (05-10 kt) over system area and to its west. The upper tropospheric ridge was around 20°N and an anticyclonic circulation lay over Chhattisgarh (India). East-southeastwrlly winds prevailing in upper tropospheric levels were steering the system nearly westwards.

**At 1800 UTC of 25 October**, the relative vorticity at low level was  $200 \times 10^{-6} \text{s}^{-1}$  to the southeast of system centre with vertical extension upto 500 hPa level. Low-level convergence was around  $20 \times 10^{-6} \text{s}^{-1}$  to the west of system area. The upper-level divergence was  $5 \times 10^{-6} \text{s}^{-1}$  to the system area and extending south-southwestwards upto southern India. The VWS was low (05-10 kt) over system area and to its west. The upper tropospheric ridge was around 20°N. East-southeasterly winds prevailing in upper tropospheric levels are likely to steer the system nearly west-southwestwards.

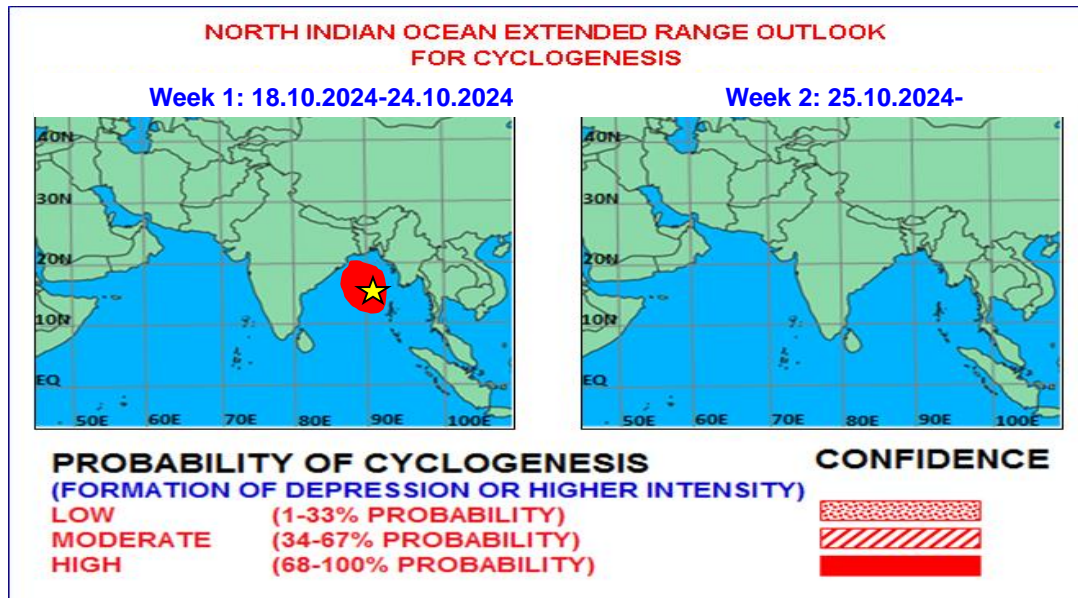
#### 4. Monitoring SCS “DANA”:

India Meteorological Department (IMD) maintained round the clock watch over the north Indian Ocean and the cyclone was monitored since 16<sup>th</sup> October, about 6 days prior to formation of depression on 22<sup>nd</sup> October. First information about likely formation of a cyclonic circulation over Andaman Sea with an advisory for continuous watch was issued in the Daily Report under Tropical Cyclone Forecasting Programme dated 16<sup>th</sup> October (about 4 days ahead of formation of cyclonic circulation on 20<sup>th</sup> October). Subsequently, the extended range outlook issued on 17<sup>th</sup> October (about 5 days ahead of formation of depression over the Bay of Bengal and 7.5 days ahead of landfall) indicated with high confidence (67-100% probability) likelihood of the formation of a depression over the Eastcentral BoB around 23<sup>rd</sup> October and movement towards Odisha coast (**Fig. 5**). Actually, the depression formed over Eastcentral BoB on 22<sup>nd</sup> October.

- ❖ **Pre-cyclone watch** for Odisha and West Bengal coasts was issued at 1330 hours IST of 20<sup>th</sup> October at the stage of an upper air cyclonic circulation which lay over North Andaman Sea (about 4.5 days ahead of landfall).
- ❖ **Cyclone Alert** (Yellow Message) for Odisha and West Bengal coasts was issued at 2030 hours IST of 22<sup>nd</sup> October with the formation of Deep Depression over eastcentral BoB at 1730 hours IST of 22<sup>nd</sup> October (about 2 days ahead of landfall).
- ❖ The **landfall close to Bhitarkanika and Dhamara** during early hours of 25<sup>th</sup> October was first indicated in the first bulletin issued at 1430 hrs IST of 21<sup>st</sup> October in the graphical track forecast issued by IMD (about 3 days and 9 hours ahead of landfall).
- ❖ **Cyclone Warning** (Orange Message) for Odisha and West Bengal coasts was issued at 1145 hours IST of 23<sup>rd</sup> October at the stage of cyclonic storm over eastcentral BoB (about 36 hours ahead of landfall).
- ❖ **Cyclone Warning** (Red Message) for Odisha and West Bengal coasts was issued on 0230 hours IST of 24<sup>th</sup> October on formation of severe cyclonic storm over central & adjoining northwest BoB (about 24 hours ahead of landfall)
- ❖ **Post Landfall Outlook** (Red Message) for interior districts of Odisha was issued at 1630 hours IST of 24<sup>th</sup> October (about 10 hours ahead of landfall).

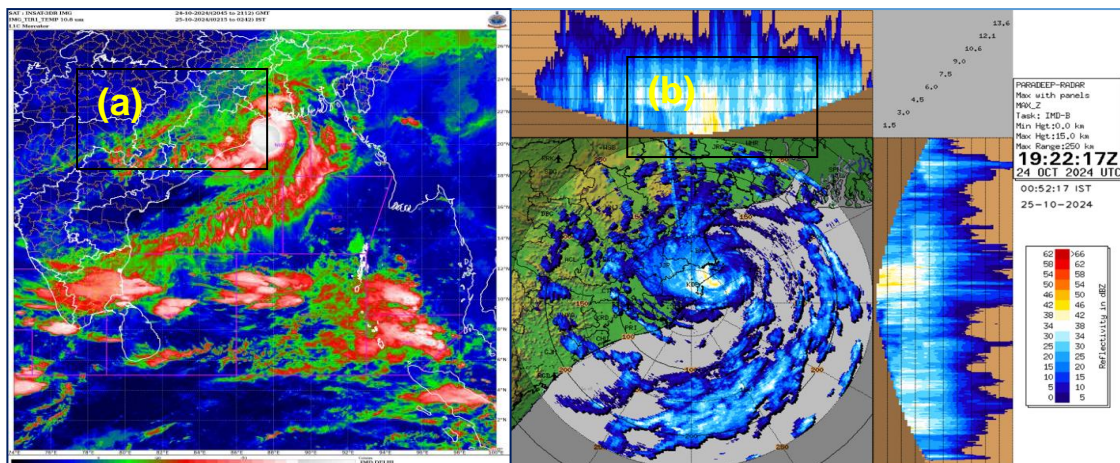
The cyclone was monitored with the help of available satellite observations from INSAT 3DR, SCATSAT (OCEANSAT 3), ASCAT, microwave imageries, doppler weather Radar at Paradip & Gopalpur, available ships, buoys observations & coastal observations in the region. Various global models and dynamical-statistical models run by Ministry of Earth Sciences (MoES) institutions including IMD, NCMRWF, IITM & INCOIS and guidance from models from various international agencies under bilateral arrangement were utilized to predict the genesis, track and intensity of the cyclone as well as associated severe weather. The forecasts were mainly based on multi-model ensemble technique developed by IMD which were further modulated by analysis of observations and forecasters

intervention at IMD through their knowledge, experience and expertise. An indigenously developed digitized forecasting system of IMD (Decision Support System) was utilized for analysis and comparison of various observations and numerical weather prediction model's guidance, decision making process and warning products generation. Typical satellite and radar-based products utilised for monitoring the system are presented in **Fig. 6**.



**Fig. 5:** Extended Range Outlook issued on 17<sup>th</sup> October, indicating probable area of genesis (formation of depression) and likely movement towards Odisha coast with High confidence.

● : Probable Area of cyclogenesis, ★ : Actual Point of genesis



**Fig. 6:** Typical (a) INSAT 3D imagery at 0215 IST of 25<sup>th</sup> October and (b) Doppler Weather Radar Paradip imagery at 0052 IST of 25<sup>th</sup> during severe cyclonic storm “DANA”



#### 4.1 Features observed through satellite

At **0300UTC of 19 October** scattered to broken low and medium clouds with embedded intense to very intense convection lay over westcentral BoB, off Andhra Pradesh coast, eastcentral BoB, south BoB & Andaman Sea (minimum cloud top temperature (CTT) minus 75-90<sup>0</sup>C). Scattered low and medium clouds with embedded moderate to intense convection lay over north BoB, off Gangetic West Bengal & Bangladesh coasts, Gulf of Martaban, and Tenasserim coast.

At **0300 UTC of 20 October** scattered to broken low and medium clouds with embedded intense to very intense convection lay over eastcentral adjoining northeast & southeast BoB and Andaman Sea, Tenasserim coast, Gulf of Martaban (minimum CTT minus 80 -93 <sup>0</sup>C). Scattered low and medium clouds with embedded moderate to intense convection lay over rest of Bay of Bengal.

At **0300 UTC of 21 October** scattered low and medium clouds with embedded intense to very intense convection lay over northeast and eastcentral BoB, north Andaman Sea, Tenasserim coast, gulf of Martaban (minimum CTT minus 80-93 <sup>0</sup>C). Scattered low and medium clouds with embedded moderate to intense convection lay over northwest and westcentral BoB, Arakan coast and south Andaman Sea.

At **0000 UTC of 22 October** clouds are organised in shear pattern. The associated CI No. Was **1.5**. Scattered to broken low/med clouds with embedded intense to very intense convection over northeast, central and south BoB, north Andaman Sea & neighbourhood (minimum CTT: minus 80-90 <sup>0</sup>C).

At **0300 UTC of 22 October** banding features are appearing in cloud organisation. The intensity is characterised as **CI 1.5**. Scattered to broken low/med clouds with embedded intense to very intense convection lay over east BoB, Andaman Islands, north Andaman Sea & neighbourhood (minimum CTT: minus 80-93 <sup>0</sup>C).

At **1200 UTC of 22 October** the cloud mass shows further organisation in past six hours. Banding features are seen in cloud organisation. The intensity is characterised as **CI2.0**. Scattered to broken low & medium clouds with embedded intense to very intense convection lay over central & adjoining north Bay of Bengal, north Andaman Sea & neighbourhood. Minimum CTT was minus 80-93<sup>0</sup>C. Multisatellite winds indicate stronger winds in northeast sector. Total precipitable water imagery indicates warm moist air incursion into the core. IR/WV difference indicates deep convection upto upper tropospheric levels. ASCAT pass indicates stronger winds in northeast sector.

At **0000 UTC of 23 October** the cloud mass shows further organisation in past six hours. The satellite imagery shows that the system is shear pattern. The intensity is characterised as **CI2.5**. The very intense convective cloud mass associated with the system lies over west sector of the system centre. Minimum CTT minus 93

degrees Celsius. Associated scattered to broken low/medium clouds with embedded intense to very intense convection over central & north BoB between latitude 12.0N to 21.0N and longitude 84.0E to 93.0E (minimum CTT is minus 80-93 °C).

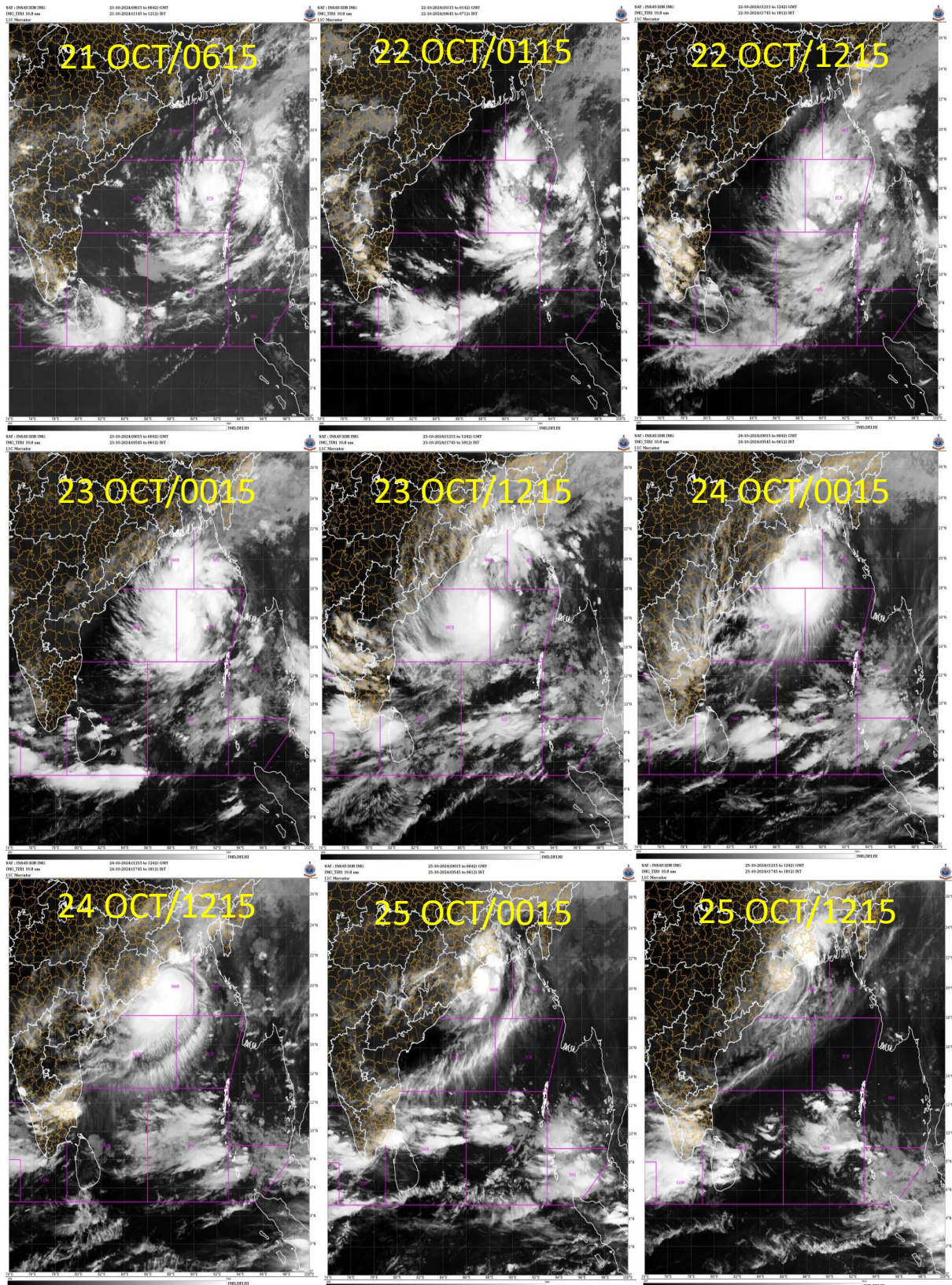
At **0300 UTC of 23 October** the cloud mass shows irregular CDO pattern. Visible imagery depicts low level cyclonic circulation (LLCC) embedded in north-east sector of CDO. Diameter size of CDO is about 160 km yields CF2 and BF = 0.5 which yields DT = 2.5. Met T= 2.5 with normal intensification and PT = 2.5. The intensity is characterised as **T2.5**. Associated scattered to broken low/medium clouds with embedded intense to very intense convection over central & north BoB between latitude 13.0°N to 21.5°N and longitude 84.0E to 93.0E. Minimum CTT is minus 80-93°C. IR/WV difference imagery indicate intense convection upto upper tropospheric levels. Total precipitable imagery indicate warm moist air incursion into the core. Multi-satellite winds indicate stronger winds in the northern sector.

At **0900 UTC of 23 October** vortex (dana) over eastcentral BoB with centred near 16.8°N/89.0°E with intensity CI**3.0** and associated scattered to broken low/medium clouds with embedded intense to very intense convection over central & north bay between latitude 13.0°N to 21.5°N and longitude 84.0°E to 93.0°E (minimum CTT minus 80-93 °C). Scattered to broken low/medium clouds with embedded intense to very intense convection over north, southeast & central BoB (minimum CTT minus 80-93 °C) with scattered low/medium clouds with embedded moderate to intense convection over southwest BoB, Andaman Sea, Arakan coast & Tenasserim coast.

At **0000 UTC of 24 October** severe cyclonic storm “Dana” intensity CI**3.5** with associated scattered to broken low/medium clouds with embedded intense to very intense convection over central & north BoB between latitude 15.0N & 21.0N and longitude 85.0E to 90.0E. Minimum CTT is minus 93°C.

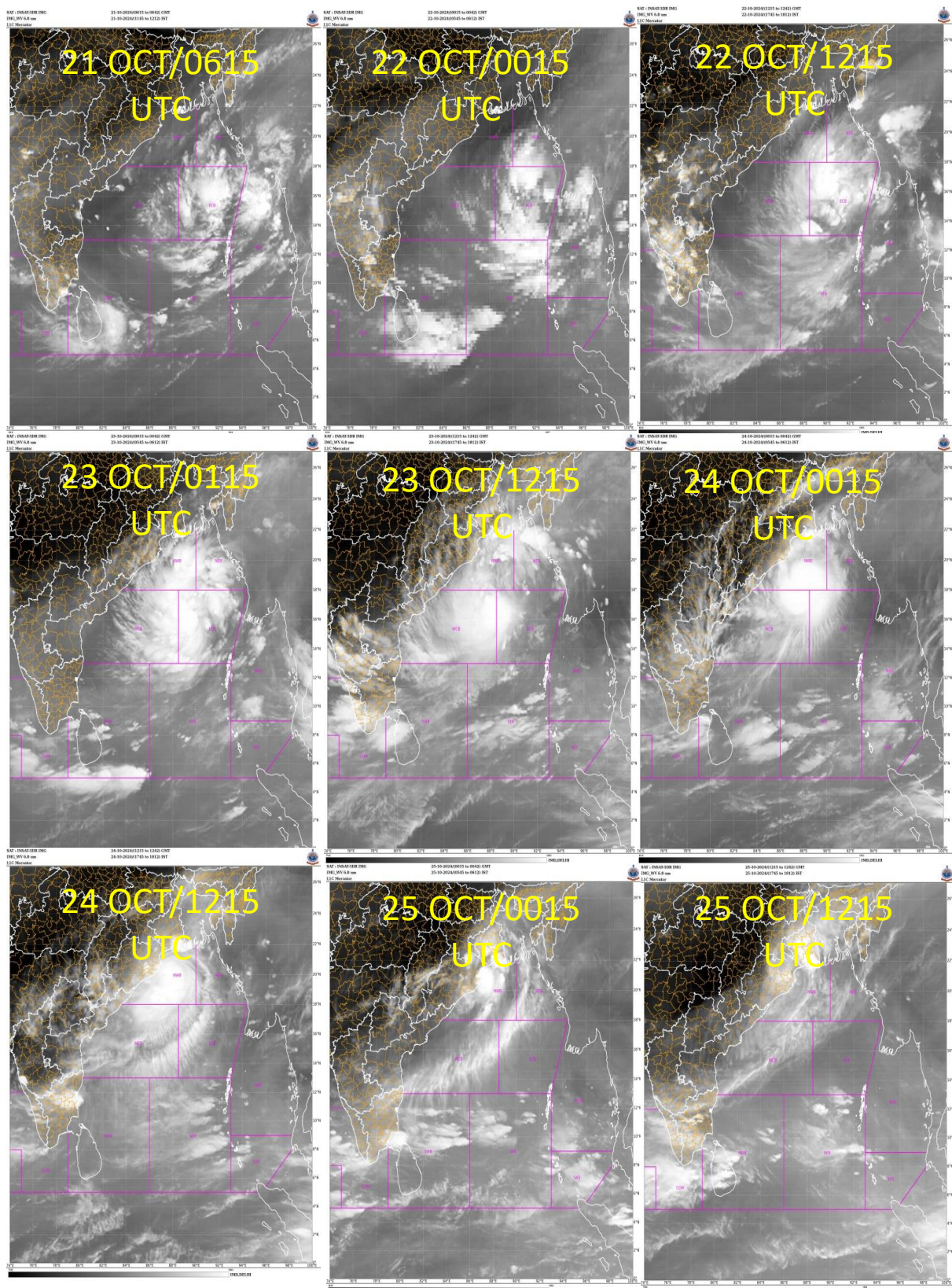
At **0300 UTC of 24 October** the cloud mass is organised in CDO pattern. Current intensity is characterised as **CI3.5**. IR/VIS imagery depicts LLCC embedded in north-east sector of CDO. Diameter size of CDO is about 150 kms yields CF=3, BF = 0.5 yields DT = 3.5 MET and PT agree hence FT based on DT + BF= 3.0+0.5=3.5. Associated scattered to broken low/medium clouds with embedded intense to very intense convection over central & north BoB between latitude 15.0N & 21.0N and longitude 85.0E to 90.0E. Minimum CTT is minus 93°C. Total precipitable water imagery indicate warm moist air incursion into the core from southwest. Multisatellite winds indicate stronger winds in northeast sector.





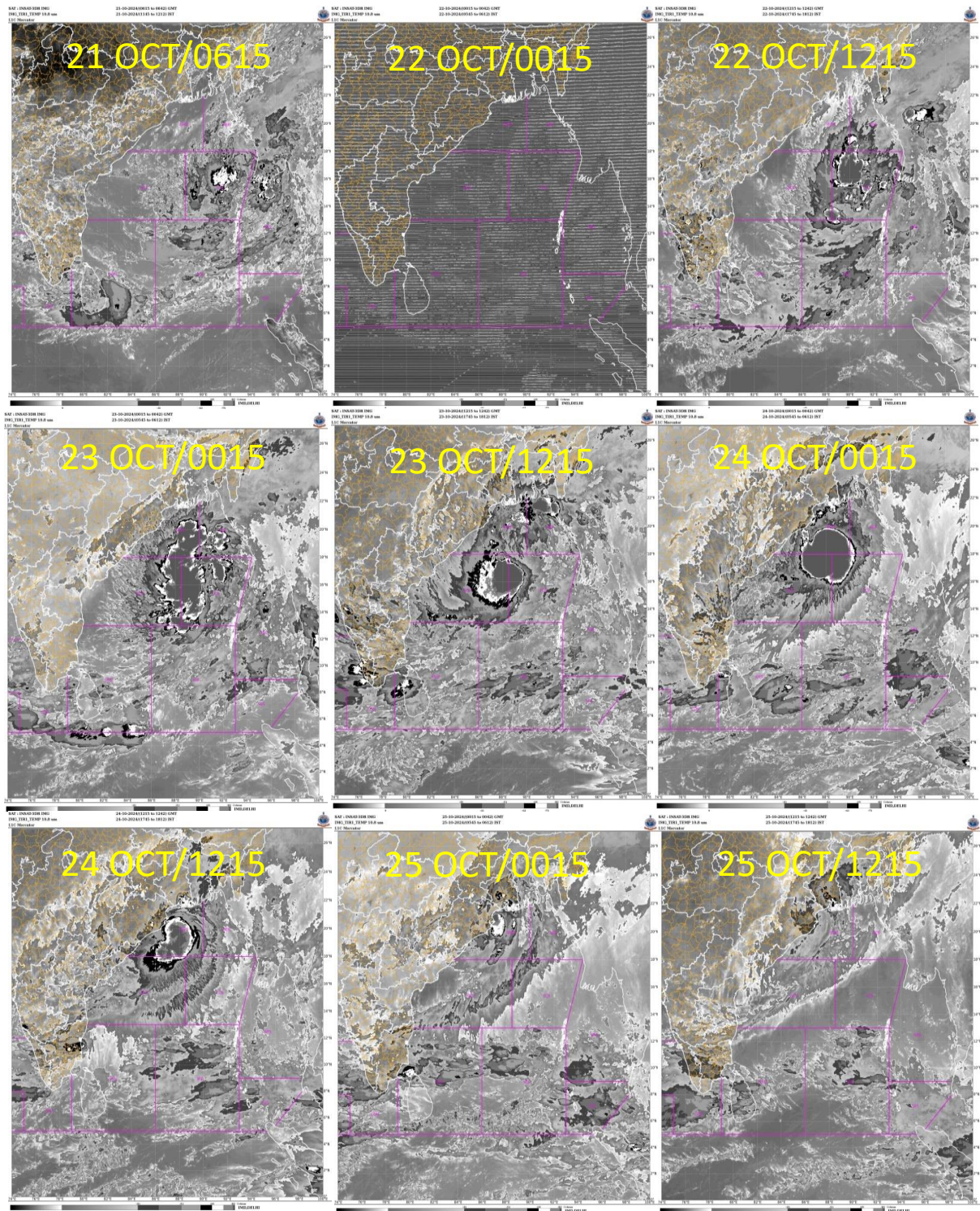
**Fig. 7(a): INSAT-3D IR imageries during life cycle of SCS DANA (22nd-26th October, 2024)**





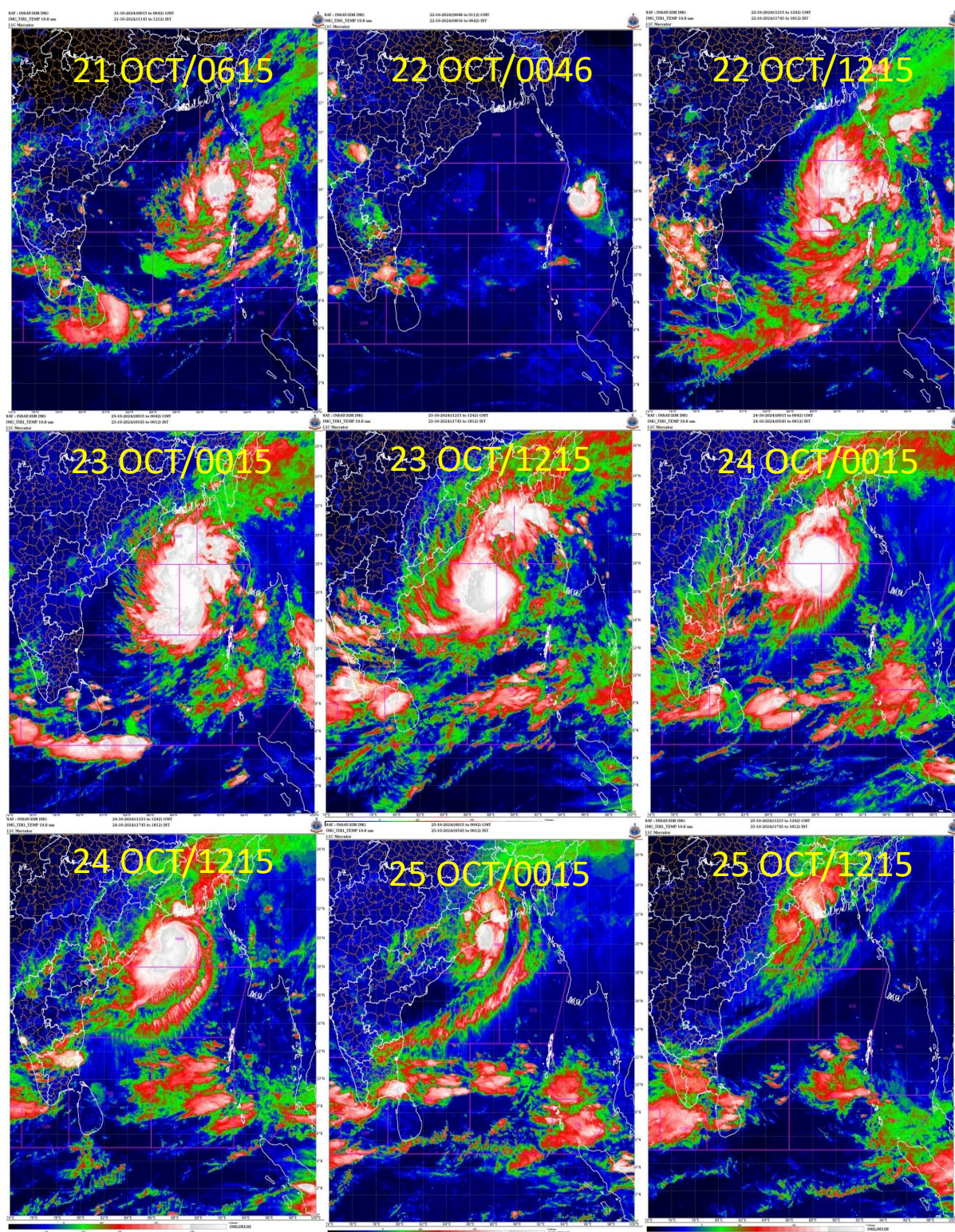
**Fig. 7(b): INSAT-3D Water Vapour imageries during life cycle of SCS DANA (22nd-26th October, 2024)**





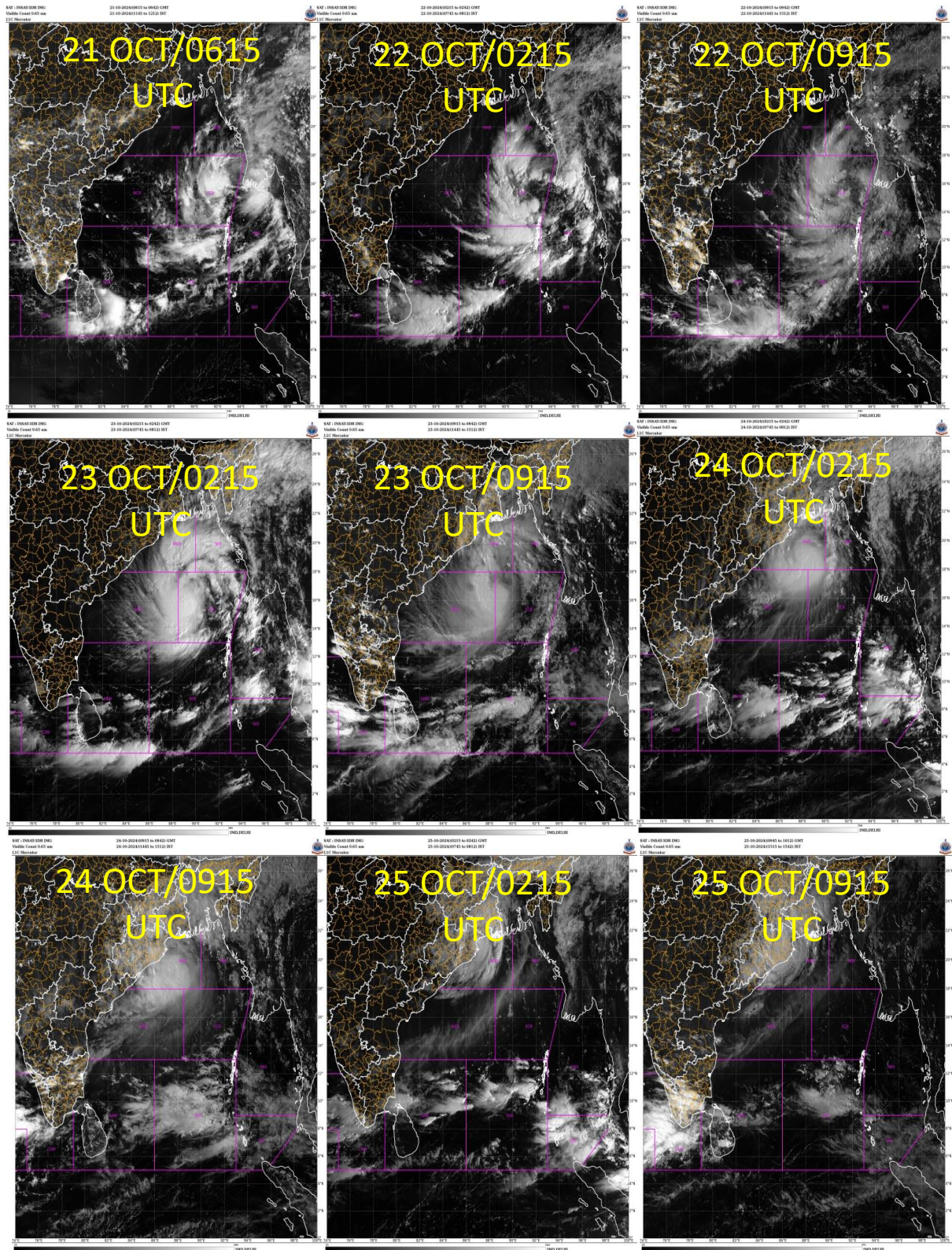
**Fig. 7(c): INSAT-3D enhanced IR BD imageries during life cycle of SCS DANA (22nd-26th October, 2024)**





**Fig. 7(d): INSAT-3D IR enhanced colour imageries during life cycle of SCS DANA (22nd-26th October, 2024)**





**Fig. 7(e): INSAT-3D Visible imageries during life cycle of SCS DANA (22<sup>nd</sup> -26<sup>th</sup> October, 2024)**

At **0300 UTC of 25 October** the current intensity was characterised as **CI3.0**. Associated scattered to broken low/medium clouds with embedded intense to very intense convection lay over northeast Odisha. Minimum CTT is minus 75-90°C. Moderate to intense convection over Gangetic west Bengal, northwest Odisha, southeast Jharkhand and Bangladesh.

At **0900UTC of 25 October** as per the satellite imagery, the associated scattered to broken low/medium clouds with embedded intense to very intense convection lay over northeast Odisha. Minimum CTT is minus 75-90°C. Moderate to intense convection over Gangetic west Bengal, southeast Jharkhand and north Bay of Bengal.

Typical INSAT-3D visible/IR imageries, enhanced colored imageries and cloud top brightness temperature imageries are presented in **Fig.7(a) – 7(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.

#### **4.2 Features observed through Doppler Weather Radar (DWR)**

The SCS “DANA” reached near coast of north Odisha close to Habalikhathi Nature Camp (Bhitarkanika) and Dhamara during 0130 hrs IST to 0330 hrs IST of 25<sup>th</sup> October (2000 to 2200 UTC of 24<sup>th</sup> October) as an SCS with a wind speed of 100-110 kmph gusting to 120 kmph. The landfall process commenced in the midnight (2330 hours IST/1800 UTC) of 24<sup>th</sup> October and continued for 9 hours till 0830 hours IST/ 0300 UTC of 25<sup>th</sup> October. **Fig. 8(a) to 8(d)** are displaying sequentially different radar imageries (PPI\_V and Max dBZ) at different times on 25<sup>th</sup> and 26<sup>th</sup> October during the landfall of the cyclone. Every plot in the figure is representing Max (dBZ) plot of radar reflectivity with vertical cross sections in East-West and North-South directions. The radar imageries starting 00:12 UTC of 25 October to 11:42 UTC of 26 October was showing the movement of the cyclone during this period.



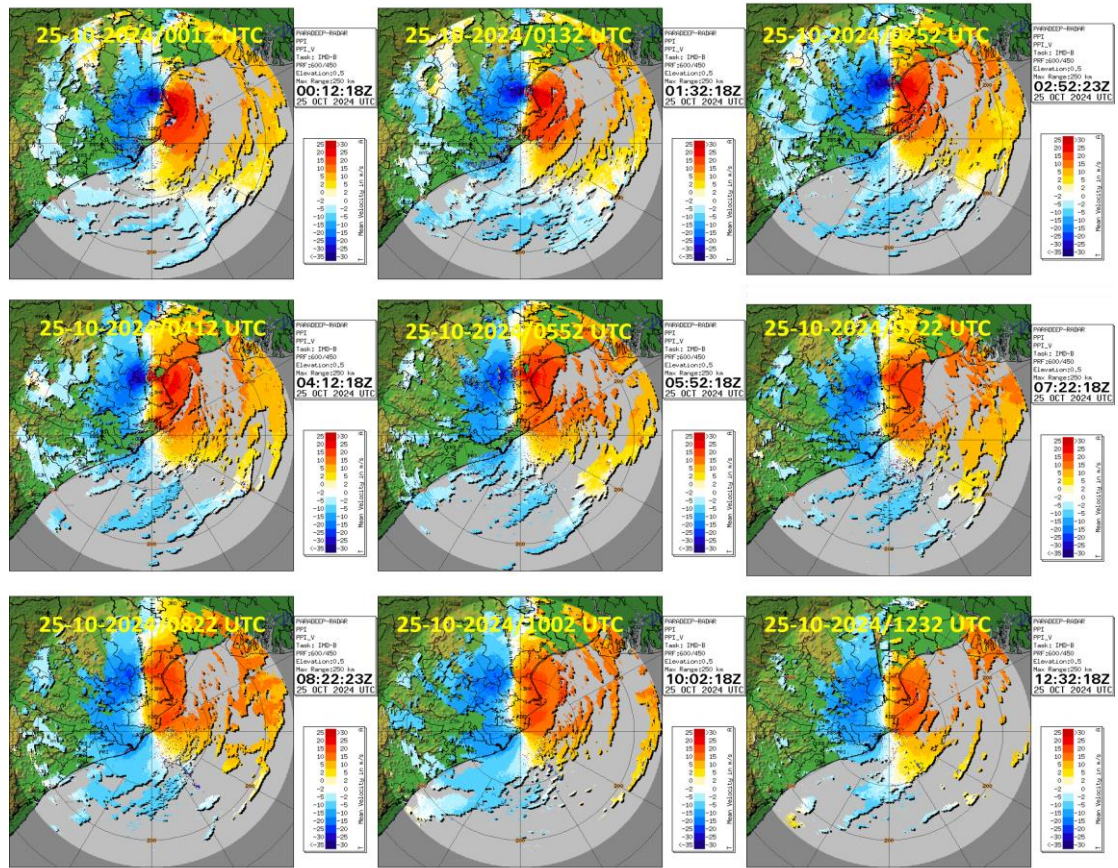


Fig. 8(a): DWR Paradip PPI\_V during the day of landfall (25<sup>th</sup> October, 2024)

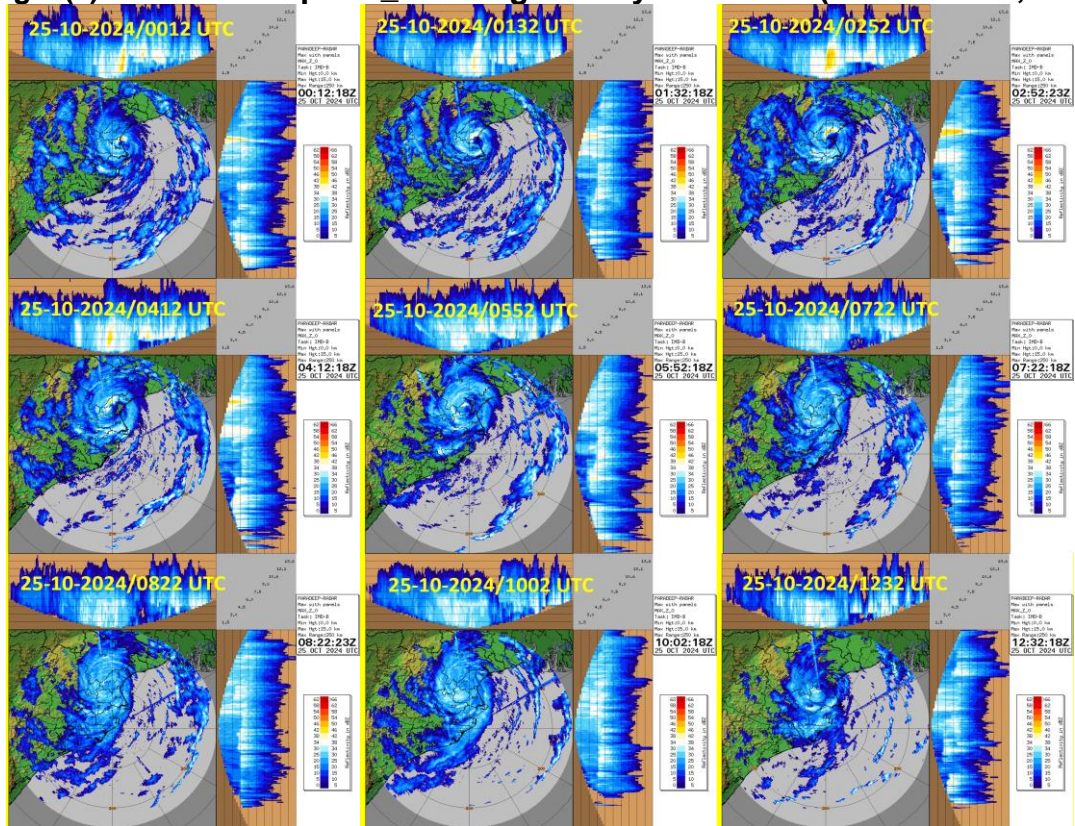


Fig. 8(b): DWR Paradip Max (dBZ) imagery of reflectivity during the day of landfall (25 October, 2024)



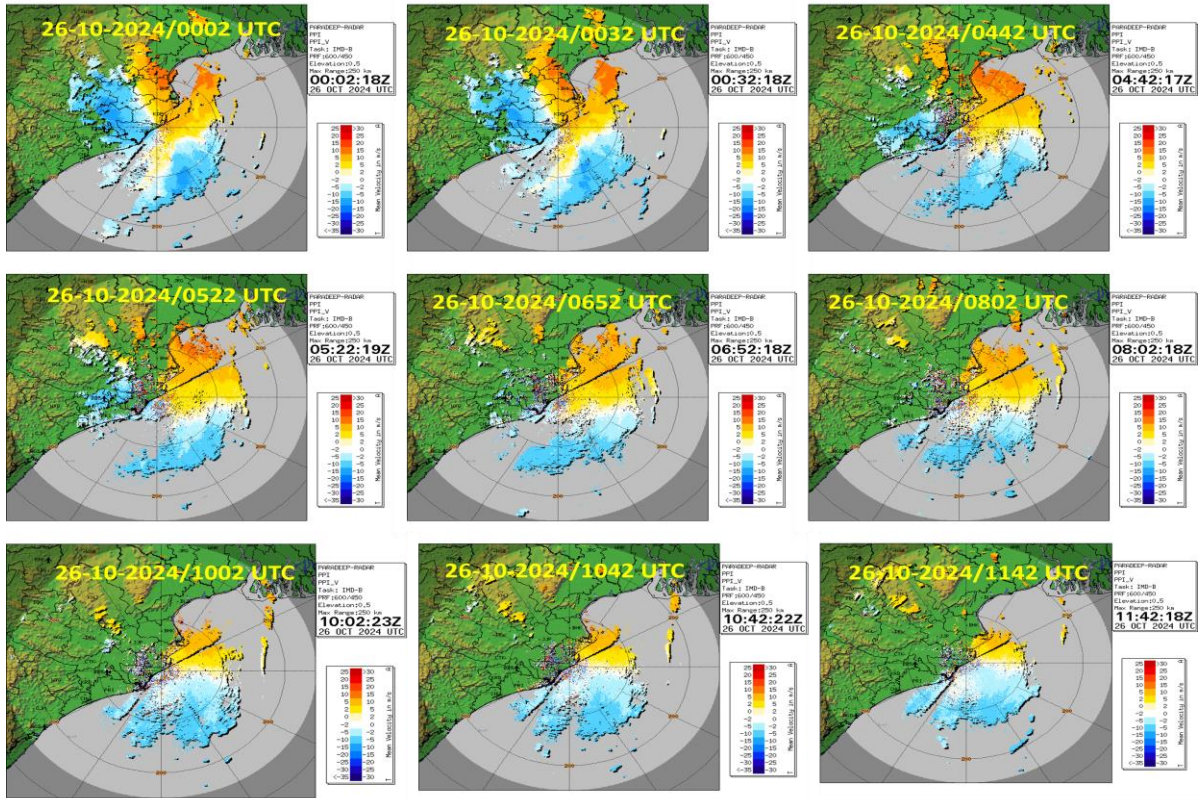


Fig. 8(c): DWR Paradip PPI\_V images during 26 October, 2024

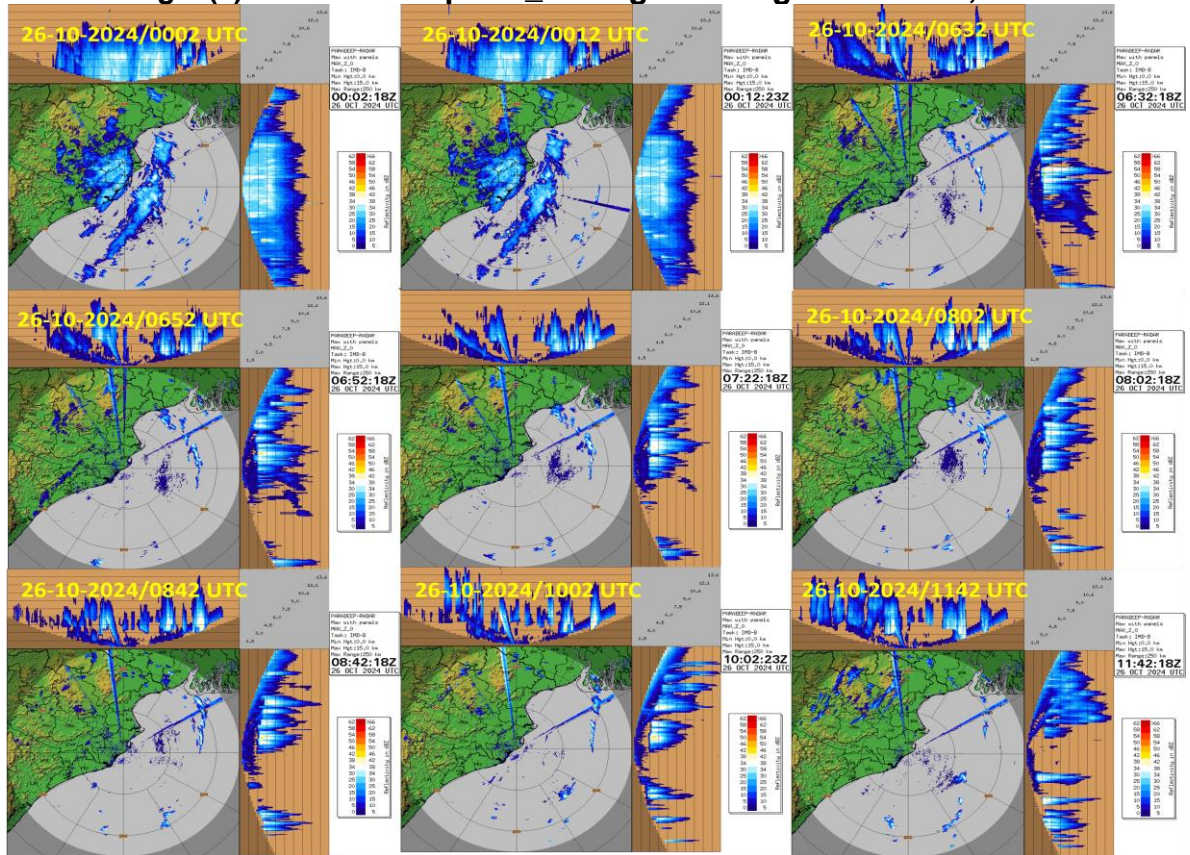
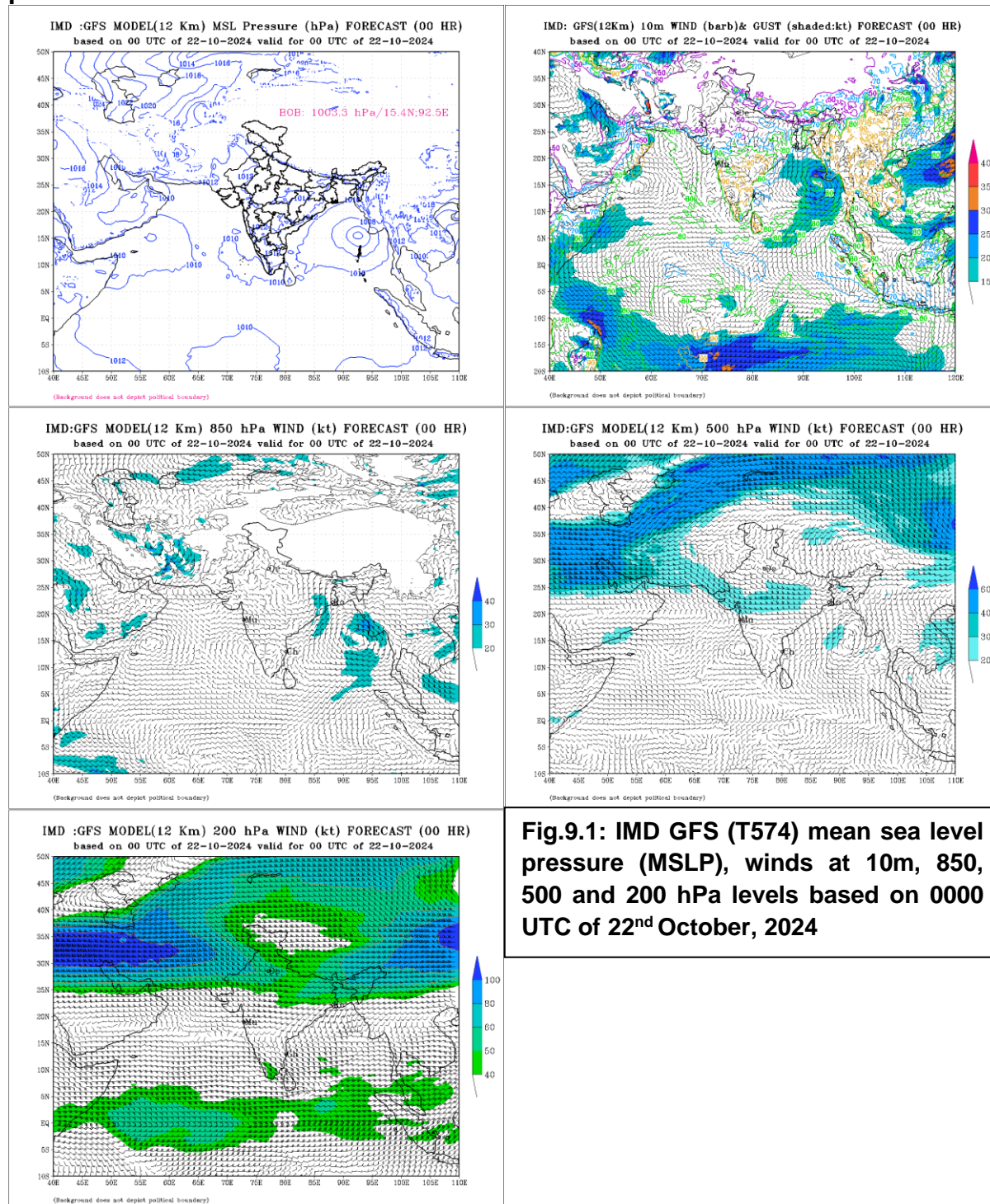


Fig. 8(d): DWR Paradip Max (dBZ) imageries of reflectivity during 26 October, 2024



## 5. Dynamical features

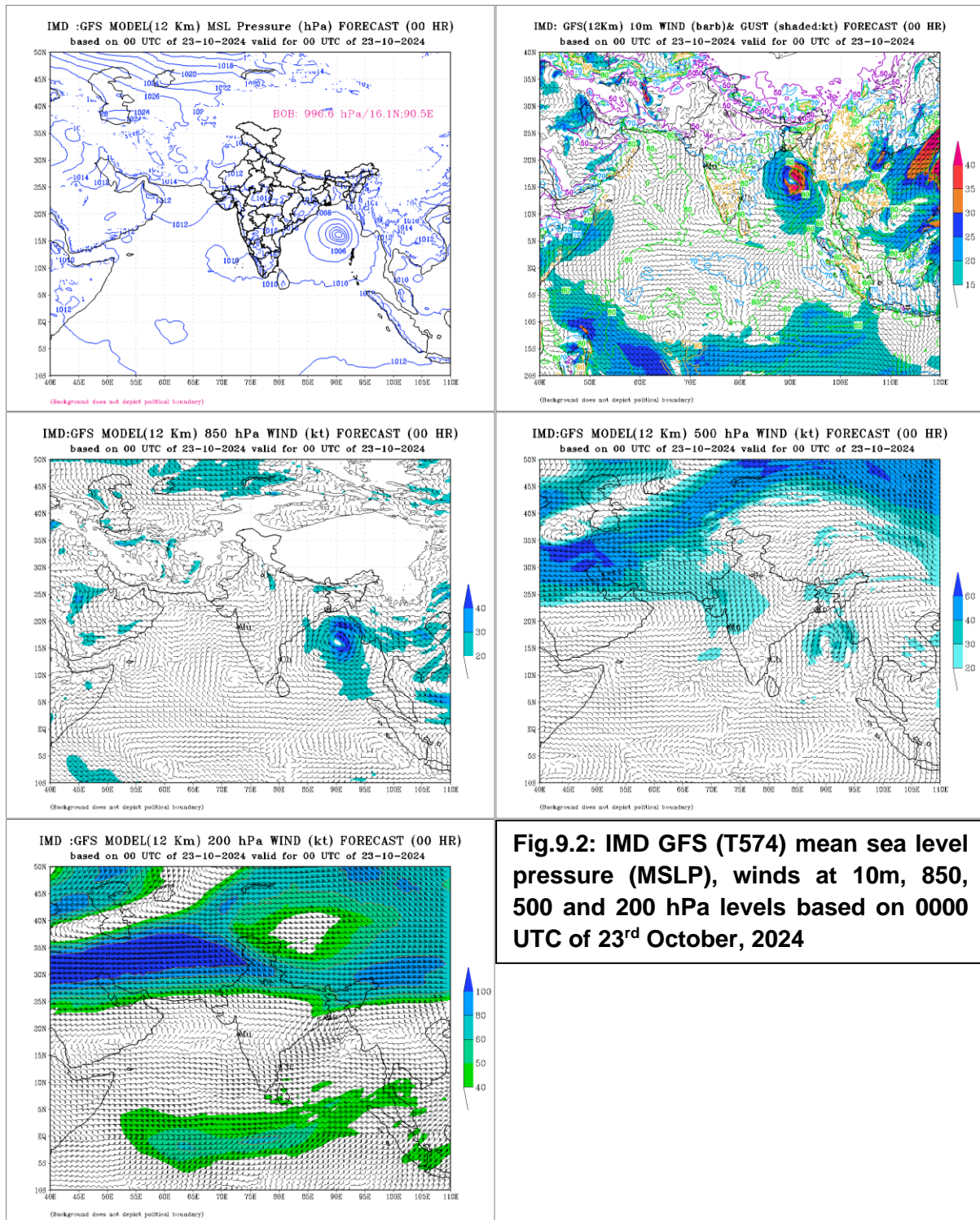
The analyses of IMD GFS (T1534) model for mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa pressure levels valid at 0000 UTC of everyday during 22<sup>nd</sup> October – 26<sup>th</sup> October are presented in **Fig. 9.1 – 9.5** indicating the location, movement and intensity of the system during its life period.



The top two panels of Fig. 9.1 are showing the surface MSLP and 10 m wind characteristics at 0000 UTC of 22nd October, 2024. The model was indicating 3 closed isobars with outer one covering a large area and center over eastcentral BoB and adjoining areas of north Andaman Sea. It indicated that the system attained the



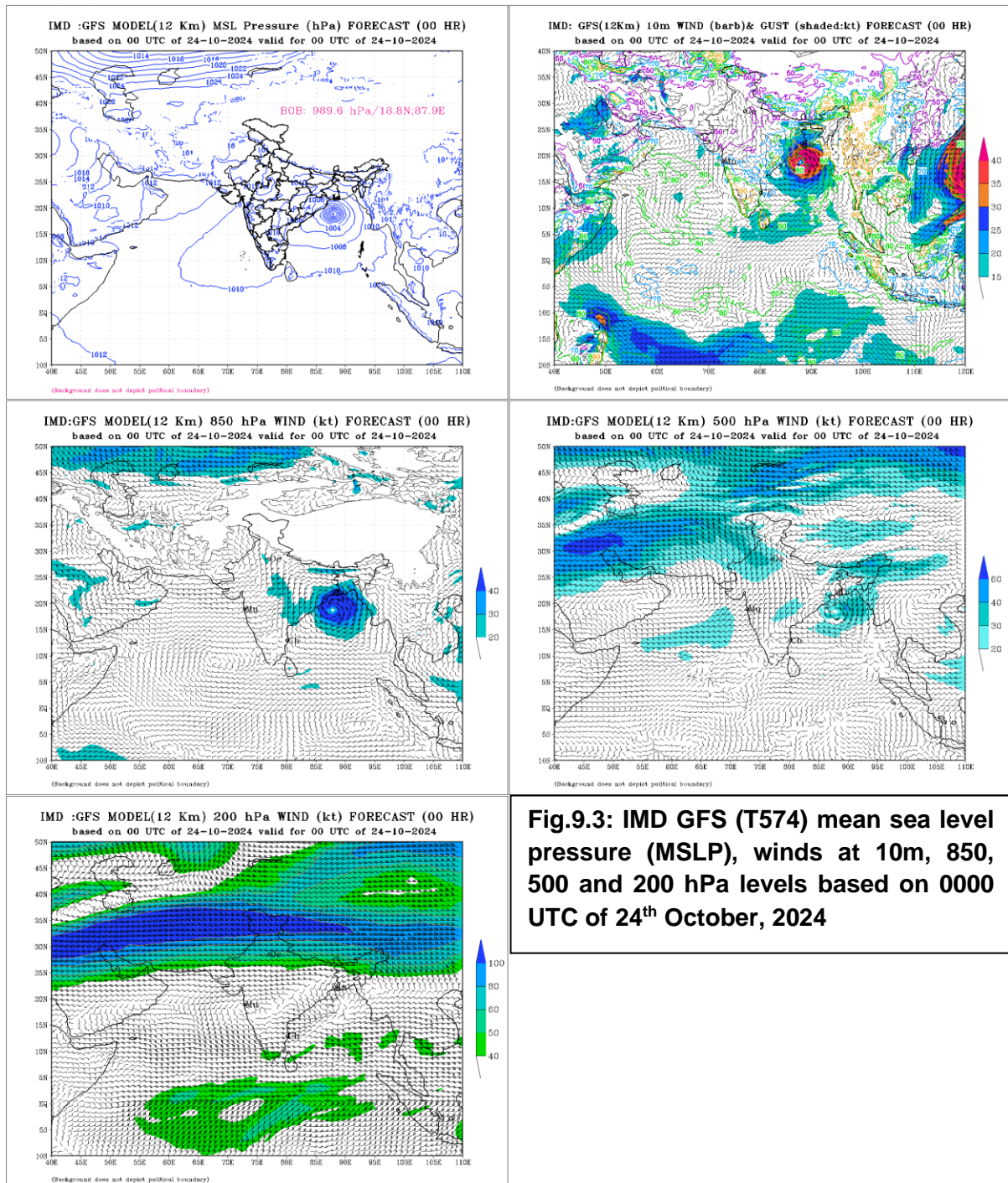
stage of depression. The associated cyclonic circulations were found to be extended from the surface up to 500 hPa pressure level. The upper-tropospheric winds at 200 hPa indicated southeasterly winds at the top of the system with a major poleward outflow. The isobaric analysis in the top MSL panel and in top panel of wind 10 m above the surface are clearly showing the location of the of cyclonic storm over eastcentral BoB at 0000 UTC of 23<sup>rd</sup> October 2024.



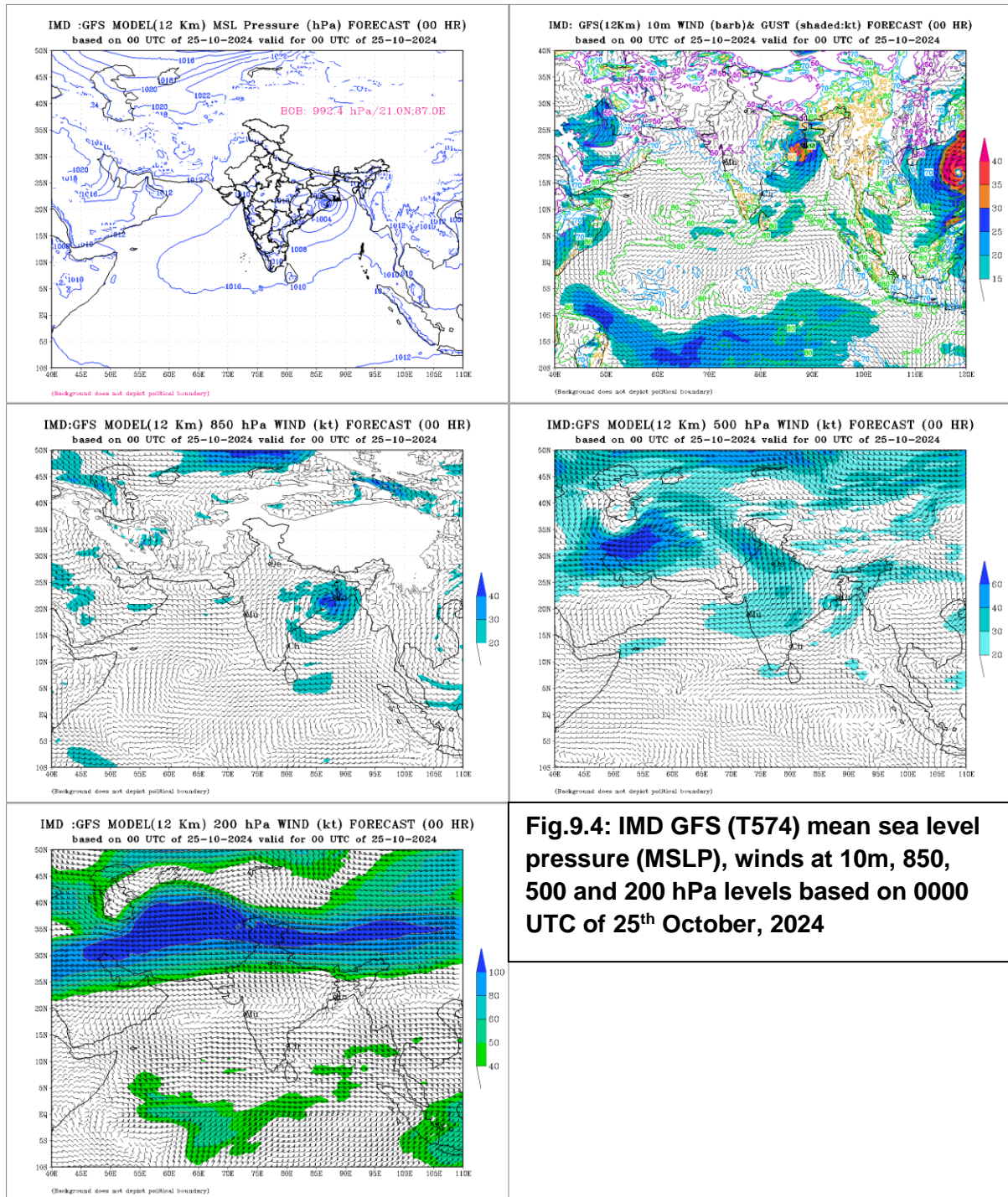


Comparing the Fig. 9.1 and 9.2 it is clear that the cyclonic storm moved west-northwestwards and intensified further into a cyclonic storm with more than 4 closed isobars and maximum sustained wind speed crossed 35 knots in the plot of 10 m wind. The associated cyclonic circulations in upper levels were also showing stronger winds with a circular structure vertically extending up to 500 hPa level. However, the radiuses of maximum winds at southeast and northeast sectors were larger than other sectors.

The environmental upper-tropospheric winds at 200 hPa pressure level were modulated by the outflow of the cyclonic storm mostly poleward at the top finally merging with the mid-latitude westerlies situating north of the system.



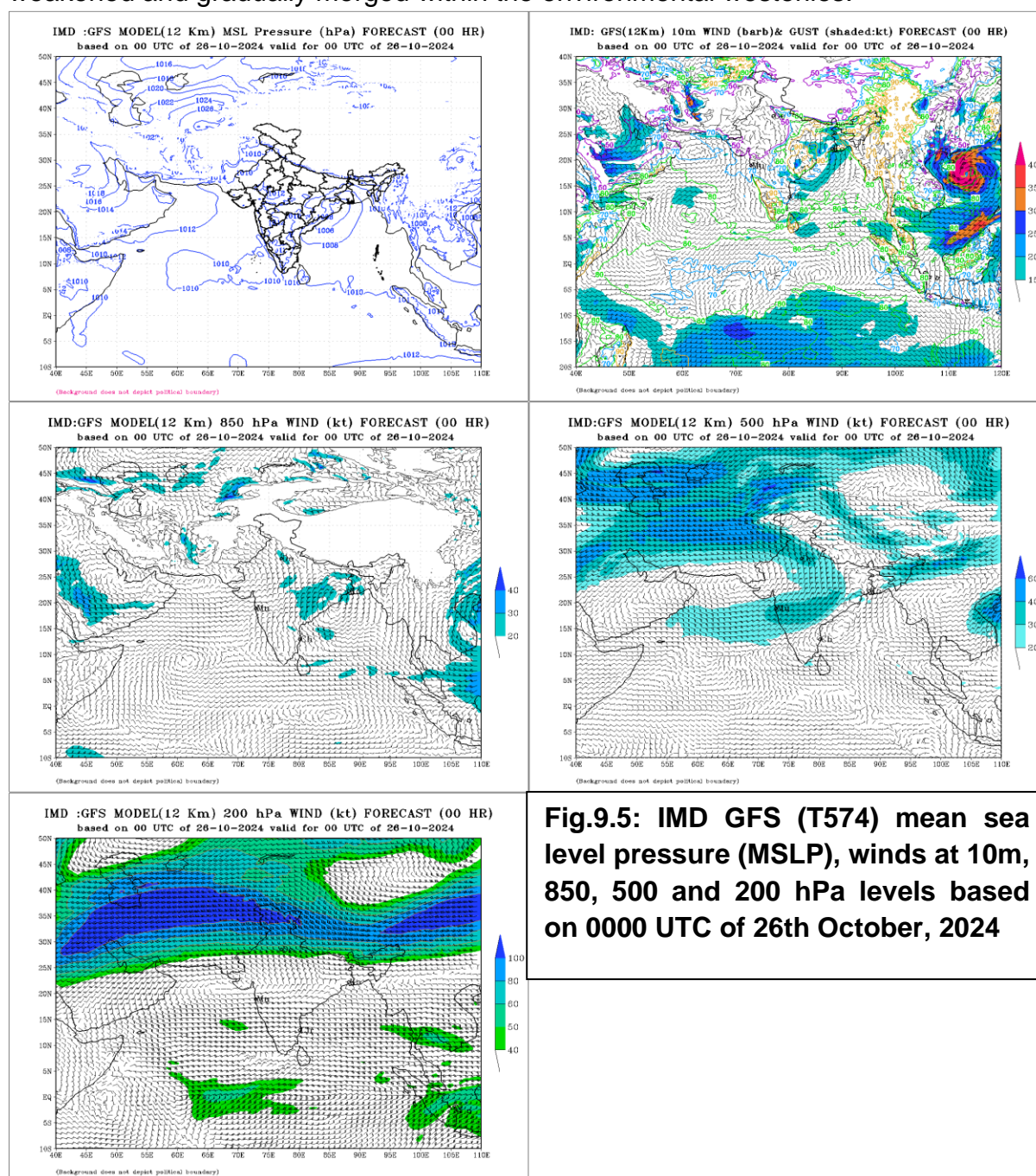




The model analyses at 0000 UTC of 24<sup>th</sup> October are shown in Fig. 9.3. The MSLP and 10 m wind are showing further movement of the system in west-northwest direction with the center of the storm located over northwest BoB. As the number of closed isobars increased and MSW at 10 m winds also crossed 40 knots in their respective plots, it clearly captured the intensity of the system to the stage of severe cyclonic storm. The horizontal wind distributions at 850 and 500 hPa pressure levels retained the asymmetry of the storm as it was found in the previous day with larger RMW at southeast and northeast sectors compared to others. The outflow at the top of the storm was influenced by the upper-tropospheric westerlies north of the system at 200 hPa pressure level.



The Fig. 9.4 shows the analyses of the model at 0000 UTC of 25<sup>th</sup> October, 2025 when the system was over the north coastal Odisha and adjoining areas. The isobaric analysis at the top-left panels indicated that the system maintained the intensity of cyclonic storm along with maximum values of 10 m wind speed above 35 knots in top-right plot. The associated cyclonic circulations at 850 and 500 hPa pressure levels were indicating that the system had vertical extension up to 500 hPa. The upper-tropospheric outflow at the top of the system was still visible although weakened and gradually merged within the environmental westerlies.



**Fig.9.5: IMD GFS (T574) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 26th October, 2024**

The model analyses at 0000 UTC of 26th October are shown in Fig. 9.5. The surface features represented by the MSLP and 10 m winds indicated the weakening of the system with westward movement over interior Odisha. It was visible as a low-

pressure area over the region. Associated cyclonic circulation was still evident at 850 hPa pressure level but at 500 hPa pressure level it was hardly noticeable. The extension of the system in the upper-troposphere disappeared as it was fully dominated by the westerly winds at 200 hPa pressure level.

## 6. Realized Weather

### 6.1. Realized rainfall

**Table 2: Realized rainfall of the Severe Cyclonic Storm “DANA” over Eastcentral Bay of Bengal during 22<sup>nd</sup> – 26<sup>th</sup> October, 2024**

Date/Base Time of observation	24 hr Heavy rainfall warning ending at 0300 UTC of next day	Realised 24-hour heavy rainfall ending at 0300 UTC of date
20.10.2023 / 0300 UTC	<p>❖ <b>Heavy rainfall</b> at isolated places is very likely over Odisha on 23rd &amp; <b>heavy to very heavy rainfall</b> at a few places and <b>extremely heavy rainfall</b> at isolated places on 24th &amp; 25th October.</p> <p>❖ <b>Heavy rainfall</b> at isolated places is very likely over <b>coastal districts of</b> West Bengal on 23rd and heavy to very heavy rainfall at a few places over Gangetic West Bengal on 24th &amp; 25th October.</p> <p>❖ <b>Heavy rainfall</b> at isolated places is very likely over North coastal Andhra Pradesh on 24th and 25th October.</p>	<p><b>23 October, 2024:</b></p> <p><b>Kerala &amp; Mahe:</b> Idamalayar Dam 12; Nooranad &amp; Mavelikara 9 each; Kalamassery 8, Kottarakkara; Thenmala, Kayamkulam &amp; Pampadumpara 7 each.</p> <p><b>Tamil Nadu:</b> Kelavarapalli Dam, Thuckalay 12 each; Kovilpatti 11; Krishnagiri, Sankarapuram &amp; Ambur 10 each; Bhavanisagar 9; Valparai, Vaniyambadi, Barur, Makkinampatti, Mambzhathuraiyaru, Hogenekal, Anaikedanku &amp; Thirparappu 7 each.</p>
21.10.2023/ 0300UTC	<p>❖ <b>Heavy rainfall</b> at isolated places is very likely over <b>Balasore, Bhadrak, Kendrapara, Jagatsingpur, Puri, Khorda, Ganjam, Gajapati</b>, districts of Odisha on 23rd Oct. &amp; <b>heavy to very heavy rainfall</b> at a few places and <b>extremely heavy rainfall</b> at isolated places over <b>Baleswar, Mayurbhanj, Bhadrak, Kendrapara, Jagatsingpur Kendujhar, Jajpur, Cuttack and Dhenkanal and Puri</b> districts of Odisha on 24th &amp; 25th October.</p> <p>❖ <b>Heavy rainfall</b> at isolated places is</p>	<p><b>24 October, 2024:</b></p> <p><b>Odisha:</b> Chandbali &amp; Rajkanika 16 each;</p>

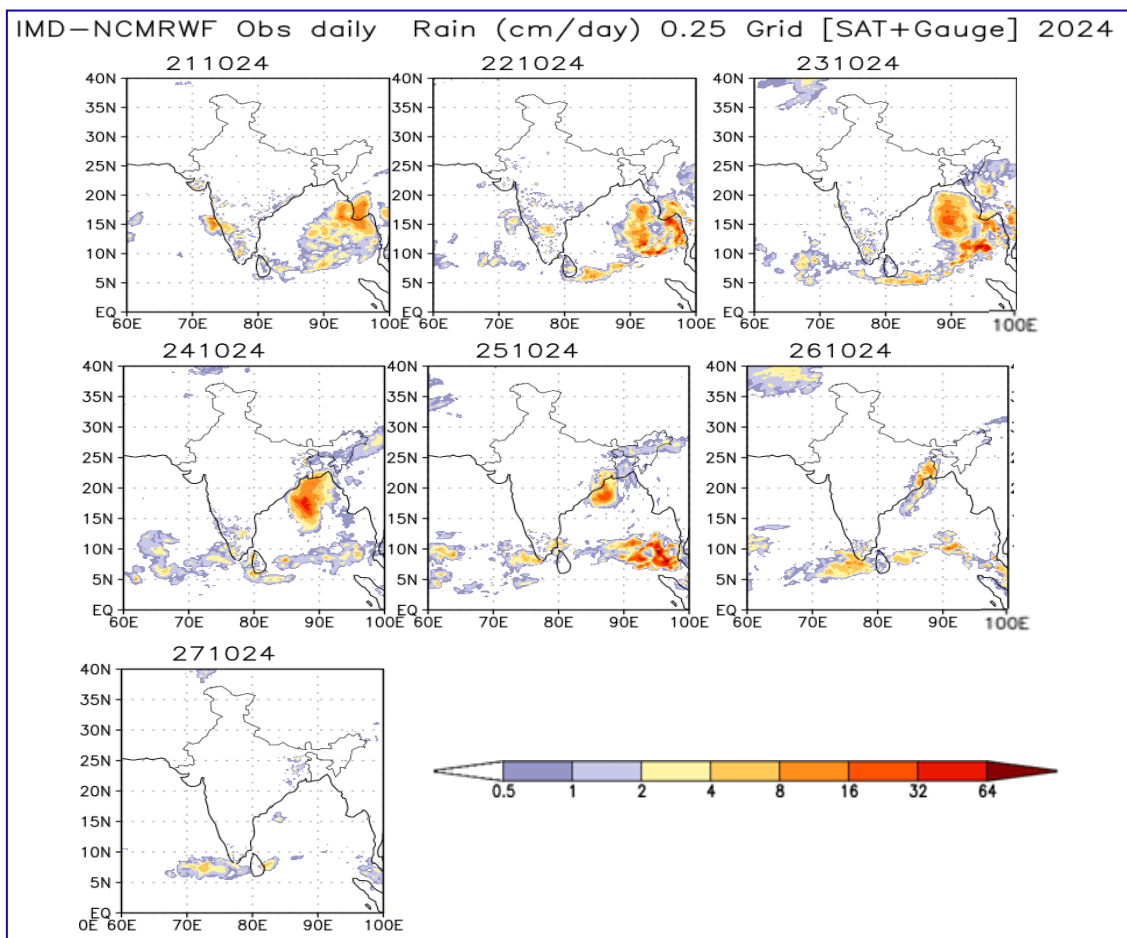
	<p>very likely on 23rd October and heavy to very heavy rainfall at a few places <b>with extremely heavy rainfall</b> at isolated places over <b>South &amp; North 24 Parganas, East &amp; West Medinipur, Howrah, Hooghly, Kolkata and Bankura</b> districts of Gangetic West Bengal on 24th &amp; 25th October.</p> <p>❖ <b>Heavy rainfall</b> at isolated places is very likely over <b>Srikakulam, Vizianagaram and Vishakhapatnam</b> districts of North coastal Andhra Pradesh on 24th and 25th October.</p>	<p>Nawana 14; Marsaghai, Basudevapur 11 &amp; Oupada 11 each; Rajnagar 10; Mohakalapada 9; Aul &amp; Paradeep 8 each; Derabis, Bhadrak, Balasore, Jaipur, Kendrapada, Nilgiri, Kendrapara &amp; Pattamundai 7 each</p> <p><b>Tamil Nadu, Puducherry &amp; Karaikal:</b> Anaimaduvu Dam 15; Orthanad 13; Kozhiporvilai, Mannargudi, Thuckalay, Neyyoor &amp; Aduthurai 11 each; Suthamalli Dam, Eraniel &amp; Kodavasal 10 each; Manjalaru &amp; Needamangalam 9 each; Madurai, Tiruvarur, Parangipettai, Nannilam, Mayiladuthurai, Kuruvadi, Idayapatti, Tirupuvanam &amp; Colachel 8 each; Kumbakonam, Tiruvaikar, Kurunthancode, Mayiladuthurai, Ariyalur, Ariyalur Taluk Office, Budalur, Vettikadu, Tiruvarur, Natham, Lower Anaicut, Natham, Thiruvaidaimaruthur &amp; Mylaudy 7 each;</p>
22.10.2023/ 0300UTC	<p>❖ <b>Heavy rainfall</b> at isolated places is very likely over <b>Balasore, Bhadrak, Kendrapara, Jagatsingpur, Puri and Khorda</b>, districts of Odisha on 23rd Oct. &amp; <b>heavy to very heavy rainfall</b> at a few places and <b>extremely heavy rainfall</b> at isolated places over <b>Baleswar, Mayurbhanj, Bhadrak, Kendrapara, Jagatsingpur Kendujhar, Jajpur, Cuttack and Dhenkanal, Khorda and Puri</b> districts of Odisha on 24th &amp; 25th October.</p> <p>❖ <b>Heavy rainfall</b> at isolated places is very likely on 23rd October and heavy to very heavy rainfall at a few places <b>with extremely heavy rainfall</b> at isolated places over <b>South &amp; North 24 Parganas, East &amp; West Medinipur, Jhargram, Howrah, Hooghly, Kolkata and Bankura</b> districts of Gangetic West Bengal on 24th &amp; 25th October.</p> <p>❖ <b>Heavy rainfall</b> at isolated places on 24th and <b>heavy to very heavy rainfall</b> at isolated places on 25th October.</p>	<p><b>Gangetic West Bengal:</b> Diamond Harbour, Kalaikunda &amp; Amfu</p>
23.10.2023/ 0300UTC	<p>❖ <b>Heavy rainfall</b> at isolated places is very likely over <b>Balasore, Bhadrak, Kendrapara, Jagatsingpur, Puri and Khorda</b>, districts of Odisha</p>	



	<p>commencing from evening of 23rd Oct. &amp; <b>heavy to very heavy rainfall</b> at a few places and <b>extremely heavy rainfall</b> at isolated places over <b>Baleswar, Mayurbhanj, Bhadrak, Kendrapara, Jagatsingpur Kendujhar, Jajpur, Cuttack and Dhenkanal, Khorda and Puri</b> districts of Odisha on 24th &amp; 25th October.</p> <p>❖ <b>Heavy rainfall</b> at isolated places is very likely on 23rd October and heavy to very heavy rainfall at a few places with <b>extremely heavy rainfall</b> at isolated places over <b>South &amp; North 24 Parganas, East &amp; West Medinipur, Jhargram, Howrah, Hooghly, Kolkata and Bankura</b> districts of Gangetic West Bengal on 24th &amp; 25th October.</p> <p>❖ <b>Heavy rainfall</b> at isolated places on 24th and <b>heavy to very heavy rainfall</b> at isolated places on 25th October.</p>	<p>Kharagpur 9 each; Durgachack 8; Mohanpur, Jhargram &amp; Uluberia 7 each;</p> <p><b>Kerala &amp; Mahe:</b> Mannarkkad (dist Palakkad) 7;</p> <p><b>Coastal Karnataka:</b> Dharmasthala &amp; Belthangadi 7 each;</p> <p><b>Jharkhand:</b> Gurabandha 7;</p> <p><b>25 October, 2024:</b> ❖ <b>Odisha:</b> Oupada 24; hamnagar 21, Khaira &amp; handaripokhari 21 each; lawana, Bonth 19 each; handbalit 17; Bhadrak 6; Rajkanika &amp; Bari 15 each; Jajpur, Udala, Nilgiri Tihidi 14 each; khuapada 13; Aul 12; injharpur &amp; Remuna 11 each; Kaptipada, Soro &amp; G Nagar 10 each; hasipura, Basudevpur, alasore, Gobindpur &amp; handanpur 9 each; etanati, Balimundali, usumi, Derabis, ahanga, Jaipur &amp; handikhol 8 each; atadihi, Samakhunta, nandpur, Nischintakoili, attamundai, Kendrapara Kendrapada 7 each.</p>
24.10.2023/ 0300UTC	<p>❖ <b>Heavy to very heavy rainfall</b> at a few places and <b>extremely heavy rainfall</b> at isolated places over <b>Baleswar, Mayurbhanj, Bhadrak, Kendrapara, Jagatsingpur Kendujhar, Jajpur, Cuttack and Dhenkanal, Khorda and Puri</b> districts of Odisha on 24th &amp; 25th October.</p> <p>❖ <b>Heavy to very heavy rainfall</b> at a few places with <b>extremely heavy rainfall</b> at isolated places over <b>South &amp; North 24 Parganas, East &amp; West Medinipur, Jhargram, Howrah, Hooghly, Kolkata and Bankura</b> districts of Gangetic West Bengal on 24th &amp; 25th October.</p> <p>❖ <b>Heavy rainfall</b> at isolated places on 24th and <b>heavy to very heavy rainfall</b> at isolated places on 25th October.</p>	<p>❖ <b>Gangetic West Bengal:</b> Barrackpur 17; Harinkhola 15; Alipore &amp; Durgachack 12 each;</p>
25.10.2023/ 0300UTC	<p>❖ <b>Heavy rainfall over to very heavy rainfall</b> at a few places over <b>Keonjhar, Mayurbhanj, Balasore, Bhadrak, Dhenkanal, Cuttack, Jajpur, Kendrapara, Angul, Nayagarh,</b></p>	

	<p><b>Khorda, Puri and Jagatsinghpur</b> districts of Odisha on 25th October. <b>Extremely heavy rainfall</b> at isolated places is very likely over <b>Keonjhar, Mayurbhanj, Balasore and Bhadrak</b> districts of Odisha on 25th October.</p> <p>❖ <b>Heavy to very heavy rainfall</b> at a few places <b>with extremely heavy rainfall</b> at isolated places over <b>East &amp; West Medinipur</b>, districts of Gangetic West Bengal on 25th October.</p> <p>❖ <b>Heavy to very heavy rainfall</b> at isolated places is likely over south Jharkhand on 25th October.</p>	<p>Diamond Harbour, Kalyani, Amtala, Uluberia, Midnapore, Mohanpur, Midnapore &amp; Panagarh 11 each; Burdwan, Kalaikunda, Dum Dum &amp; Saltlake 10 each; Mankar, Gheropara, Lalgah &amp; Manteswar 9 each; Debagram, Kharagpur, Canning &amp; Sri Niketan 8 each, Labpur, Bankura, Suri &amp; Mangalkote 7 each.</p> <p>❖ <b>Tamil Nadu, Puducherry &amp; Karaikal:</b> Namakkal &amp; Chittampatti 11 each; Colachel, Idayapatti &amp; Usilampatti 9 each; Sholavandan, Kuppanampatti &amp; Bhoothapandy 8each; Kallandri, Tallakulam, Uppar Dam, Dindigul, Nilakottai, Adayamada, Madurai city, Madurai North &amp; Periyapatti 7 each.</p> <p>❖ <b>Jharkhand:</b> Maheshpur 8, Pakuria 7;</p> <p>❖ <b>Kerala &amp; Mahe:</b> Kanjirapuzha &amp; Airport Chakka 7 each;</p>
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**Fig. 10: NCMRWF-IMD satellite gauge merged data plots of 24 hours accumulated realized rainfall ending at 0830 IST of 21<sup>st</sup> to 27<sup>th</sup> October, 2024**

24 hours accumulated realized rainfall based on NCMRWF-IMD satellite gauge merged data (Fig. 10) during the period from 21 to 27 October, 2024 indicated high rainfall over the coastal regions of Odisha and West Bengal recorded on 24<sup>th</sup>, 25<sup>th</sup> and 26<sup>th</sup> October associated with the system.

## 6.2. Realised wind

**Table 3: Realised wind of the Severe Cyclonic Storm “DANA” over Eastcentral Bay of Bengal during 22<sup>nd</sup> – 26<sup>th</sup> October, 2024**

Date/Base Time of observation	24 hr wind warning ending at 0300 UTC of next day	Realised 24-hour wind ending at 0300 UTC of date
20.10.2023 / 0300 UTC	<b>Andaman Sea:</b> Squally weather with wind speed reaching 35-45 gusting to 55 kmph is very likely over Andaman Sea till 21st October. <b>Eastcentral Bay of Bengal:</b>	❖ At the time of landfall, the estimated maximum

	<p>Squally wind speed reaching 40-50 gusting to 60 kmph is very likely on 21st October, 55-65 gusting to 75 kmph by 22nd evening, 70-90 kmph gusting to 100 kmph from 23rd evening till 24th morning.</p> <p><b>Adjoining areas of Westcentral Bay of Bengal:</b> Squally wind speed reaching 45-55 gusting to 65 kmph is very likely on 23rd and 24th Oct.</p> <p><b>North Bay of Bengal:</b> Squally wind speed reaching 40-50 gusting to 60 kmph is very likely to commence from 23rd morning. It would gradually increase becoming gale wind speed reaching 100-110 kmph gusting to 120 kmph from 24th Oct evening to 25th Oct morning and decrease thereafter.</p> <p><b>Along &amp; off Odisha-west Bengal coasts:</b> Squally wind speed reaching 40-50 gusting to 60 kmph is very likely to commence from 23rd Oct evening. It would gradually increase becoming gale wind speed reaching 100-110 kmph gusting to 120 kmph from 24th Oct night till 25th Oct morning.</p>	<p>sustained wind speed was about 100-110 kmph gusting to 120 kmph over Kendrapara and Bhadrak districts of Odisha.</p> <p>❖ Realised estimated wind distribution in the tropical cyclone field during its life cycle is presented in <b>Fig.11.</b></p>
21.10.2023/ 0300UTC	<p><b>Andaman Sea:</b> Squally weather with wind speed reaching 35-45 gusting to 55 kmph is very likely over Andaman Sea on 21st October.</p> <p><b>Eastcentral Bay of Bengal:</b> Squally wind speed reaching 35-45 gusting to 65 kmph is very likely on 21st October, 55-65 gusting to 75 kmph by 22nd evening, 70-90 kmph gusting to 100 kmph from 23rd evening till 24th morning.</p> <p><b>Adjoining areas of Westcentral Bay of Bengal:</b> Squally wind speed reaching 45-55 gusting to 65 kmph is very likely on 23rd and 24th Oct. <b>North Bay of Bengal:</b> Squally wind speed reaching 40-50 gusting to 60 kmph is very likely to commence from 23rd morning. It would gradually increase becoming gale wind speed reaching 100-110 kmph gusting to 120 kmph from 24th Oct evening to 25th Oct morning and decrease</p>	



	<p>thereafter.</p> <p><b>Along &amp; off Odisha-west Bengal coasts:</b> Squally wind speed reaching 40-50 gusting to 60 kmph is very likely to commence from 23rd Oct evening. It would gradually increase becoming gale wind speed reaching 100-110 kmph gusting to 120 kmph from 24th Oct night till 25th Oct morning.</p>	
22.10.2023/ 0300UTC	<p><b>Eastcentral Bay of Bengal:</b> Squally wind speed reaching 40-50 kmph gusting to 60 kmph is very likely on 22nd October, 50-60 kmph gusting to 70 kmph by 22nd night, 70-90 kmph gusting to 100 kmph from 23rd evening till 24th morning.</p> <p><b>Adjoining areas of Westcentral Bay of Bengal:</b> Squally wind speed reaching 40-50 kmph gusting to 60 kmph is very likely to commence from 22nd evening, 70-80 kmph gusting to 90 kmph from 23rd morning to 24th afternoon.</p> <p><b>Northwest Bay of Bengal:</b> Squally wind speed reaching 40-50 kmph gusting to 60 kmph is very likely to commence from 23rd morning. It would gradually increase becoming gale wind speed reaching 70-90 kmph gusting to 100 kmph from 23rd night to 24th morning and 100-110 kmph gusting to 120 kmph from 24th Oct evening to 25th Oct morning and decrease gradually thereafter.</p> <p><b>Adjoining areas of northeast Bay of Bengal:</b> Squally wind speed reaching 40-50 kmph gusting to 60 kmph is very likely to commence from 23rd night, becoming 50-60 kmph gusting to 70 kmph from 24th till 25th morning and decrease gradually thereafter.</p> <p><b>Along &amp; off Odisha-west Bengal coasts:</b> Squally wind speed reaching 40-50 gusting to 60 kmph is very likely to commence from 23rd Oct evening. It would gradually increase becoming gale wind speed reaching 60-70 kmph gusting to 80 kmph from 24th morning and reaching 100-110 kmph gusting to 120 kmph from 24th night till 25th Oct morning and decrease gradually thereafter.</p>	

23.10.2023/ 0300UTC	<p><b>Eastcentral Bay of Bengal:</b> Gale wind speed reaching 65-75 kmph gusting to 85 kmph is prevailing and likely to increase becoming 70-90 kmph gusting to 100 kmph from 23rd evening till 24th morning. It is likely to decrease thereafter.</p> <p><b>Adjoining areas of Westcentral Bay of Bengal:</b> Gale wind speed reaching 60-70 kmph gusting to 80 kmph is prevailing. It is likely to increase gradually becoming 80-90 kmph gusting to 100 kmph from 23rd afternoon and 90-100 kmph gusting to 110 kmph from 24th morning till 24th afternoon. It is likely to decrease thereafter. <b>Northwest Bay of Bengal:</b> Squally wind speed reaching 40-50 kmph gusting to 60 kmph is prevailing. It is very likely to increase gradually becoming Gale wind speed reaching 70-90 kmph gusting to 100 kmph from 23rd evening till 24th night and thereafter 100-110 kmph gusting to 120 kmph till 25th Oct morning. It is likely to decrease gradually thereafter.</p> <p><b>Adjoining areas of northeast Bay of Bengal:</b> Squally wind speed reaching 40-50 kmph gusting to 60 kmph is very likely to commence from 23rd night, becoming 50-60 kmph gusting to 70 kmph from 24th till 25th morning and decrease gradually thereafter.</p> <p><b>Along &amp; off Odisha-west Bengal coasts:</b> Squally wind speed reaching 40-50 gusting to 60 kmph is very likely to commence from 23rd Oct evening. It would gradually increase becoming gale wind speed reaching 60-70 kmph gusting to 80 kmph from 24th morning and 100-110 kmph gusting to 120 kmph along &amp; off north Odisha and east Medinipur district of West Bengal; Gale wind speed reaching 60-80 kmph gusting to 90 kmph is likely along &amp; off south Odisha and remaining districts of coastal West Bengal from 24th night till 25th Oct morning and decrease gradually thereafter. <b>South Jharkhand:</b> Squally wind speed reaching 40-50 kmph gusting to 60 kmph would prevail during 25th morning to 26th evening.</p>	



24.10.2023/ 0300UTC	<p><b>Northwest Bay of Bengal:</b> Gale wind speed reaching 95-105 kmph gusting to 115 kmph is prevailing. It is likely to increase gradually becoming 105-115 kmph gusting to 125 kmph from 24th Oct evening.</p> <p><b>Adjoining areas of central Bay of Bengal:</b> Gale wind speed reaching 95-105 kmph gusting to 115 kmph is prevailing and likely to continue till 24th Oct afternoon. It is likely to decrease gradually thereafter.</p> <p><b>Along &amp; off Odisha-west Bengal coasts:</b> Gale wind speed reaching 60-70 kmph gusting to 80 kmph is prevailing. It would gradually increase becoming 100-110 kmph gusting to 120 kmph along &amp; off north Odisha and east Medinipur district of West Bengal from 24th afternoon till morning of 25th October and decrease gradually thereafter. Gale wind speed reaching 60-80 kmph gusting to 90 kmph is likely along &amp; off south Odisha and remaining districts of coastal West Bengal from 24th evening till 25th Oct morning and decrease gradually thereafter.</p> <p><b>Adjoining areas of northeast Bay of Bengal:</b> Squally wind speed reaching 50-60 kmph gusting to 70 kmph is likely to prevail till 25th morning and decrease gradually thereafter. <b>South Jharkhand:</b> Squally wind speed reaching 40-50 gusting to 60 kmph is very likely to prevail from morning of 25th till evening of 26th October.</p>	
25.10.2023/ 0300UTC	<p><b>Northwest Bay of Bengal:</b> Gale wind speed reaching 65-75 gusting to 85 kmph is prevailing and would gradually decrease becoming squally wind speed reaching 50-60 kmph gusting to 70 kmph from evening of 25th October 2024.</p> <p><b>Along &amp; off Odisha-west Bengal coasts and adjoining interior districts:</b> Gale wind speed reaching 60-70 kmph gusting to 80 kmph would prevail over Balasore, Mayurbhanj, Keonjhar, Bhadrak, Kendrapara districts of Odisha and East Mednipur district of West Bengal till evening of 25th October 2024 and decrease thereafter. Squally wind speed reaching 40-60 kmph gusting to 70 kmph</p>	

	<p>would prevail over Jagatsinghpur, Cuttack, Dhenkanal, Angul &amp; adjoining areas of Sundargarh &amp; Khorda districts of Odisha and south 24 Paraganas, West Mednipur &amp; Jhargram districts of West Bengal till evening of 25 th October and decrease thereafter.</p> <p><b>South Jharkhand:</b> Squally wind speed reaching 40-50 gusting to 60 kmph is very likely to prevail from afternoon of 25th till evening of 26th October.</p>	
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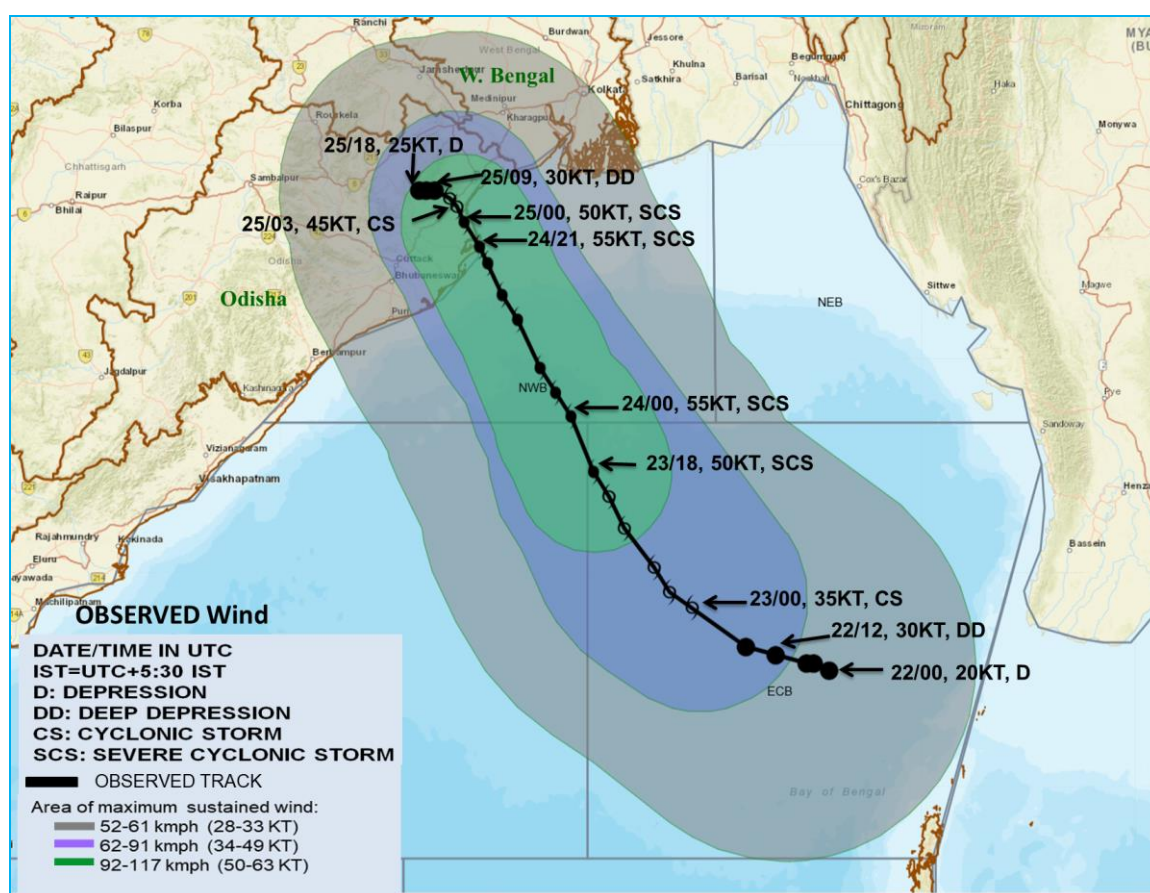


Fig. 11: Estimated maximum sustained wind during the life cycle of SCS DANA

### 6.3. Realised storm surge

Table 4: Realised Storm Surge of the Severe Cyclonic Storm “DANA” over Eastcentral Bay of Bengal during 22<sup>nd</sup> – 26<sup>th</sup> October, 2024

Date/Base Time of observation	24 hr storm surge warning ending at 0300 UTC of next day	Realised 24-hour storm surge ending at 0300 UTC of date
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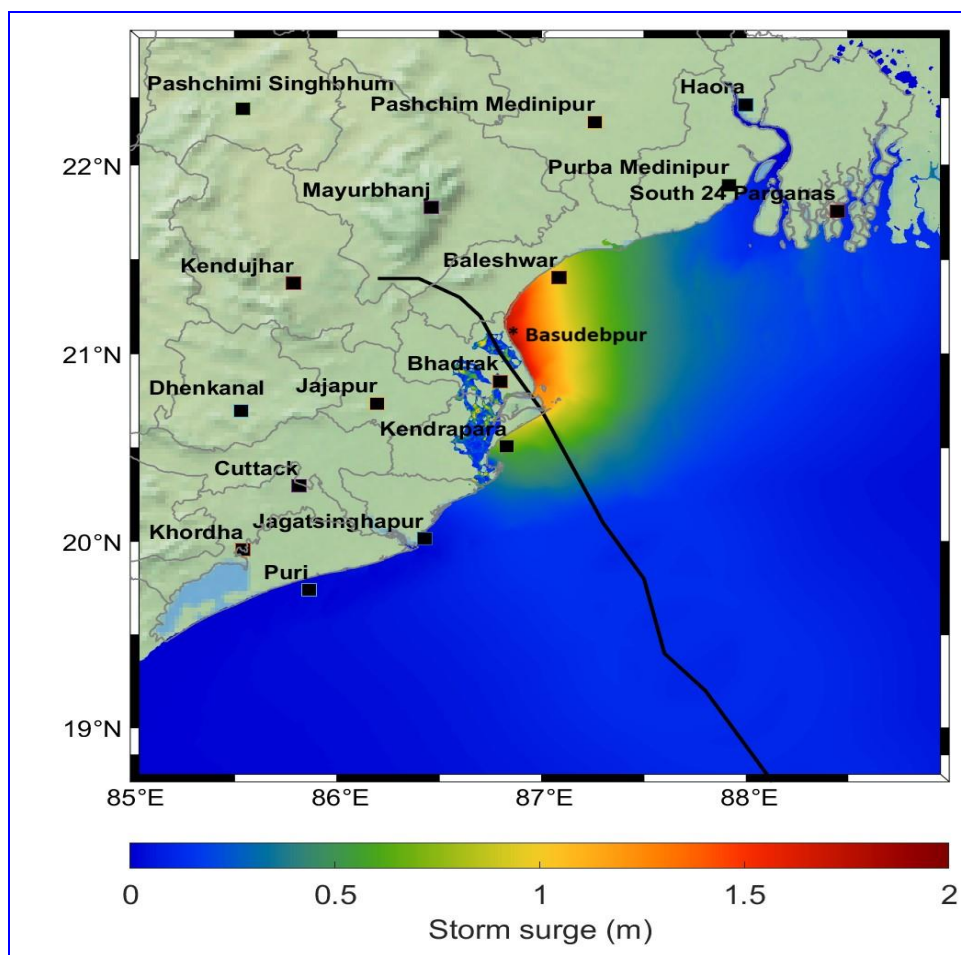
20.10.2023 / 0300 UTC	<p><b>Andaman Sea:</b> Sea condition is likely to be Moderate to Rough till 21st October.</p> <p><b>Eastcentral Bay of Bengal:</b> Sea condition is likely to become Rough to Very Rough from 21st Oct morning to 22nd October evening, becoming very rough to high thereafter till 24th Oct morning.</p> <p><b>Adjoining areas of Westcentral Bay of Bengal:</b> Sea condition is likely to be Rough to Very Rough on 23rd and 24th Oct.</p> <p><b>North Bay of Bengal:</b> Sea condition is likely to be Rough to Very Rough from 23rd morning and would become High from 24th Oct morning till 25th Oct forenoon.</p> <p><b>Along &amp; off Odisha-west Bengal coasts:</b> Sea condition is likely to be Rough to Very Rough from 23rd evening and would become High from 24th Oct evening to 25th Oct forenoon.</p>	<p>❖ Maximum estimated storm surge of height of 1-2 m inundated low-lying areas of Kendrapara, Bhadrak and Balasore districts of Odisha during landfall.</p> <p>❖ Realised estimated storm surge is presented in <b>Fig. 12.</b></p>
21.10.2023/ 0300UTC	<p><b>Andaman Sea:</b> Sea condition is likely to be Moderate to Rough on 21st October.</p> <p><b>Eastcentral Bay of Bengal:</b> Sea condition is likely to become Rough to Very Rough from 21st October morning to 22nd October evening, becoming very rough to high thereafter till 24th October morning.</p> <p><b>Adjoining areas of Westcentral Bay of Bengal:</b> Sea condition is likely to be Rough to Very Rough on 23rd and 24th October.</p> <p><b>North Bay of Bengal:</b> Sea condition is likely to be Rough to Very Rough from 23rd morning and would become High from 24th October morning till 25th Oct forenoon.</p> <p><b>Along &amp; off Odisha-west Bengal coasts:</b> Sea condition is likely to be Rough to Very Rough from 23rd evening and would become High from 24th October evening to 25th Oct forenoon</p>	
22.10.2023/	<p><b>Eastcentral Bay of Bengal:</b> Sea condition is likely to be Rough to Very Rough on</p>	

0300UTC	<p>22nd October, becoming very rough to high from 23rd morning till 24th October morning.</p> <p><b>Adjoining areas of Westcentral Bay of Bengal:</b> Sea condition is likely to be Rough to Very Rough on 23rd and very rough to high on 24th October.</p> <p><b>Northwest Bay of Bengal:</b> Sea condition is likely to be Rough to Very Rough from 23rd morning and would become High to Very High from 23rd night till 25 th morning and improve gradually thereafter.</p> <p><b>Adjoining areas of northeast Bay of Bengal:</b> Sea condition is likely to be Rough to Very Rough from 23rd night till 25th morning and improve gradually thereafter.</p> <p><b>Along &amp; off Odisha-west Bengal coasts:</b> Sea condition is likely to be Rough to Very Rough from 23rd evening and would become High to Very High from 24th October morning to 25th Oct forenoon and improve gradually thereafter.</p>	
23.10.2023/ 0300UTC	<p>Storm surge of 1.0 to 2.0 m height above astronomical tide is very likely to inundate low lying areas of Kendrapara, Bhadrak &amp; Balasore districts of Odisha and East Medinipur districts of West Bengal during the time of landfall. Storm surge of 0.5 to 1.0 m height above astronomical tide is very likely to inundate low lying areas of South 24-Parganas district of West Bengal and Jagatsingpur district of Odisha during the time of landfall.</p> <p><b>Eastcentral Bay of Bengal:</b> Sea condition is likely to be high till 24th October evening and improve gradually thereafter.</p> <p><b>Adjoining areas of Westcentral Bay of Bengal:</b> Sea condition is likely to be very Rough to high on 23rd and high till 24th October evening. It is likely to improve gradually thereafter.</p> <p><b>Northwest Bay of Bengal:</b> Sea condition is likely to be Very Rough till 23rd evening and would become High to Very High from 23rd night till 25th morning and improve gradually thereafter.</p>	



	<p><b>Adjoining areas of northeast Bay of Bengal:</b> Sea condition is likely to be Rough to Very Rough from 23rd night till 25th morning and improve gradually thereafter.</p> <p><b>Along &amp; off Odisha-west Bengal coasts:</b> Sea condition is likely to be Rough to Very Rough from 23rd evening and would become High to Very High from 24th October morning to 25th Oct forenoon and improve gradually thereafter</p>	
24.10.2023/ 0300UTC	<p>Storm surge of 1.0 to 2.0 m height above astronomical tide is very likely to inundate low lying areas of Kendrapara, Bhadrak &amp; Balasore districts of Odisha and East Medinipur districts of West Bengal during the time of landfall. Storm surge of 0.5 to 1.0 m height above astronomical tide is very likely to inundate low lying areas of South 24-Parganas district of West Bengal and Jagatsinghpur district of Odisha during the time of landfall.</p> <p><b>Northwest Bay of Bengal:</b> Sea condition is likely to be Very High till 25 th morning and improve gradually thereafter.</p> <p><b>Adjoining areas of central Bay of Bengal:</b> Sea condition is likely to be very high to high till 24th October evening. It is likely to improve gradually thereafter. <b>Adjoining areas of northeast Bay of Bengal:</b> Sea condition is likely to be Rough to Very Rough till 25th morning and improve gradually thereafter.</p> <p><b>Along &amp; off Odisha-west Bengal coasts:</b> High to Very High till 25th Oct forenoon and improve gradually thereafter.</p>	
25.10.2023/ 0300UTC	<p>Storm surge of upto 1.0 m height above astronomical tide is very likely to inundate low lying areas of Bhadrak &amp; Balasore districts of Odisha and East Medinipur districts of West Bengal during next 3 hours. Storm surge of upto 0.5 m height above astronomical tide is very likely to inundate low lying areas of South 24-Parganas district of West Bengal during next 3 hours.</p>	

	Northwest Bay of Bengal and along & off Odisha-west Bengal coasts: Sea condition is likely to be High to Very rough till 25 th evening and improve gradually thereafter.	
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**Fig.12: Estimated storm surge based on best track parameters of SCS DANA**

## 7 Damage report:

As per media reports, no death was reported from Odisha due to cyclone. One died in West Bengal due to electrocution. In Bangladesh, 1 person died due to falling of tree and another due to drowning in a lake. About 5,800 homes were damaged due to Cyclone Dana, eight lakh people were evacuated to 6,210 cyclone relief centres in Odisha. A total of 35.95 lakh people in Odisha were impacted by cyclone Dana and subsequent flooding in 14 districts. The worst-hit districts were Kendrapara, Balasore and Bhadrak (PTI, 17 October).



## 8 Performance of operational NWP models

Various global models and dynamical-statistical models run by Ministry of Earth Sciences (MoES) institutions including IMD, NCMRWF, IITM & INCOIS and guidance from models from various international agencies under bilateral arrangement. IMD operationally runs Global and regional models short-range (3-days) to medium-range (10 days) prediction of tropical cyclones over North Indian Ocean region. The IMD Global Forecast System (IMD-GFS-T1534L64) at the resolution of 12 km with 6 hourly assimilation cycle with Global Data Assimilation System (GDAS) was utilized for medium range prediction (10 days). The WRF-VAR model was run at the horizontal resolution of 3 km to produce forecasts for 3 days over a domain covering the area of responsibility for RSMC, New Delhi. Initial and boundary conditions were obtained from the IMD Global Forecast System (IMD-GFS). The boundary conditions are updated at every six hours interval. The cyclone specific triple-nested (18x6x2 km) coupled Hurricane Weather Research Forecast (HWRF) model were utilized to predict the genesis, track, landfall and intensity of the cyclone as well as associated severe weather. Global model is also run at NCMRWF. This unified model (NCUM) is adapted from UK Meteorological Office.

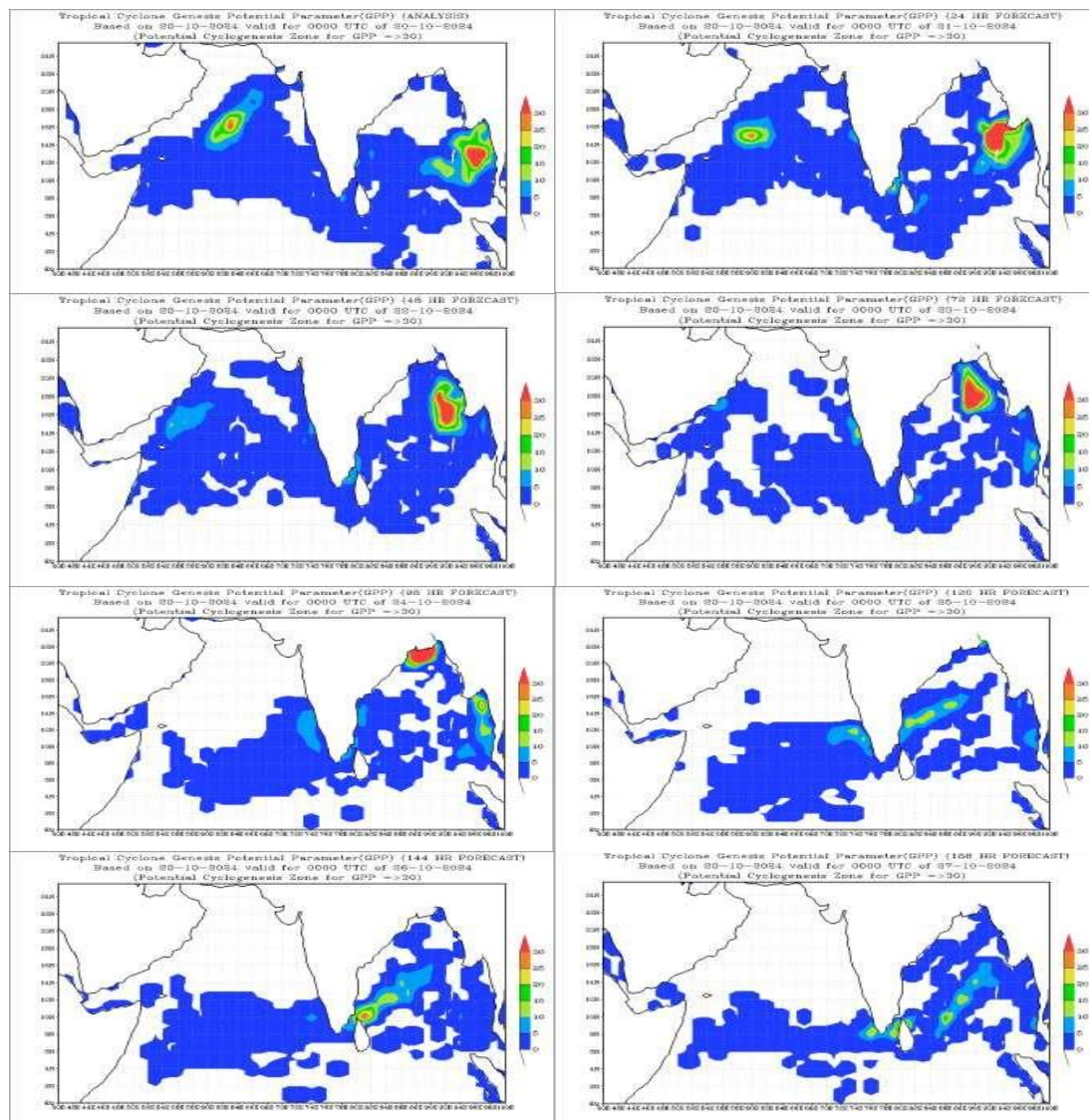
In addition to the above deterministic NWP models, there were two different ensemble prediction systems i.e. Global Ensemble Forecast System based on IMD-GFS model and NCMRWF Ensemble Prediction System (NEPS). Both EPSs run with 12 km horizontal resolution to produce forecast for 10 days daily based on initial condition at 0000 UTC. IMD also run operationally dynamical statistical models. The dynamical statistical models have been developed for (a) Cyclone Genesis Potential Parameter (GPP), (b) Multi-Model Ensemble (MME) technique for cyclone track prediction, (c) Cyclone intensity prediction, (d) Rapid intensification and (e) Predicting decay in intensity after the landfall. Genesis Potential Parameter (GPP) is used for predicting potential of cyclogenesis (T3.0) and forecast for potential cyclogenesis zone. Two different multi-model ensemble (MME) prediction systems are operational in IMD to generate track and intensity forecasts (at 12h interval up to 120h) of tropical cyclones for the Indian Seas. The MME systems are developed applying simple statistical methods such as multiple linear regression technique using available global forecasts from member models e.g. IMD-GFS, IMD-WRF, GFS (NCEP), NCUM, 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 Severe cyclone Dana are presented and discussed.

The forecasts were mainly based on multi-model ensemble technique developed by IMD. which was further value added to arrive at consensus forecast by considering various prognostic & diagnostic features, observational features, initial conditions and consistency of individual models etc. A digitized forecasting system of IMD was utilized for analysis and comparison of various observations and numerical weather

prediction models guidance, decision making process and warning products generation.

## 8.1 Prediction of Cyclogenesis (Genesis Potential Parameter (GPP) for DANA

Grid point analysis and forecast of GPP is used to identify potential zone of cyclogenesis. **Fig 13** below shows the predicted zone of cyclogenesis.

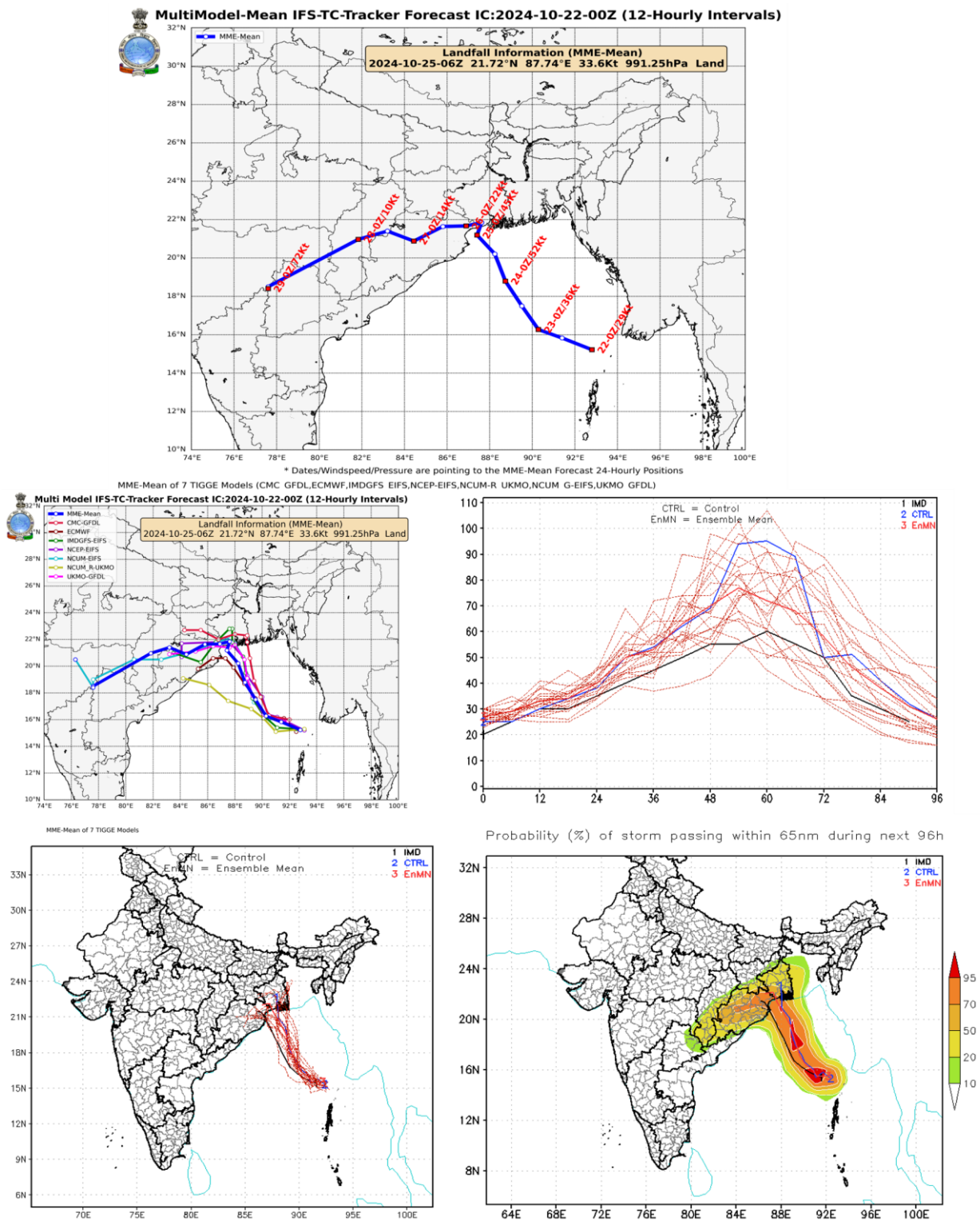


**Fig.13: Predicted zone of Cyclogenesis based on 0000 UTC of 20th October, 2024**

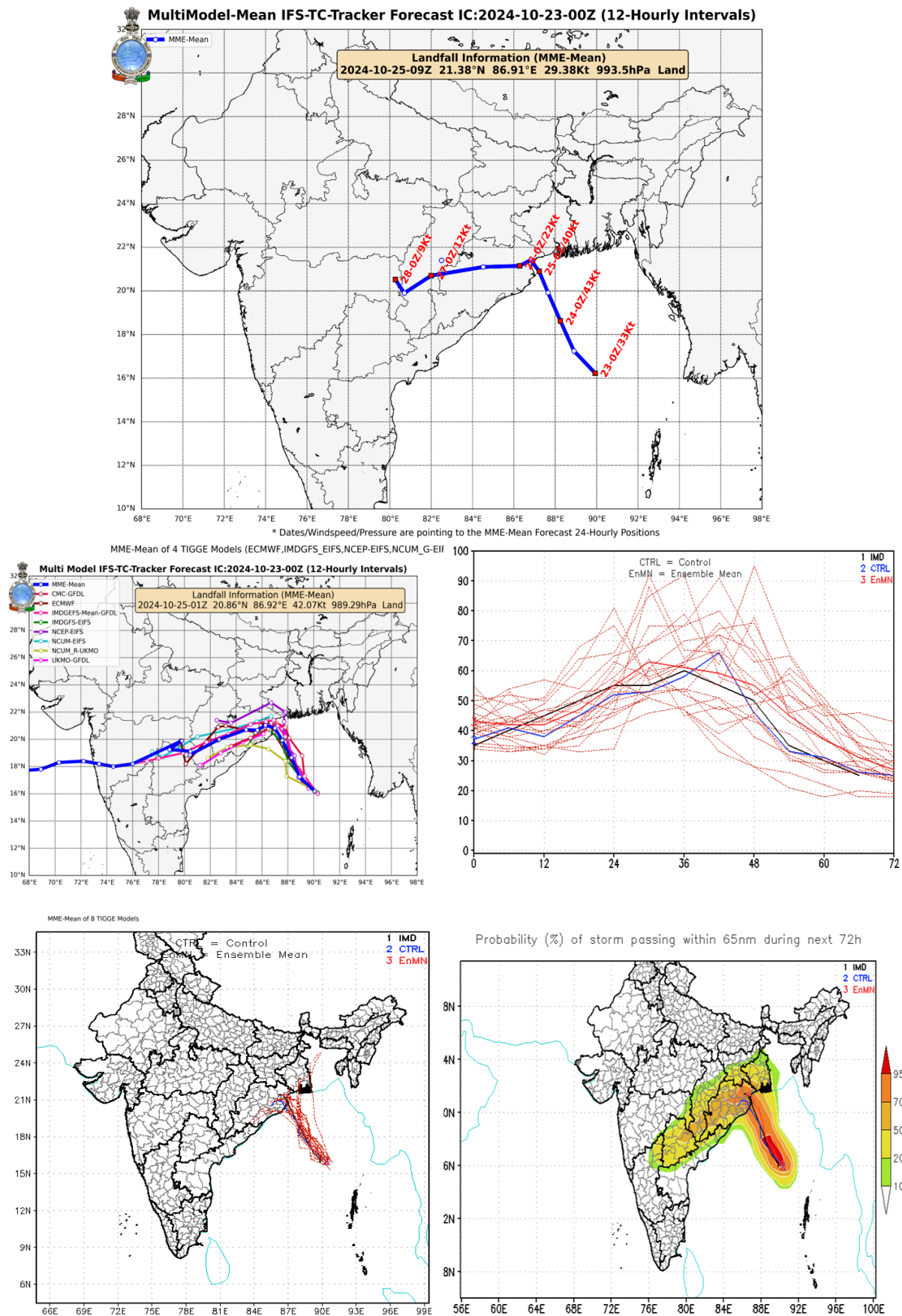
## 8.2 Track and intensity prediction by NWP models

The fig 14.1 to 14.3 are representing track and intensity predictions by different NWP models.

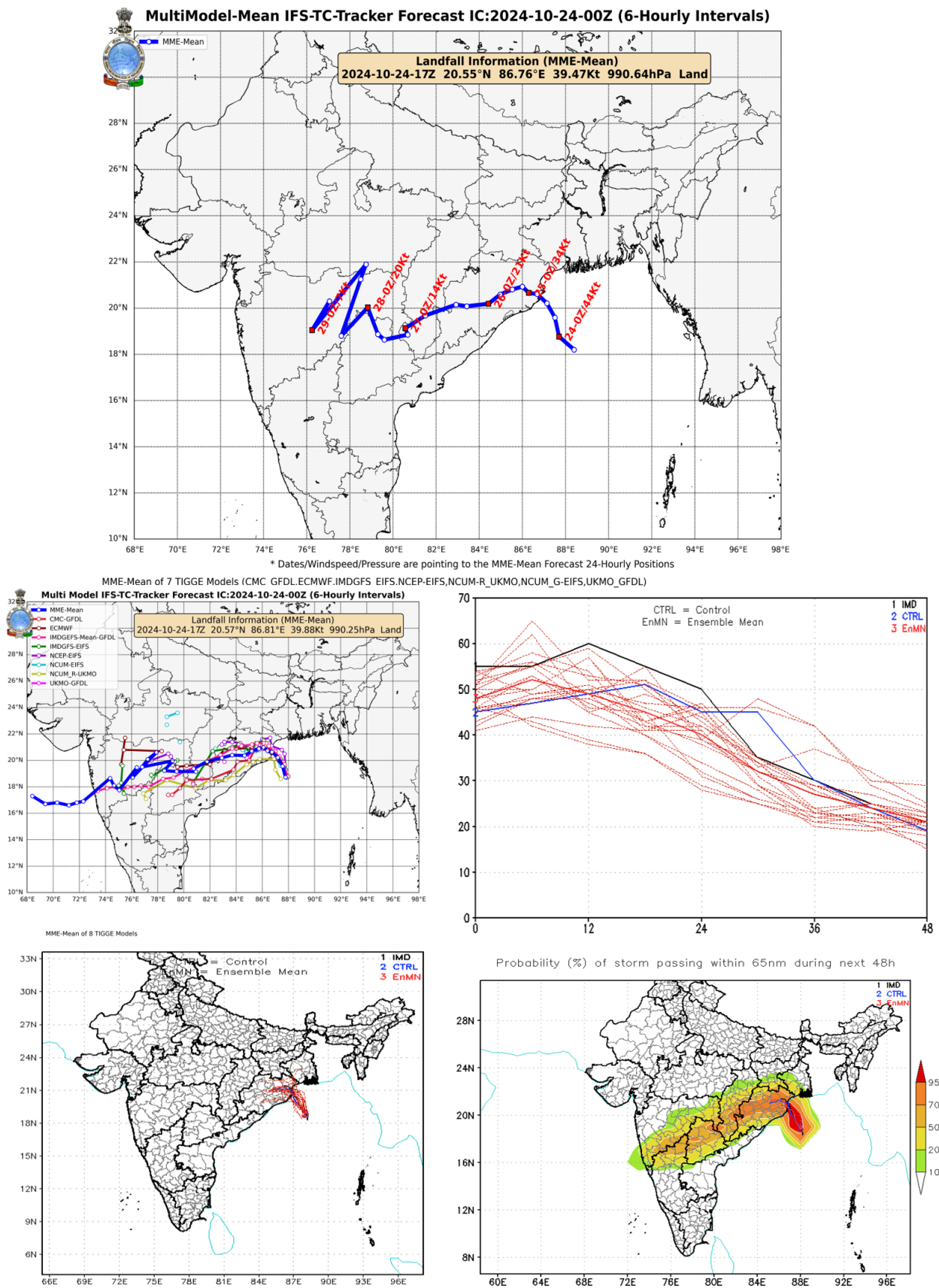




**Fig. 14.1: NWP model track forecast based on 0000 UTC of 22.10.2024**



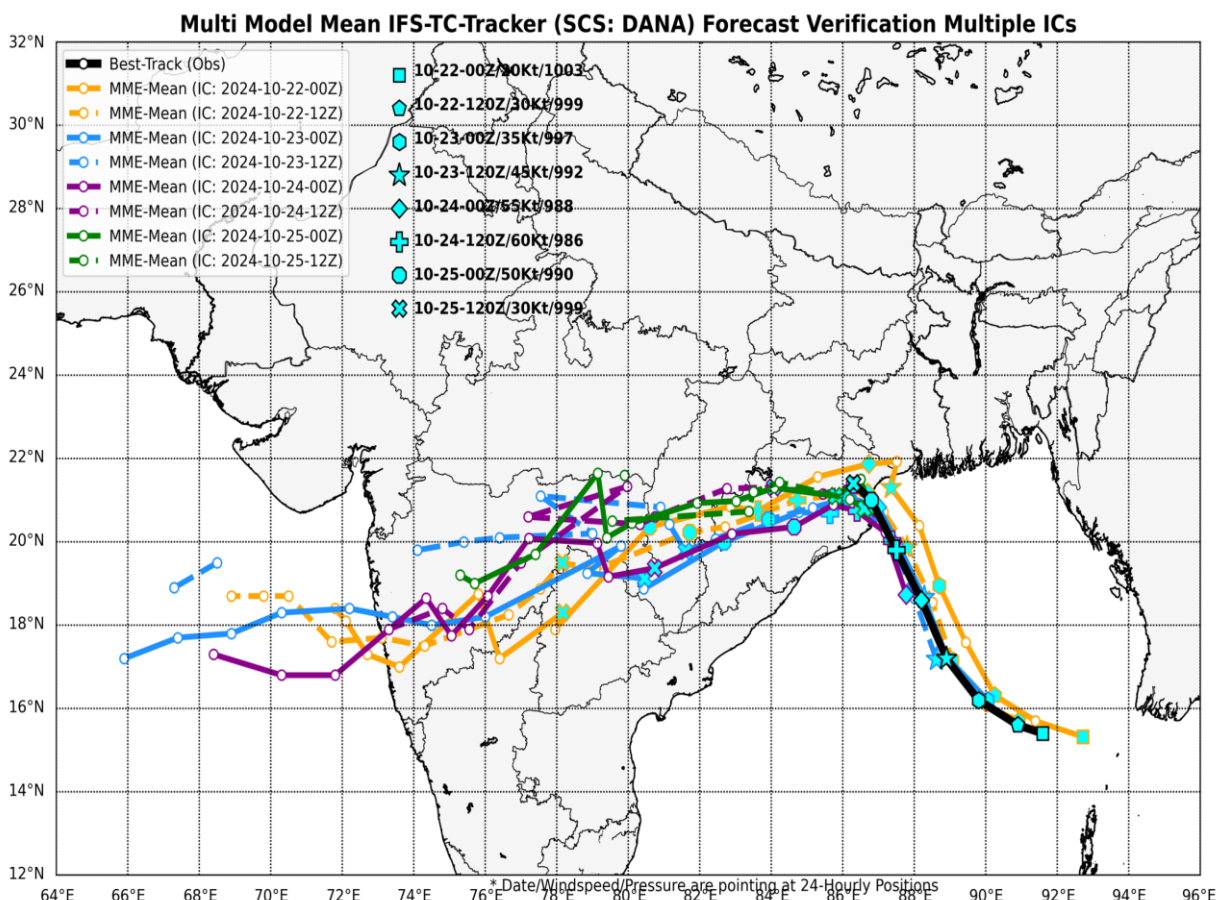
**Fig. 14.2: NWP model track forecast based on 0000 UTC of 23.10.2024**



**Fig. 14.3: NWP model track forecast based on 0000 UTC of 24.10.2024**



The Fig. 14 displayed the track & intensity forecasts from all models. In general, all of them indicated initial northwestwards movement till 0000 UTC of 23<sup>rd</sup> October then nearly north-northwestward movement till 0000 UTC of 25<sup>th</sup> October and further west-northwestwards movement after landfall. The mean track of GEFS also showed similar track. In general MME mean track was very much close to the best track as it was very close to north Odisha. The verification of MME mean track with respect to the Best Track is presented in **Fig.15**.



**Fig. 15: Verification of MME mean track with respect to the Best Track**

### 8.3 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 5.1**. From the verification of the forecast guidance available from various NWP models, it is found that the average track forecast errors of ECMWF model were minimum for 24 and 48 hr and 72 hours forecast followed by MME.

**Table 5.1. Average track forecast errors (Direct Position Error (DPE)) in km  
(Number of forecasts verified is given in the parentheses)**

Lead Time	12Hr	24Hr	36Hr	48Hr	60Hr	72Hr	84Hr
<b>HWRF</b>	<b>32</b>	<b>40</b>	<b>51</b>	<b>55</b>	<b>118</b>		
<b>GEFS (CNTL)</b>	<b>22(7)</b>	<b>49(6)</b>	<b>83(5)</b>	<b>97(4)</b>	<b>109(3)</b>	<b>192(2)</b>	<b>249(1)</b>
<b>GEFS (ENS_MEAN)</b>	<b>30(7)</b>	<b>40(6)</b>	<b>62(5)</b>	<b>94(4)</b>	<b>100(3)</b>	<b>128(2)</b>	<b>134(1)</b>
<b>NCUM_R- UKMO</b>	<b>73.31 (7)</b>	<b>83.33 (6)</b>	<b>158.63 (5)</b>	<b>196.63 (4)</b>	<b>282.84 (3)</b>	<b>396.0 (2)</b>	<b>nan (0)</b>
<b>NCEP-GFDL</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>
<b>ECMWF-EIFS</b>	<b>51.13 (6)</b>	<b>58.43 (6)</b>	<b>89.26 (5)</b>	<b>98.98 (4)</b>	<b>63.49 (3)</b>	<b>36.25 (2)</b>	<b>63.71 (1)</b>
<b>IMDGFS- EIFS</b>	<b>19.45 (7)</b>	<b>35.52 (6)</b>	<b>63.29 (5)</b>	<b>103.08 (4)</b>	<b>122.93 (3)</b>	<b>175.18 (2)</b>	<b>219.34 (1)</b>
<b>IMDGFS- GFDL</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>
<b>IMDGEFS_m ean_GFDL</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>
<b>NCEP-EIFS</b>	<b>31.67 (7)</b>	<b>40.65 (6)</b>	<b>53.21 (5)</b>	<b>80.7 (4)</b>	<b>134.45 (3)</b>	<b>136.43 (2)</b>	<b>131.78 (1)</b>
<b>NCUM_G- EIFS</b>	<b>50.32 (6)</b>	<b>47.21 (6)</b>	<b>60.01 (5)</b>	<b>66.78 (4)</b>	<b>94.83 (3)</b>	<b>112.58 (2)</b>	<b>164.2 (1)</b>
<b>NCUM_G- UKMO</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>
<b>IMDOPER</b>	<b>27.19 (7)</b>	<b>38.45 (6)</b>	<b>34.45 (5)</b>	<b>21.3 (4)</b>	<b>18.95 (3)</b>	<b>16.49 (2)</b>	<b>52.93 (1)</b>
<b>MMEM</b>	<b>29.48 (7)</b>	<b>26.02 (6)</b>	<b>46.07 (5)</b>	<b>42.45 (4)</b>	<b>60.33 (3)</b>	<b>57.1 (2)</b>	<b>138.23 (1)</b>
<b>HWRF-GFDL</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>
<b>UKMO_GFDL</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>
<b>CMC_GFDL</b>	<b>49.96 (6)</b>	<b>61.13 (6)</b>	<b>82.79 (5)</b>	<b>117.61 (4)</b>	<b>137.28 (3)</b>	<b>203.3 (2)</b>	<b>272.98 (1)</b>

**Table 5.2. Average Intensity Forecast Errors of maximum sustained wind in knots  
(Number of forecasts verified is given in the parentheses).**

<b>Lead Time</b>	<b>12Hr</b>	<b>24Hr</b>	<b>36Hr</b>	<b>48Hr</b>	<b>60Hr</b>	<b>72Hr</b>	<b>84Hr</b>
<b>HWRF</b>	<b>9</b>	<b>8</b>	<b>6</b>	<b>14</b>	<b>12</b>		
<b>CTRL</b>	<b>-7(7)</b>	<b>-2(6)</b>	<b>1(5)</b>	<b>8(4)</b>	<b>9(3)</b>	<b>-2(2)</b>	<b>11(1)</b>
<b>EnMN</b>	<b>-5(7)</b>	<b>-3(6)</b>	<b>0(5)</b>	<b>7(4)</b>	<b>6(3)</b>	<b>5(2)</b>	<b>8(1)</b>
<b>NCUM_R-UKMO</b>	<b>16.14 (7)</b>	<b>15.0 (6)</b>	<b>11.8 (5)</b>	<b>10.25 (4)</b>	<b>10.0 (3)</b>	<b>6.0 (2)</b>	<b>nan (0)</b>
<b>NCEP-GFDL</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>
<b>ECMWF-EIFS</b>	<b>11.83 (6)</b>	<b>14.33 (6)</b>	<b>16.8 (5)</b>	<b>19.75 (4)</b>	<b>19.0 (3)</b>	<b>16.0 (2)</b>	<b>11.0 (1)</b>
<b>IMDGFS-EIFS</b>	<b>8.71 (7)</b>	<b>5.5 (6)</b>	<b>9.0 (5)</b>	<b>8.0 (4)</b>	<b>17.0 (3)</b>	<b>9.0 (2)</b>	<b>10.0 (1)</b>
<b>IMDGFS-GFDL</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>
<b>IMDGEFS_mean _GFDL</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>
<b>NCEP-EIFS</b>	<b>9.43 (7)</b>	<b>10.33 (6)</b>	<b>12.2 (5)</b>	<b>9.25 (4)</b>	<b>10.33 (3)</b>	<b>8.5 (2)</b>	<b>8.0 (1)</b>
<b>NCUM_G-EIFS</b>	<b>14.17 (6)</b>	<b>12.67 (6)</b>	<b>13.8 (5)</b>	<b>9.25 (4)</b>	<b>6.0 (3)</b>	<b>7.0 (2)</b>	<b>2.0 (1)</b>
<b>NCUM_G-UKMO</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>
<b>IMDOPER</b>	<b>1.43 (7)</b>	<b>2.5 (6)</b>	<b>6.0 (5)</b>	<b>6.25 (4)</b>	<b>8.33 (3)</b>	<b>2.5 (2)</b>	<b>10.0 (1)</b>
<b>MMEM</b>	<b>6.77 (7)</b>	<b>7.22 (6)</b>	<b>6.06 (5)</b>	<b>4.5 (4)</b>	<b>2.72 (3)</b>	<b>2.78 (2)</b>	<b>0.83 (1)</b>
<b>HWRF-GFDL</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>
<b>UKMO_GFDL</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>	<b>nan (0)</b>
<b>CMC_GFDL</b>	<b>9.17 (6)</b>	<b>7.83 (6)</b>	<b>7.0 (5)</b>	<b>7.5 (4)</b>	<b>5.33 (3)</b>	<b>14.5 (2)</b>	<b>2.0 (1)</b>



**Table 5.3. Root Mean Square (RMSE) errors of maximum sustained wind in knots of CNTL and ENS\_MEAN from GEFS model (Number of forecasts verified is given in the parentheses)**

<b>Lead Time</b>	<b>12Hr</b>	<b>24Hr</b>	<b>36Hr</b>	<b>48Hr</b>	<b>60Hr</b>	<b>72Hr</b>	<b>84Hr</b>
<b>HWRF</b>	<b>11</b>	<b>8</b>	<b>8</b>	<b>19</b>	<b>16</b>		
<b>GEFS CNTL</b>	<b>11(7)</b>	<b>5(6)</b>	<b>7(5)</b>	<b>14(4)</b>	<b>21(3)</b>	<b>3(2)</b>	<b>11(1)</b>
<b>GEFS ENS_MEAN</b>	<b>8(7)</b>	<b>8(6)</b>	<b>6(5)</b>	<b>9(4)</b>	<b>8(3)</b>	<b>6(2)</b>	<b>8(1)</b>

**Table 5.4 LANDFALL POINT (in Km)**

<b>Lead Time</b>	<b>6 Hr</b>	<b>18Hr</b>	<b>30 Hr</b>	<b>42 Hr</b>	<b>54 Hr</b>	<b>66 Hr</b>
<b>Initial Condition</b>	<b>1200 UTC 24 Oct</b>	<b>0000 UTC 24 Oct</b>	<b>1200 UTC 23 Oct</b>	<b>0000 UTC 23 Oct</b>	<b>1200 UTC 22 Oct</b>	<b>0000 UTC 22 Oct</b>
<b>HWRF</b>	<b>33</b>	<b>44</b>	<b>46</b>	<b>16</b>		
<b>GEFS CNTL</b>	<b>8</b>	<b>16</b>	<b>98</b>	<b>43</b>	<b>108</b>	<b>150</b>
<b>GEFS ENS_MEAN</b>	<b>0</b>	<b>16</b>	<b>83</b>	<b>66</b>	<b>108</b>	<b>113</b>
<b>NCUM_R-UKMO</b>	<b>15.25</b>	<b>83.47</b>	<b>82.6</b>	<b>203.37</b>	<b>235.09</b>	<b>293.87</b>
<b>ECMWF-EIFS</b>	<b>8.76</b>	<b>34.6</b>	<b>49.59</b>	<b>13.3</b>	<b>83.76</b>	<b>11.83</b>
<b>IMDGFS-EIFS</b>	<b>3.42</b>	<b>21.04</b>	<b>127.96</b>	<b>26.27</b>	<b>137.0</b>	<b>157.81</b>
<b>NCEP-EIFS</b>	<b>20.34</b>	<b>44.99</b>	<b>19.39</b>	<b>145.33</b>	<b>143.52</b>	<b>143.52</b>
<b>NCUM_G-EIFS</b>	<b>357.31</b>	<b>23.65</b>	<b>26.38</b>	<b>83.4</b>	<b>15.76</b>	<b>160.38</b>
<b>CMC_GFDL</b>	<b>47.73</b>	<b>12.26</b>	<b>28.75</b>	<b>24.73</b>	<b>11.13</b>	<b>243.99</b>
<b>MMEM</b>	<b>9.45</b>	<b>12.55</b>	<b>4.48</b>	<b>23.5</b>	<b>62.89</b>	<b>128.81</b>
<b>IMDOPER</b>	<b>2.28</b>	<b>20.34</b>	<b>35.59</b>	<b>12.26</b>	<b>5.72</b>	<b>12.5</b>

**Table 5.5 LANDFALL TIME (in hrs) (+ indicates delay landfall, - indicates early landfall)**

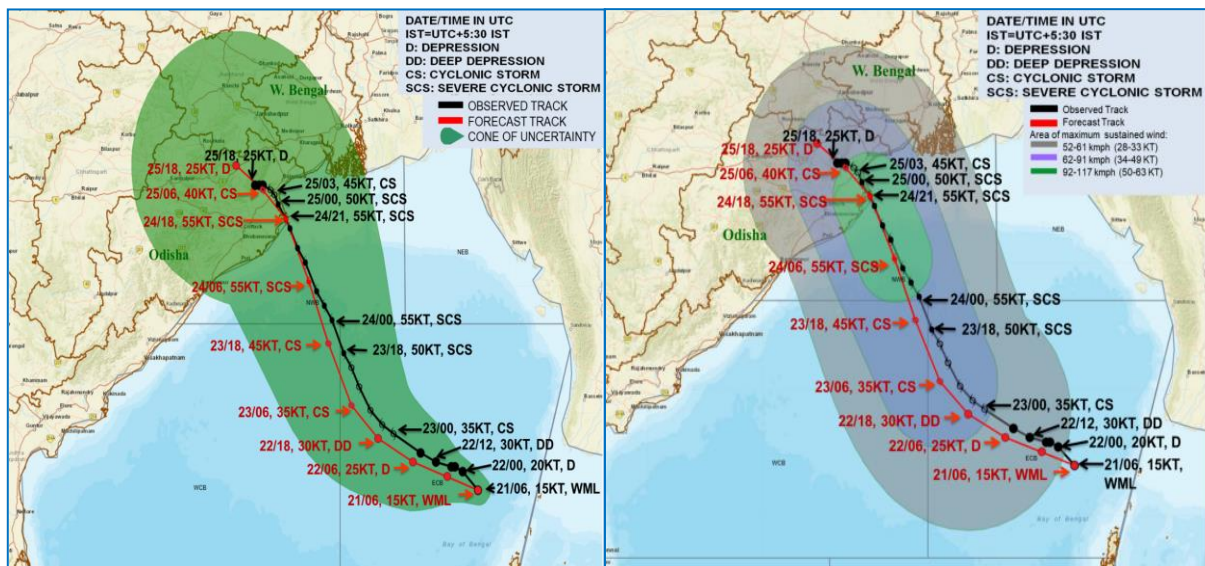
Lead Time	6 Hr	18Hr	30 Hr	42 Hr	54 Hr	66 Hr
Initial Condition	1200 UTC 24 Oct	0000 UTC 24 Oct	1200 UTC 23 Oct	0000 UTC 23 Oct	1200 UTC 22 Oct	0000 UTC 22 Oct
HWRF	-1	-2	-2	-3		
GEFS CNTL	0	-6	6	0	-6	0
GEFS ENS_MEAN	0	-6	12	12	0	0
NCUM_R-UKMO	3	5	4	0	-1	0
ECMWF-EIFS	0	7	8	6	-12	4
IMDGFS-EIFS	1	2	-8	2	3	-1
NCEP-EIFS	0	-1	-2	-7	-8	-2
NCUM_G-EIFS	-51	3	3	-8	-6	-6
CMC_GFDL	-4	2	-1	-19	-29	-2
MMEM	2	3	0	-3	-8	-6
IMDOPER	0	-3	-4	0	0	0

## 9 Operational Forecast Performance:

### i) Pre-Genesis Forecast performance

- ❖ First information about likely formation of an upper air cyclonic circulation over Andaman Sea around 21<sup>st</sup> October was issued in the daily report on 16<sup>th</sup> October under Tropical Cyclone Forecasting Programme carried out by IMD since 2008 during October to December as an initiative to improve forecast through enhanced observations & model guidance (about 3 days ahead of the formation of upper air cyclonic circulation over central Andaman Sea on 19<sup>th</sup> October).
- ❖ First information about likelihood of cyclogenesis (formation of Depression) with High confidence (67-100%) was issued in the extended range outlook issued on 17<sup>th</sup> October (about 5 days ahead of formation of depression on 22<sup>nd</sup> October) (**Fig.5**).

- ❖ Regular updates were since then issued in six hourly forecasts given by National Weather Forecasting Centre and daily tropical weather outlook issued by Regional Specialised Meteorological Centre (RSMC) New Delhi.
- ❖ First Special Message issued by IMD at 1330 hours IST (0800 UTC) 20<sup>th</sup> October when the system lay as an upper air cyclonic circulation over central Andaman Sea indicated formation of low-pressure area around 21<sup>st</sup>, depression by 22<sup>nd</sup> and cyclonic storm by 23<sup>rd</sup> October over eastcentral BoB. It was also indicated that the system would reach northwest BoB off Odisha-West Bengal coasts by 24<sup>th</sup> morning.
- ❖ In the first Special Message itself at the stage of a cyclonic circulation, Pre-cyclone Watch for Odisha and West Bengal coasts was issued about 4.5 days ahead of landfall over Odisha coast.
- ❖ First pre-genesis (before formation of depression) track & intensity forecast along with cone of uncertainty and wind distribution around the centre of the storm was issued by IMD at 1000 hrs IST of 21<sup>st</sup> October indicating likely intensification into a severe cyclonic storm on 24<sup>th</sup> morning (0530 hours IST/0000 UTC) over northwest BoB. The pre-genesis track, intensity and landfall forecast along with observed track & intensity during life cycle of “DANA” indicating accuracy in track, intensity & landfall prediction at the stage of low-pressure area is presented in **Fig. 16**. There was almost zero error in prediction of landfall point, time and intensity at this stage.

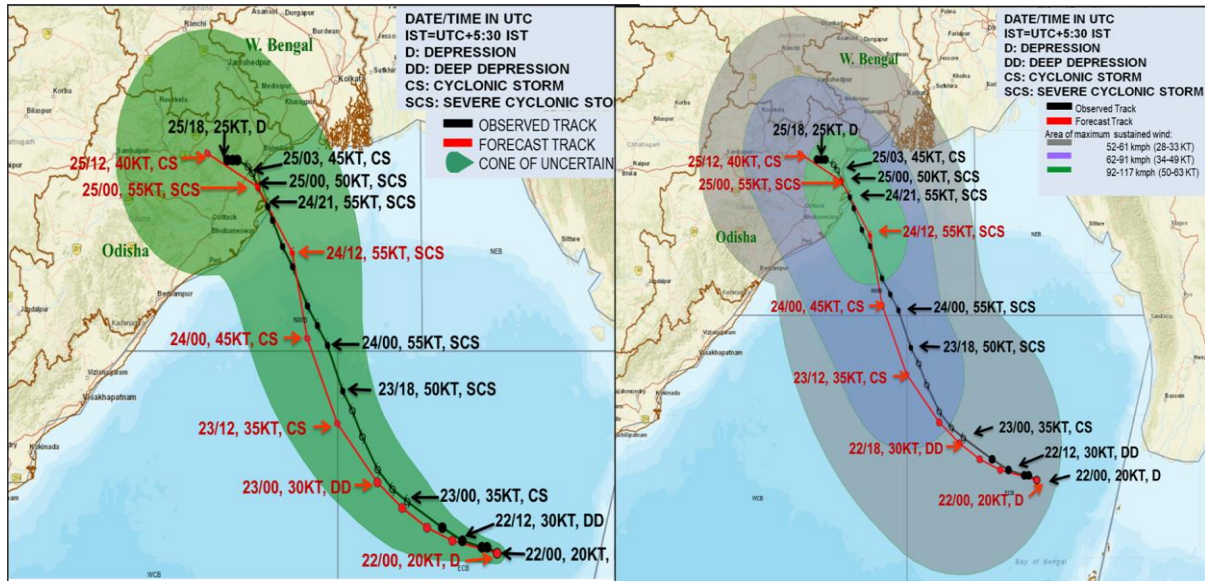


**Fig. 16: Observed track & intensity along with predicted Pre-genesis track and intensity forecast issued at the stage of well-marked low-pressure area on 21<sup>st</sup> October 2024 about 3.5 days ahead of landfall on 25<sup>th</sup> October demonstrating accuracy in track, landfall and intensity forecast**



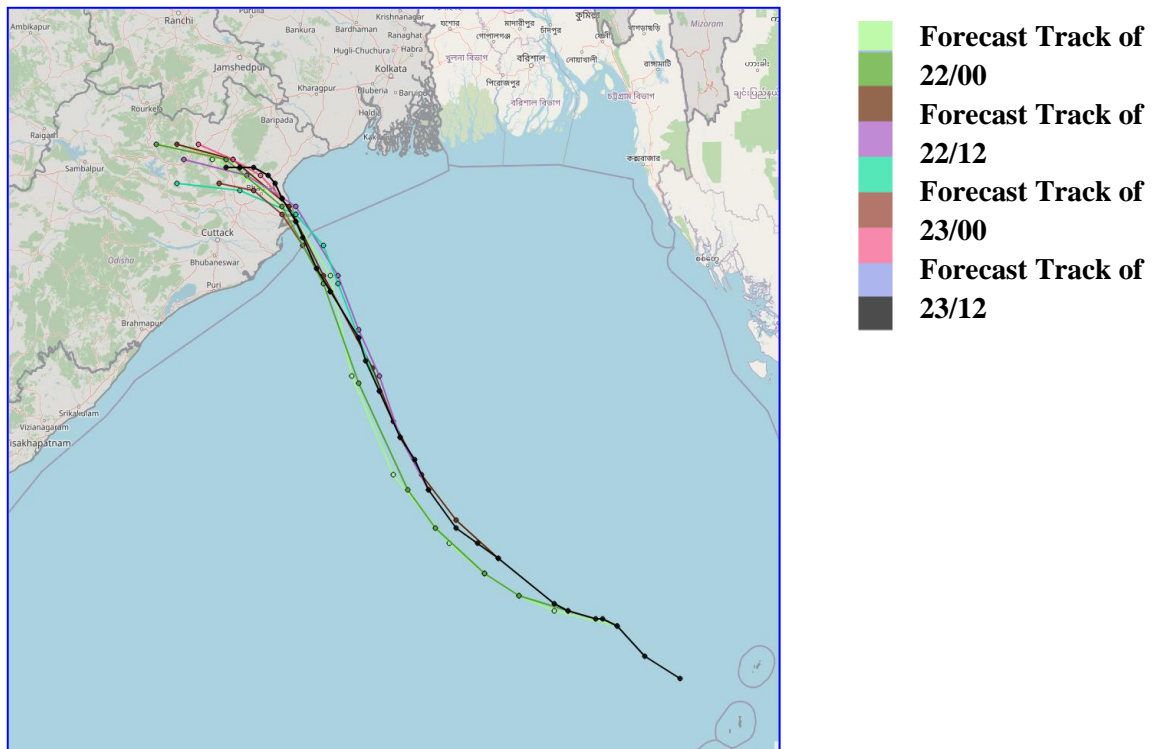
## ii) Track, intensity and landfall forecast performance

- ❖ With the formation of depression on 22<sup>nd</sup> October morning, it was indicated that the system would cross North Odisha & West Bengal coasts between Puri & Sagar Island in the early morning hours during 2330 hours IST (1800 UTC) of 24<sup>th</sup> to 0530 hours IST (0000 UTC) of 25<sup>th</sup> October as a severe cyclonic storm with wind speed of 100-110 gusting to 120 kmph. The track & intensity forecast issued at 0930 hours IST of 22<sup>nd</sup> October along with actual track & intensity forecast during life cycle of “DANA” is presented in **Fig. 17**.



**Fig. 17: Track & Intensity Forecast issued on the formation of depression on 22<sup>nd</sup> October (3 days ahead of landfall) indicating accuracy in track, landfall point & time and intensity forecast**

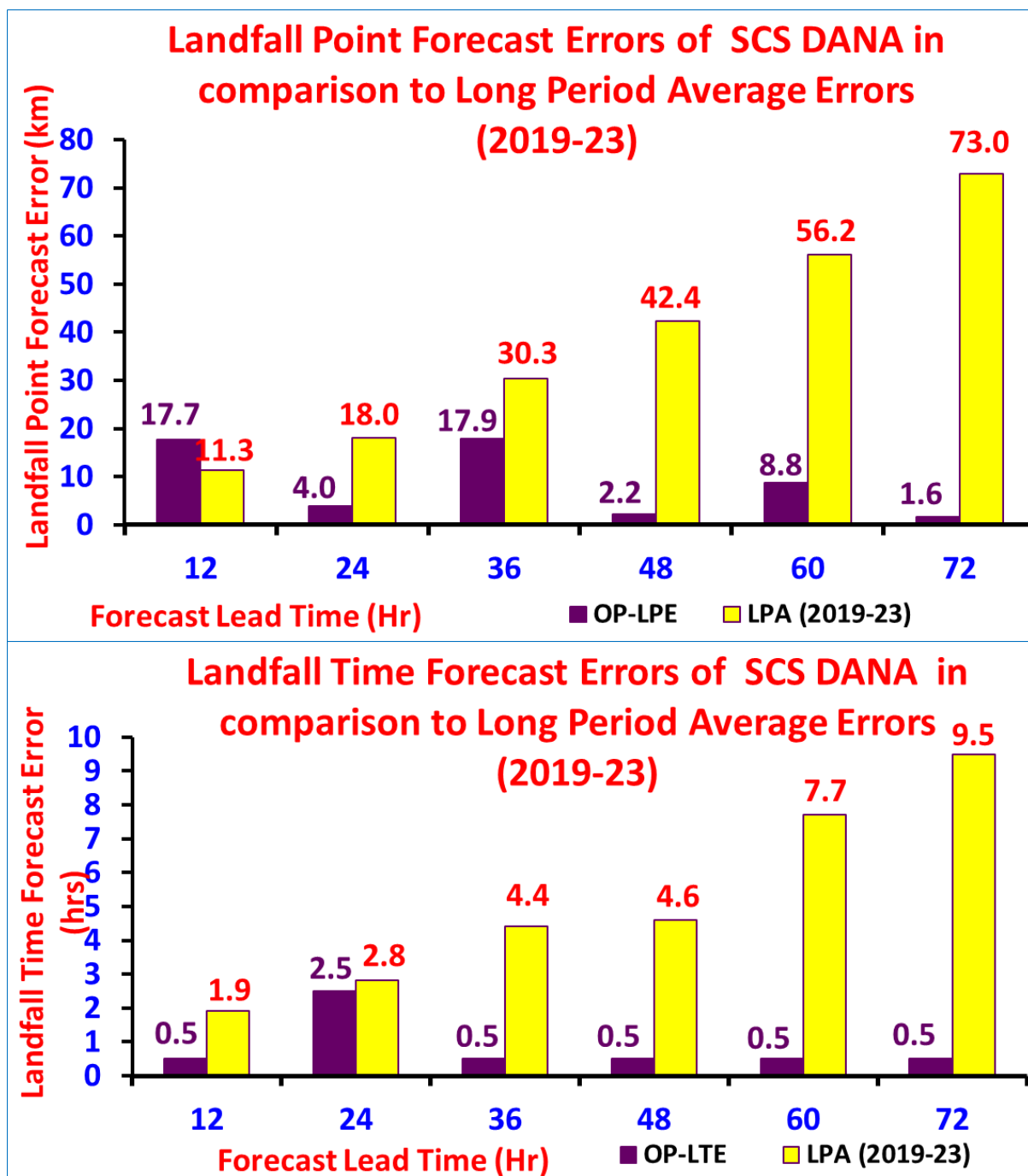
- ❖ The warnings were regularly updated every six hourly and three hourly at the depression and cyclonic storm stage respectively with track, intensity & landfall forecast. Various tracks issued based on 0000 (0530 hours IST) & 1200 UTC (1730 hours IST) since 22<sup>nd</sup> October to 25<sup>th</sup> October showing the consistency in track & intensity forecast during the life cycle of “DANA” is presented in **Fig. 18**.



**Fig. 18: All operational forecasts issued based on 0000(0530) and 1200(1730) UTC(IST) during 22<sup>nd</sup>-25<sup>th</sup> October indicating consistency in track, landfall and intensity prediction during life period of SCS “DANA”**

**Date and time are given in UTC. IST=UTC+ 0530 hrs**

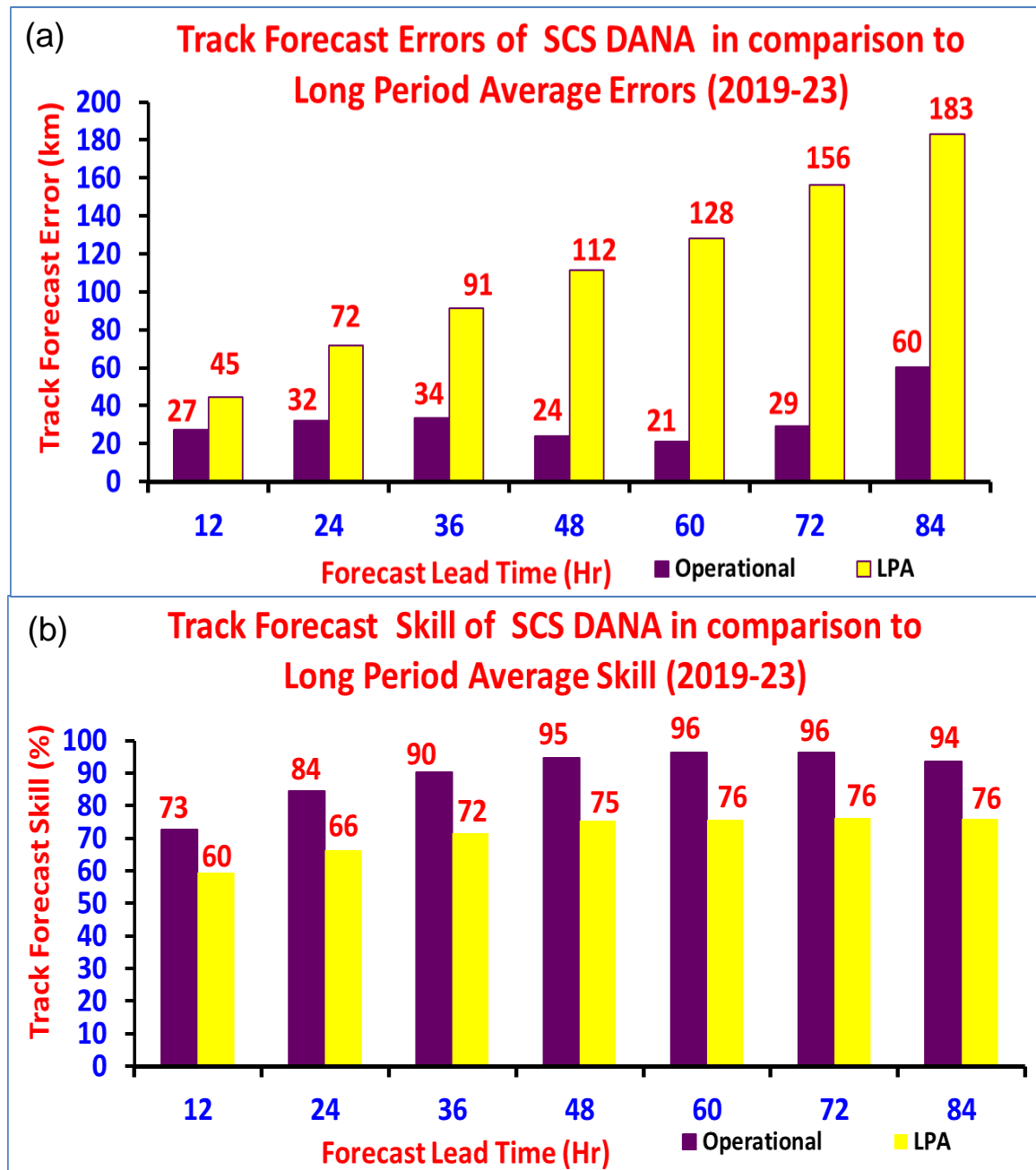
- ❖ The landfall point forecast errors for 24, 48 and 72 hrs lead period were 4, 2 and 2 km respectively against the long period average errors of 18, 42 and 73 km based on data of 2019 - 23 (**Fig. 19a**). The landfall time forecast errors for 24, 48 and 72 hrs lead period were 2.5, 0.5 and 0.5 hours respectively against the long period average error of 2.8, 4.6 and 9.5 hours respectively based on the data of 2019-23 (**Fig. 19b**). **The operational landfall point & time forecast errors were markedly less than the LPA errors for all lead periods. There was almost zero error in landfall point prediction for all lead periods upto 90 hours. The landfall intensity forecast errors were also almost zero even upto 90 hrs lead period.**



**Fig. 19: (a) Landfall point and (b) time errors against the long period average (LPA) errors based on 2019-2023**

- ❖ The track forecast errors for 24, 48 and 72 hrs lead period were 32, 24 and 29 km against the long period average errors of 72, 112 and 156 km respectively based on the data of 2019-23 (**Fig. 20a**). The track forecast skills calculated against Climatology & Persistence (CLIPER) forecast for 24, 48 and 72 hrs lead period were 84, 95 and 96 % respectively against the long period average skills of 66, 75 and 76% respectively based on the data of 2019-23 (**Fig. 20b**). **For all lead periods, the operational track forecast errors were markedly below the long period average errors.**





**Fig. 20: Track forecast errors and (b) skills against Climatology & Persistence (CLIPER) compared to long period average (LPA) errors & skills respectively based on 2019-2023**

- ❖ The absolute errors (AE) in intensity (wind) forecast for 24, 48 and 72 hrs lead period were 2.7, 5.0 and 3.8 knots against the long period average errors of 7.1, 10.3 and 13.8 knots based on the data of 2019-23 respectively (**Fig. 21a**). The skills in intensity forecast based on AE calculated against the persistence-based forecasts for 24, 48 and 72 hours lead period were 81, 81 and 90 % against the long period average skills of 57, 71 and 77% based on data of 2019-23 respectively (**Fig. 21b**). **For all lead periods, the operational intensity forecast errors were less and the skills were more than the long period average.**

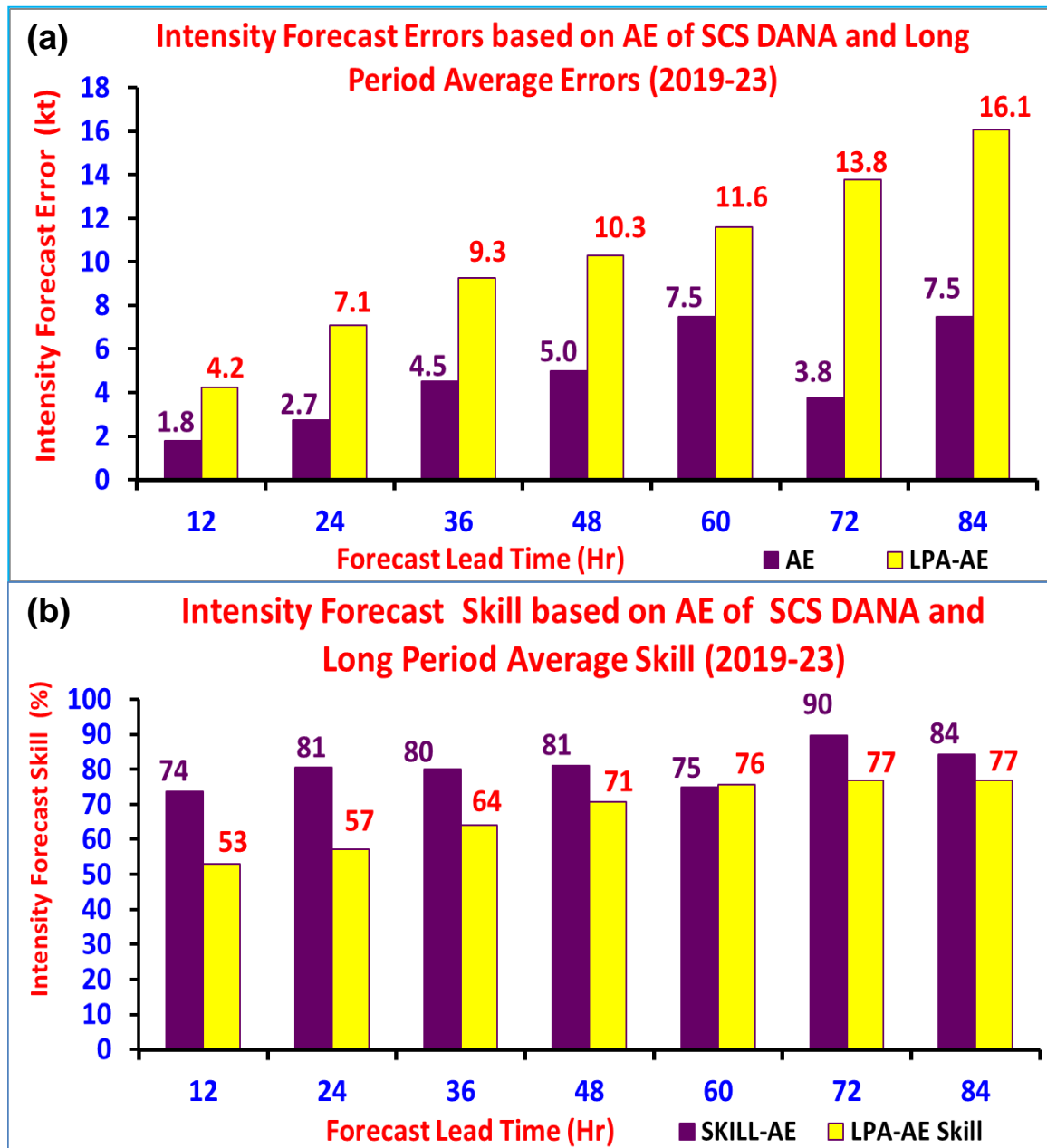
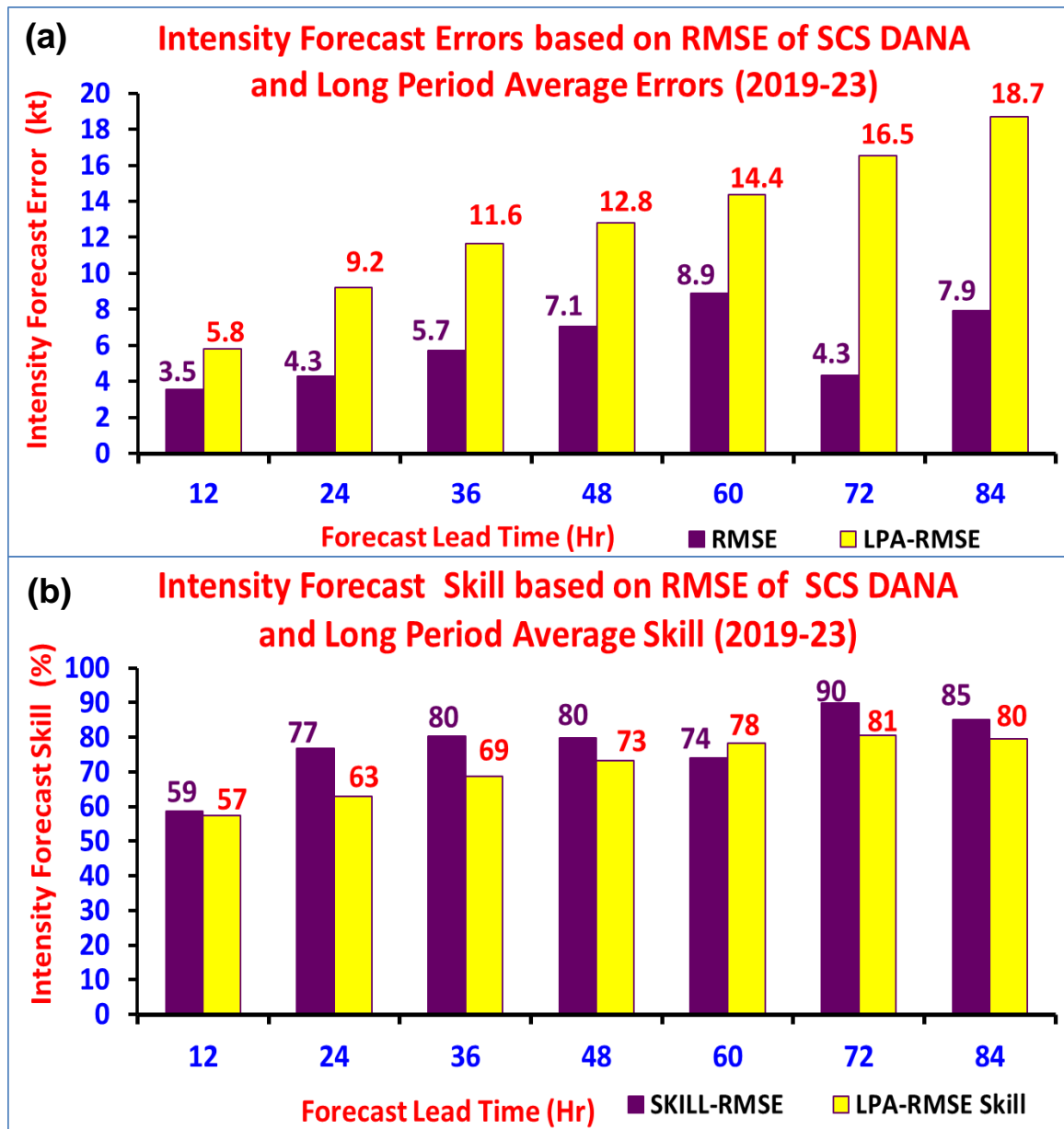


Fig. 21: Intensity forecast errors (AE) and (b) skills against Persistence compared to long period average (LPA) errors & skills respectively based on absolute error (AE).

- ❖ The root mean square errors (RMSE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 4.3, 7.1 and 4.3 knots against the long period average errors of 9.2, 12.8 and 16.5 knots based on data of 2019-23 respectively (**Fig.22a**). The skills in intensity forecast based on RMSE calculated against persistence-based forecast for 24, 48 and 72 hrs lead period were 77, 80 and 90% against the long period average skills of 63, 73 and 81% based on data of 2019-23 respectively (**Fig. 22b**). **For all lead periods, the operational intensity forecast errors were less and the skills were more than the long period average.**



**Fig. 22(a): Intensity forecast errors (RMSE) and (b) skills against Persistence forecast compared to long period average (LPA) errors & skills respectively**



**Table 6: Operational Track forecast errors and skill of SCS “DANA” as compared to long period average (2019-23)**

Lead Period (hrs)	N	Operational Track forecast error (km)	Operational Track Forecast Skill (%)	Long Period Average (2019-23)	
				Track Forecast Error (km)	Track Forecast Skill (%)
12	14	27	73	45	60
24	11	32	84	72	66
36	10	34	90	91	72
48	8	24	95	112	75
60	6	21	96	128	76
72	4	29	96	156	76
84	2	60	94	183	76

**N: no. of observations verified**

**Table 7: Operational Absolute errors (AE) and Root Mean Square errors (RMSE) and corresponding skill in intensity forecast of SCS “DANA” as compared to long period average (2019-23)**

Lead Period	N	AE	RMSE	Skill-AE	Skill-RMSE	Long Period Average (2019-23)			
						AE	RMSE	Skill-AE	Skill-RMSE
12	14	1.8	3.5	74	59	4.2	5.8	53	57
24	11	2.7	4.3	81	77	7.1	9.2	57	63
36	10	4.5	5.7	80	80	9.3	11.6	64	69
48	8	5.0	7.1	81	80	10.3	12.8	71	73
60	6	7.5	8.9	75	74	11.6	14.4	76	78
72	4	3.8	4.3	90	90	13.8	16.5	77	81
84	2	7.5	7.9	84	85	16.1	18.7	77	80

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

**Table 8: Landfall point and time errors of SCS “DANA” as compared to long period average (2019-23)**

Lead Period	Base Time	Landfall Point (N/E)		Landfall Time (hours)		Landfall Point (N/E)			
		Forecast	Actual	Forecast	Actual	OP-LPE (km)	OP-LTE (hr)	LPA-LPE (km)	LPA-LTE (hr)
12	24/12	20.63/86.92	20.79/86.94	24/2130	24/2200	17.7	0.5	11.3	1.9
24	24/00	20.81/86.97	20.79/86.94	25/0030	24/2200	4.0	2.5	18.0	2.8
36	23/12	20.95/86.91	20.79/86.94	25/0130	24/2200	17.9	0.5	30.3	4.4
48	23/00	20.79/86.96	20.79/86.94	24/2230	24/2200	2.2	0.5	42.4	4.6
60	22/12	20.79/86.86	20.79/86.94	24/2230	24/2200	8.8	0.5	56.2	7.7
72	22/00	20.78/86.95	20.79/86.94	24/2130	24/2200	1.6	0.5	73.0	9.5

“+” indicates delayed prediction and “-” indicates early prediction

## 10. Warnings and advisories issued

### Bulletins issued by Cyclone Warning Division, New Delhi

- **Track, intensity and landfall forecast:** IMD continuously monitored, predicted and issued bulletins containing track and intensity forecast for +06, +12, +18, +24, +36, +48 and upto +84 hrs lead period commencing from 21<sup>st</sup> October morning till the system weakened into a deep depression. The above forecasts were issued along with the cone of uncertainty in the track forecast, once daily at the stage of low pressure area, five times a day during depression/dep depression stage and every three hourly during the cyclone period.
- **Cyclone structure forecast for shipping and coastal hazard management:** The radius of maximum wind and radii of maximum sustained wind (MSW)  $\geq 28$  and  $\geq 34$  knots wind in four geographical quadrants of cyclone were issued along with graphics, commencing from 21<sup>st</sup> October morning.
- **Adverse weather warning bulletins:** The tropical cyclone forecasts along with expected adverse weather like heavy rainfall, flash flood, gale wind and state of sea for Bay of Bengal, were issued every six/three hour to central, state and district level disaster management agencies including Ministry of Home Affairs (MHA), National Disaster Response Force (NDRF), National Disaster Management Authority (NDMA) and state disaster management agencies. The bulletins also contained the suggested actions for disaster managers and general public, in particular for fishermen, ports, offshore & onshore industries and installations and people. These

bulletins were also issued to Defence including Indian Navy & Indian Air Force and Indian Coast Guard, Ports, Shipping, Mines, Fishery, Railways, Surface transport and aviation authorities etc. For cyclone “DANA” the advisories for winds & sea condition for fishermen over Bay of Bengal were also provided to WMO and WMO/ESCAP Panel countries including Bangladesh and Myanmar.

- **Flash Flood Guidance:**

IMD, New Delhi acts as WMO’s Regional Centre for Flash Flood Guidance at watershed level over South Asian region (Nepal, Bhutan, Bangladesh, Sri Lanka and India). It covers about 1 lakh watersheds in the region. Flash flood guidance was provided every six hourly interval.

- **Warning graphics:** The graphical display of the observed and forecast track with cone of uncertainty and the wind forecast for different geographical quadrants of cyclone were disseminated by email and uploaded in the RSMC, New Delhi website (<http://rsmcnewdelhi.imd.gov.in/>) regularly. The adverse weather warnings related to fishermen were also presented in graphics along with colour codes in the website.

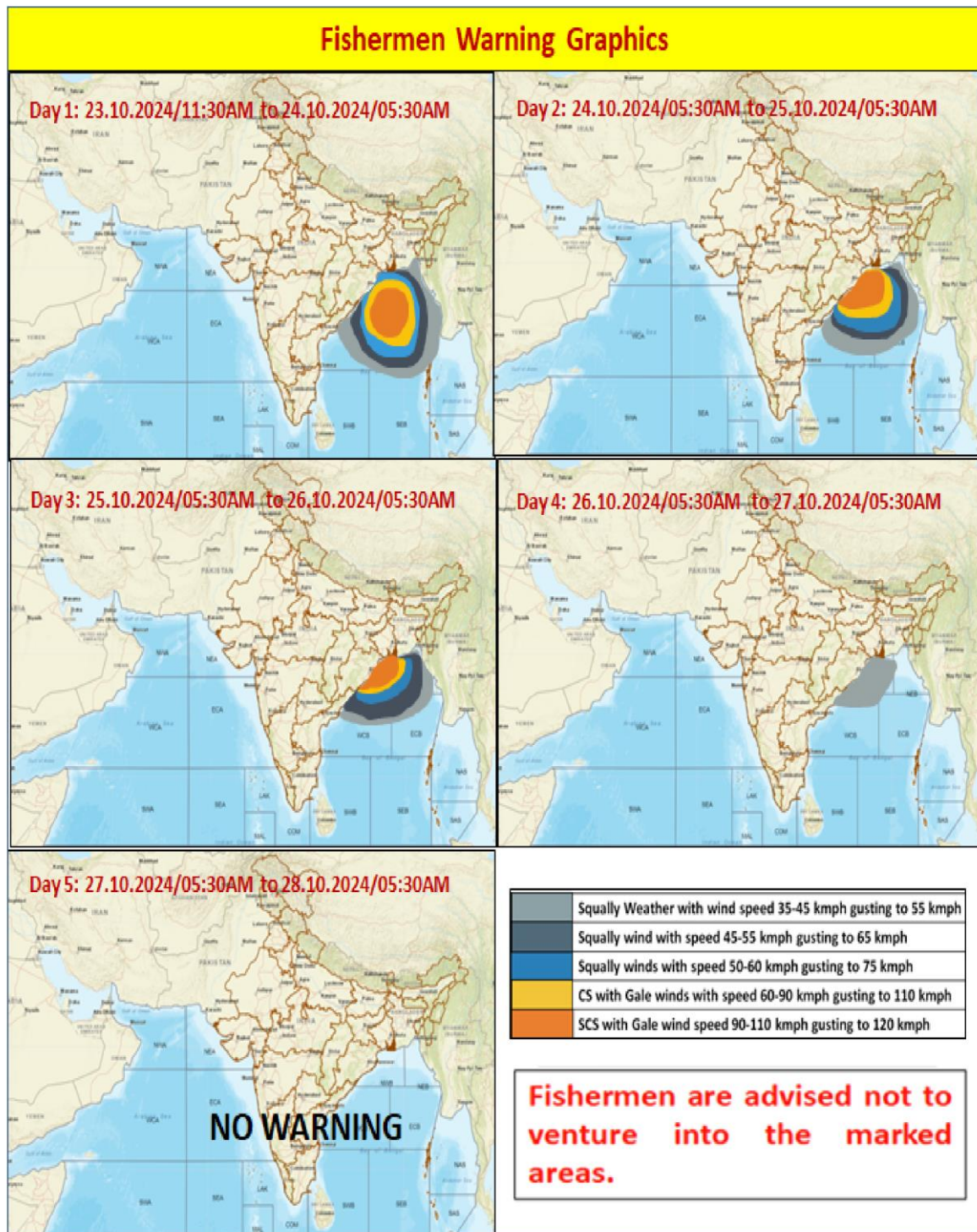
- **Four Stage Warnings:**

Total number of 21 bulletins under 4 stage warnings system were issued including 3 pre-cyclone watch, 3 cyclone alert, 10 cyclone warnings for Odisha & West Bengal coasts and 5 post-landfall outlook for interior districts of Odisha were issued during cyclone “DANA”.

- **Warnings and advisories through social media:** Daily updates (every three hour) were uploaded on Facebook and Twitter during the life period of the system since the development of low pressure area.
- **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 capsules 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 transmitted through INMARSAT & IMD websites. Bulletins for maritime interest were also issued by Area Cyclone Warning Centres of IMD at Chennai & Kolkata, Cyclone Warning Centres at Bhubaneswar and Visakhapatnam for coastal and high sea shipping community. These were transmitted through NAVTEX (Navigational Telex) & IMD websites.
- **Fishermen Warning:** Regular warnings for fishermen in Bay of Bengal and Andaman Sea were issued since 17<sup>th</sup> October by IMD HQ and Cyclones Warning Centres of IMD. Typical example of fishermen warning graphics issued on 23<sup>rd</sup> October is presented in **Fig. 23**.
- **Port Warnings:** Regular Port warnings were issued by Area Cyclone Warning Centres of IMD at Chennai & Kolkata, Cyclone Warning Centres at Bhubaneswar & Visakhapatnam and Meteorological Centre Andaman & Nicobar Islands during cyclone “DANA”. Customised bulletins for various ports were also issued by IMD Head Quarters.



- **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) by concerned Meteorological Watch Offices. It was also sent to Aviation Disaster Risk Reduction (ADRR) centre of WMO at Hong Kong from the stage of deep depression.
- **Diagnostic and prognostic features of cyclone:** The prognostic and diagnostic features of the cyclone based on all meteorological observations and numerical model guidance were described in each RSMC bulletin since 20<sup>th</sup> October onwards till dissipation of the cyclone.
- **Director General of Meteorology** and other experts in National Weather Forecasting Centre, New Delhi and Area Cyclone Warning Centres & Cyclone Warning Centre Kolkata & Chennai and Cyclone Warning Centre Bhubaneswar briefed media regularly.
- **National Crisis Management Committee Meeting (NCMC):** NCMC meeting under the Chairmanship of Cabinet Secretary was held on 21<sup>st</sup> October. DG IMD briefed the status of expected cyclone, associated adverse weather, damage expected and suggested actions during the meeting. Cyclone Warning Division representative also briefed the status of cyclone in meeting with Port Authorities and Directorate General of Hydrocarbons on 22<sup>nd</sup> and 25<sup>th</sup> October about the status of cyclone. Similar meetings were also attended by the Heads Cyclone Warning Centre Bhubaneswar and Area Cyclone Warning Centre Kolkata with Honourable Chief Minister and Chief Secretary of the states.



**Fig. 23: Typical Fishermen Warning graphics issued on 23<sup>rd</sup> October 2024**

Statistics of bulletins issued by IMD is given in **Table 9 a and b.**

**Table 9a: Bulletins issued by Cyclone Warning Division, New Delhi**

S N	Bulletins	No. of Bulleti ns	Issued to
1	National Bulletin	28	<p>1. IMD's website</p> <p>2. FAX and e-mail to Control Room NDM, Ministry of Home affairs, Control Room NDMA, Cabinet Secretariat, Minister of Sc. &amp; Tech, Secretary MoES, DST, HQ Integrated Defense Staff, DG Doordarshan, All India Radio, DG-NDRF, Director Indian Railways, Indian Navy, IAF, Chief Secretary: West Bengal, Odisha,</p> <p>Andhra Pradesh, Chhattisgarh, Jharkhand, Karnataka, Maharashtra, Gujarat and Telangana</p>
2	RSMC Bulletin	28	<p>1. IMD's website</p> <p>2. All WMO/ESCAP member countries including Bangladesh through GTS and E-mail.</p> <p>3. Indian Navy, IAF by E-mail</p>
3	GMDSS Bulletins	17	<p>1. IMD website, RSMC New Delhi website</p> <p>2. Transmitted through WMO Information System (WIS) to Joint WMO/IOC Technical Commission for Ocean and Marine Meteorology (JCOMM)</p>
4	Tropical Cyclone Vital Bulletin	11	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
5	Tropical Cyclone Advisory Centre Bulletin	11	<p>1. Met Watch offices in Asia Pacific regions and middle east through GTS to issue Significant Meteorological information for International Civil Aviation</p> <p>2. WMO's Aviation Disaster Risk Reduction (ADRR), Hong Kong through ftp</p> <p>3. RSMC website</p>
6	Customis ed Location specific forecast	20 each	Issued to Port Authorities, offshore/onshore industries, Indian Oil Corporation, Indian Air Force and Indian Coast Guard by email to concerned stake holders
7	Press Release	7	Disaster Managers, Media persons by email and uploaded on website



8	DGM Bulletins	5	High level disaster managers by email and FAX including Principal secretary to Prime Minister, Home Secretary, NDMA, NDRF, Secretaries of various Ministries & concerned states and disaster management agencies mentioned in SN1.
9	Press Briefings	Daily	Regular briefing frequently
10	Hourly Bulletin	22	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 Defence Staff, Director General Doordarshan, All India Radio, PIB MOES, DG National Disaster Response Force, Director Punctuality, Indian Railways, Secretaries to Govt of India for Surface Transport, Mines, Agriculture, Ports, Shipping & Waterways, Fishery, Aviation, Power, Telecommunication, Petroleum & Natural Gas etc. and Chief Secretary to Government of Odisha, West Bengal, Andhra Pradesh, Tamil Nadu, Andaman & Nicobar Islands, Puducherry, Tripura, Mizoram, Manipur and Nagaland, Andaman & Nicobar Islands. 3. WMO/ESCAP Panel member countries
11	Warnings through SMS	156059 to General Public and 2112 through transmitt	SMS to (i) disaster managers at national level and concerned states (every time when there was change in track, intensity and landfall characteristics) by IMD Headquarters, (ii) to General Public registered through RSMC website by IMD Headquarters and RMC Kolkata office (iii) to fishermen through INCOIS network.
12	Warnings through Social Media	Every three hourly	Cyclone Warnings were uploaded on Social networking sites (Facebook and Twitter) since inception to weakening of system (every six hourly).

**Table 9b: Bulletins issued by Area Cyclone Warning Centre (ACWC) Kolkata, Cyclone warning Centre (CWC) Bhubaneswar & Visakhapatnam (VSK)**

S.No.	Type of Bulletin	No. of Bulletins issued		
		CWC Bhubaneswar	ACWC Kolkata	CWC VSK
1.	Sea Area Bulletins	-	17	---
2.	Coastal Weather Bulletins	20	i) West Bengal ports: 17 ii) Andaman ports: 17	17
3.	Fishermen Warnings issued	20	i) West Bengal Coast: 16 ii) Andaman Coast: 11	16
4.	Port Warnings	20	iii) West Bengal Ports: 22 iv) Andaman Port: 18	13
5.	Heavy Rainfall Warning	14	23	0
6.	Gale Wind Warning	14	21	Squally Wind Warnings (5)
7.	Storm Surge Warning	14	17	---
8.	Information & Warning to State Government and other Agencies	30	23	11
9.	SMS	-	---	---
10.	No. of Press releases	7	8	11
11.	No. of impact-based warnings	23	23	05
12.	No. of whatsapp messages	Every 3 hourly	86434	Special (2849), Nowcast (5838)
13.	No. of updates on facebook	59	23	06
14.	No. of updates on X(twitter) , Instagram	59	23	06 Each
15.	No. of Forecast / Warning video released	5	3	Everyday.
16.	Death reported (along with source)	Zero	1	-

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