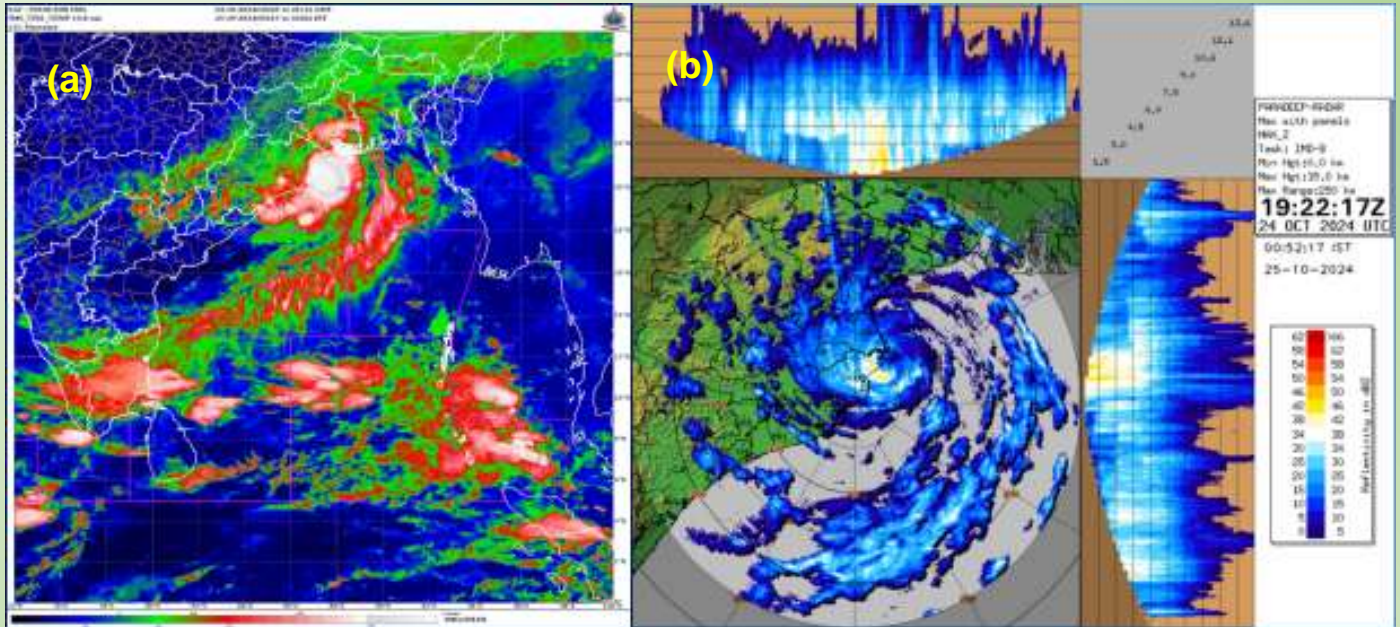




## Severe Cyclonic Storm “DANA” over the Bay of Bengal (22<sup>nd</sup>-26<sup>th</sup> October, 2024): A Report



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”

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

### Summary

- ❖ The severe cyclonic storm “DANA” developed over eastcentral Bay of Bengal (BoB) and adjoining North Andaman Sea as a **Low-Pressure Area**. It moved nearly north-northwestwards, intensified into a **depression** over eastcentral BoB on 22<sup>nd</sup> October, **cyclonic storm “DANA”** on 23<sup>rd</sup> October and into a **severe cyclonic storm** over central & adjoining northwest BoB in the mid-night (2330 hours IST/1800 UTC) of 23<sup>rd</sup> October, 2024. It reached its peak intensity on 24<sup>th</sup> October and **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**. It moved slowly during and after landfall. The landfall process continued for 9 hours during midnight of 24<sup>th</sup> till morning of 25<sup>th</sup> October. After landfall, it weakened rapidly into a cyclonic storm over north coastal Odisha in the forenoon of 25<sup>th</sup> and into a well marked low pressure over North Odisha in the early morning of 26<sup>th</sup> October.
- ❖ India Meteorological Department (IMD) provided 1<sup>st</sup> information about the likely development of depression around 23<sup>rd</sup> October and its intensification into a cyclonic storm over eastcentral BoB in the extended range outlook issued on 17<sup>th</sup> October (about 7.5 days ahead of landfall).
- ❖ **Pre-cyclone Watch** for Odisha-West Bengal was issued on 20<sup>th</sup> October when it was an upper air cyclonic circulation which lay over North Andaman Sea (about 4.5 days ahead of landfall). It was followed by **Cyclone Alert** (about 2 days ahead of landfall) at the stage of deep depression and **Cyclone Warning** (about 1.5 days ahead of landfall) for Odisha-West Bengal coasts.
- ❖ On 21<sup>st</sup> October at 1400 hrs IST (about 3.5 days ahead of landfall), IMD issued Pre-genesis (before genesis of depression) track, intensity and landfall prediction, i.e. **1<sup>st</sup> information about the landfall of severe cyclonic storm** over north Odisha and West Bengal coasts between Puri and Sagar Island close to Bhitarkanika and Dhamra during mid-night of 24<sup>th</sup> and early morning 25<sup>th</sup> October, 2024 as a severe Cyclonic Storm with a wind speed of 100-110 kmph gusting 120 kmph. **The same was reiterated consistently till landfall**. There was almost zero error in landfall point & time prediction, 20-30 km error in track prediction and and 3-7 knots error in intensity prediction upto 72 hours lead period.
- ❖ There was almost zero error in cyclone landfall point, landfall time and landfall intensity prediction for all lead periods of forecast upto 3.5 days.
- ❖ The operational track and intensity forecast errors were markedly less than the long period average (LPA) errors based on last five years (2019-2023) for all lead periods of forecast. The track forecast errors were 20-30 km and the intensity forecast errors were 2-5 kt (3-10 kmph) upto 72 hours lead periods.

- ❖ System caused heavy to very heavy rainfall at a few places and extremely heavy rainfall at isolated places over North Odisha and coastal districts of west Bengal on 24<sup>th</sup> and 25<sup>th</sup> October 2024 leading to floods and inundation in low lying areas. The same was predicted by IMD at **1330 hours IST of 20<sup>th</sup> October (about 4.5 days ahead of landfall)**.
- ❖ Maximum wind of 100-110 gusting to 120 kmph realised over Kendrapara and Bhadrak districts of Odisha at the time of landfall was first predicted at **1330 hours IST of 20<sup>th</sup> October (about 4.5 days ahead of landfall)**.
- ❖ Maximum estimated storm surge of height 1-2 m which inundated low lying areas of Kendrapara and Bhadrak districts of Odisha during landfall was first predicted in the bulletin issued at **0215 hours IST of 23<sup>rd</sup> October (about 2.0 days ahead of landfall)**.
- ❖ IMD issued **3 Special Messages** from the stage of cyclonic circulation, **28 National Bulletins** for national level disaster managers, **5 Special Bulletin from Director General of Meteorology, IMD, 22 Hourly Bulletins** on the day of landfall, **28 Bulletins** for members of WMO/ESCAP Panel on Tropical Cyclones including Bangladesh and Myanmar, **11 Bulletins** for International Civil Aviation, **20 customised** location specific bulletins for offshore/onshore industries, ports, Indian Air Force locations & Indian Oil Corporation locations along the East coast of India, **7 Press Releases, every three hourly SMS** to disaster managers, media & general public and **frequent updates on social media**.
- ❖ Details are discussed in Sections 1-10.

### 1. Life History of “DANA”:

- A cyclonic circulation lay over central Andaman Sea in the early morning (0530 hours IST/0000 UTC) of 19<sup>th</sup> October. 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 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 “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 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 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.
- Continuing to move further north-northwestwards slowly, it weakened into a cyclonic storm over north coastal Odisha in the forenoon (0830 hours IST/0300 UTC), 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. (All Figures and Tables are given Annexure-1)**

## 2. Monitoring of 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. 2**). Actually, the depression formed over Eastcentral BoB on 22<sup>nd</sup> October.

The cyclone was monitored with the help of available satellite observations from INSAT 3DR, SCAT SAT (OCEAN SAT 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 models guidance, decision making process and warning products generation. Typical satellite and radar based products utilised for monitoring the system are presented in **Fig. 3**.

### 3. Salient features:

- (i) It was the 2<sup>nd</sup> cyclone of the year 2024 over the Bay of Bengal.
- (ii) Climatologically, 4 severe cyclonic storms & 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.4**). The severe cyclonic storm (50 kt) 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, 1985 as a severe cyclonic storm (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, 1999 (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, Odisha Super Cyclone 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. 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 in the night (2230 hrs IST/1700 UTC) of 12<sup>th</sup> October, 2013.

#### (iii) 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. 5**). 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 cyclonic storm by 0830 IST, DD by 1730 IST, depression by 2330 hrs IST and into marked low pressure area over North Odisha in the early morning (0000 UTC) of 26<sup>th</sup> October.

#### (iv) 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. 6**) 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).

**(v) Track length:**

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

**(vi) Life Period:**

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

**(vii) 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 Bay of Bengal.

**(viii) Cyclone Warnings:**

- ❖ **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).

**4. 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. 2**).
- ❖ 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. 7**. There was almost zero error in prediction of landfall point, time and intensity at this stage.

## 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. 8**.
- ❖ 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. 9**.
- ❖ 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. 10a**). 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. 10b**). **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.**
- ❖ 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. 11a**). 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. 11b**). **For all lead periods, the operational track forecast errors were markedly below the long period average errors.**

- ❖ 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. 12a**). 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. 12b**). **For all lead periods, the operational intensity forecast errors were less and the skills were more than the long period average.**
- ❖ 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.13a**). 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. 13b**). **For all lead periods, the operational intensity forecast errors were less and the skills were more than the long period average.**

### iii) Adverse weather warnings performance:

#### Heavy rainfall warnings:

**The first special message issued at 1330 hours IST of 20<sup>th</sup> October indicated:**

- ❖ Heavy rainfall (07-11 cm) at isolated places over Odisha on 23<sup>rd</sup> & heavy to very heavy rainfall (7-20 cm) at a few places with extremely heavy rainfall ( $\geq 21$  cm) at isolated places on 24<sup>th</sup> & 25<sup>th</sup> October.
- ❖ Heavy rainfall at isolated places over coastal districts of West Bengal on 23<sup>rd</sup> and heavy to very heavy rainfall at a few places over Gangetic West Bengal on 24<sup>th</sup> & 25<sup>th</sup> October.

#### Realised Heavy rainfall:

- ❖ Moderate (2-6 cm) rainfall at many places occurred on 23<sup>rd</sup> October over North coastal Odisha and coastal West Bengal.
- ❖ Widespread rainfall occurred with heavy to very heavy rainfall at a few places over Bhadrak, Kendrapara and Jagatsinghpur districts of North coastal Odisha, heavy rainfall at isolated places over East & West Medinipur districts of West Bengal and heavy rainfall at isolated places over Singhbhum district of Jharkhand on 24<sup>th</sup> October.
- ❖ Heavy to very heavy rainfall occurred at a few places with isolated extremely heavy rainfall ( $\geq 21$  cm) over North Odisha and Gangetic West Bengal on 25<sup>th</sup> October.

#### Gale wind warnings:

**The first special message issued at 1330 hours IST of 20<sup>th</sup> October indicated:**

- ❖ Gale wind speed reaching 100-110 gusting to 120 kmph was predicted over north coastal Odisha (Bhadrak, Kendrapara and Jagatsinghpur) from 24<sup>th</sup> October night to 25<sup>th</sup> October morning and 80-100 kmph was predicted over Balasore district of Odisha and East Medinipur district of West Bengal.

#### Realised Wind:

- ❖ At the time of landfall, the estimated maximum sustained wind speed was about 100-110 kmph gusting to 120 kmph over Kendrapara and Bhadrak districts of Odisha.



- ❖ Realised estimated wind distribution in the tropical cyclone field during its life cycle is presented in **Fig.14**.

### **Storm surge warnings:**

#### **The bulletin issued at 0215 hours IST of 23<sup>rd</sup> October indicated:**

- ❖ Storm surge of height of about 1-2 meter above astronomical tide to inundate low lying areas of Kendrapara, Bhadrak, Balasore, East Medinipur districts during the time of landfall.

### **Realised storm surge:**

- ❖ Maximum estimated storm surge of height of 1-2 m inundated low-lying areas of Kendrapara, Bhadrak and Balasore districts of Odisha during landfall.
- ❖ Realised estimated storm surge is presented in **Fig. 15**.

Thus, the genesis, track, landfall & intensity of severe cyclonic storm DANA along with associated severe weather including heavy rainfall, wind and storm surge were correctly predicted with sufficient lead period (about 4-5 days in advance). It helped the disaster managers, stakeholders and public to take appropriate response actions for effective mitigation of disaster.

## **7. 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 (**Fig.13a**)
- **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 (**Fig.13b**).
- **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. 14**.
- **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.

Statistics of bulletins issued by IMD is given in **Table 1 a and b.**

**Table 1a: Bulletins issued by Cyclone Warning Division, New Delhi**

S. No.	Bulletin type	No. Of Bulletins	Issued to
1	National Bulletin	28 & 3 special messages from the stage of cyclonic circulation	1. IMD's website, RSMC New Delhi website 2. FAX and e-mail to Control Room Ministry of Home Affairs & National Disaster Management Authority, Prime Minister Office, Cabinet Secretariat, Minister of Science & Technology, Secretary MOES, Headquarter Integrated Defence Staff, Doordarshan, All India Radio, Press Information Bureau, National Disaster Response Force, 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, Jharkhand, Bihar and Andaman & Nicobar Islands.
2.	Special bulleting by DGM IMD	5	FAX and e-mail to PM office, Cabinet Secretary, Home Secretary, Control Room Ministry of Home Affairs & National Disaster Management Authority, Cabinet Secretariat, Minister of Science & Technology, Secretary MOES, Headquarter Integrated Defence Staff, Director General Door darshan, 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, Jharkhand, Bihar and Andaman & Nicobar Islands.
3	RSMC Bulletin	28	1. IMD's website 2. WMO/ESCAP member countries through GTS, E-mail and Whats App
4	Flash Flood Guidance Bulletin	8	Email to National level disaster managers, Central Water Commission, Ministry of Home Affairs, Ministry of Water Resources, South Asian countries including Bangladesh Meteorological Department, Flood Met Offices, social media, RSMC & Mausam website
5	GMDSS Bulletins	17	1. IMD website, RSMC New Delhi website, INMARSAT 2. Transmitted through WMO Information System (WIS) to Joint WMO/IOC Technical Commission for Ocean and Marine Meteorology (JCOMM)
6	Tropical Cyclone Advisory Centre Bulletin	11	1. Met Watch offices in Asia Pacific regions and middle east through GTS to issue Significant Meteorological information for International Civil Aviation 2. WMO's Aviation Disaster Risk Reduction (ADRR), Hong Kong through ftp 3. RSMC website
7	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), etc.
8	Customised 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
8	Press Release	7	Disaster Managers, Media persons by email and uploaded on website
9	Warnings through SMS	Every 6 hourly	SMS to (i) disaster managers at national level and concerned states by IMD Headquarters, (ii) general public registered through RSMC website by IMD Headquarters (iii) fishermen through INCOIS network. (iv) To farmers through KISAN portal
10	Warnings through social media	Frequent	Cyclone Warnings were uploaded on social networking sites (Facebook and Tweeter) since inception to weakening of system (almost every three hourly in cyclone stage).
11	Warnings through WhatsApp	Every 3 hourly	Warnings and bulletins were shared through WhatsApp with Disaster managers, media, WMO/ESCAP Panel member countries
12	Press Briefings	Frequently	Regular briefing frequently

**Table 1b: Bulletins issued by Area Cyclone Warning Centre (ACWC) Kolkata, Cyclone warning Centre (CWC) Bhubaneswar & Visakhapatnam**

S.No.	Type of Bulletin	No. of Bulletins issued		
		CWC Bhubaneswar	ACWC Kolkata	CWC VZG
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 /	5	3	Everyday.

	Warning video released			
16.	Death reported (along with source)	<b>Zero</b>	<b>1</b>	<b>-</b>

## 8. Realized Weather

### 8.1. Realised rainfall

The system caused widespread rainfall over North coastal districts with heavy to very heavy rainfall at a few places over Bhadrak, Kendrapara and Jagatsinghpur districts of North coastal Odisha, heavy rainfall at isolated places over East & West Medinipur districts of West Bengal and heavy rainfall at isolated places over Singhbhum district of Jharkhand on 24<sup>th</sup> October. It caused heavy to very heavy rainfall at a few places with isolated extremely heavy rainfall ( $\geq 21$  cm) over North Odisha and Gangetic West Bengal on 25<sup>th</sup> October. NCMRWF IMD satellite gauge merged data plot showing 24 hours accumulated rainfall ending at 0300 UTC of 21<sup>st</sup> -26<sup>th</sup> October is presented in **Fig. 15**.

#### 24hours cumulative rainfall ( $\geq 7$ cm) ending at 0830 hours IST of date:

##### 25<sup>th</sup> October:

- ❖ Odisha: Chandbali (Bhadrak) 16, Rajkanika (Kendrapara) 16, Nawana (Mayurbhanj) 14, Marsaghai (Kendrapara) 11, Basudevpur (Bhadrak) 11, Oupada (Balasore) 11, Rajnagar (Kendrapara) 10, Mohakalapada (Kendrapara) 9, Aul (Kendrapara) 8, Paradeep (Jagatsinghpur) 8, Derabis (Kendrapara) 7, Bhadrak (Bhadrak) 7, Balasore ( Balasore) 7, Jajpur ( Jajpur) 7, Kendrapada (Kendrapara) 7, Nilgiri (Balasore) 7, Kendrapara (Kendrapara) 7, Pattamundai (Kendrapara) 7,
- ❖ Gangetic West Bengal: Diamond Harbour (South 24 Parganas) 9, Kalaikunda (IAF) (West Midnapore) 9, Kharagpur (West Midnapore) 9, Durgachack (East Midnapore) 8, Mohanpur (West Midnapore) 7, Jhargram (dist Jhargram) 7, Uluberia (Howrah) 7;
- ❖ Jharkhand: Gurabandha (East Singhbhum) 7;

##### 26<sup>th</sup> October:

- ❖ Odisha: Oupada (dist Balasore) 24, Dhamnagar (dist Bhadrak) 21, Khaira (dist Balasore) 21, Bhandaripokhari (dist Bhadrak) 21, Nawana (dist Mayurbhanj) 19, Bonth (dist Bhadrak) 19, Chandbali (dist Bhadrak) 17, Bhadrak (dist Bhadrak) 16, Rajkanika (dist Kendrapara) 15, Bari (dist Jajpur) 15, Jajpur Pto (dist Jajpur) 14, Jajpur (dist Jajpur) 14, Udala (dist Mayurbhanj) 14, Nilgiri (dist Balasore) 14, Tihidi (dist Bhadrak) 14, Akhuapada (dist Bhadrak) 13, Aul (dist Kendrapara) 12, Binjharpur (dist Jajpur) 11, Remuna (dist Balasore) 11, Kaptipada (dist Mayurbhanj) 10, Soro (dist Balasore) 10, G B Nagar (dist Mayurbhanj) 10, Ghasipura (dist Keonjhar) 9, Basudevpur (dist Bhadrak) 9, Balasore (dist Balasore) 9, Nh5 Gobindpur (dist Balasore) 9, Chandanpur (dist Mayurbhanj) 9, Betanati (dist Mayurbhanj) 8, Balimundali (dist Mayurbhanj) 8, Kusumi (dist Mayurbhanj) 8, Derabis (dist Kendrapara) 8, Bahanga (dist Balasore) 8, Jaipur (dist Balasore) 8, Chandikhol (dist Jajpur) 8, Hatadihi (dist Keonjhar) 7, Samakhunta (dist Mayurbhanj) 7, Anandpur (dist Keonjhar) 7, Nischintakoili (dist Cuttack) 7, Pattamundai (dist Kendrapara) 7, Kendrapara (dist Kendrapara) 7, Kendrapada (dist Kendrapara) 7,
- ❖ Gangetic West Bengal: Panskura (dist East Medinipur) 20, Nandigram (East Medinipur) 17, Garbeta (West Medinipur) 17, Barrackpur (dist North 24 Parganas) 17, Shyampur Howrah (dist Howrah) 16, Harinkhola (dist Hooghly) 15, Alipore (dist Kolkata) 12, Durgachack (dist East Midnapore) 12, Diamond Harbour (dist South 24 Parganas) 11, Kalyani (dist Nadia) 11, Amtala (dist Murshidabad) 11, Uluberia (dist Howrah) 11, Midnapore(cwc) (dist West Midnapore) 11, Mohanpur (dist West Midnapore) 11,

Midnapore (dist West Midnapore) 11, Panagarh (dist Paschim Bardhaman) 11, Burdwan (dist Purba Bardhaman) 10, Kalaikunda (dist West Midnapore) 10, Dum Dum (dist North 24 Parganas) 10, Mo Saltlake (dist North 24 Parganas) 10, Mankar (dist Purba Bardhaman) 9, Gheropara (dist Birbhum) 9, Lalgarh (dist Jhargram) 9, Manteswar (dist Purba Bardhaman) 9, Debagram (dist Nadia) 8, Kharagpur (dist West Midnapore) 8, Canning (dist South 24 Parganas) 8, Sri Niketan (dist Birbhum) 8, Labpur (dist Birbhum) 7, Bankura(cwc) (dist Bankura) 7, Suri (dist Birbhum) 7, Suri (dist Birbhum) 7, Mangalkote (dist Purba Bardhaman) 7,

❖ Jharkhand: Maheshpur (dist Pakur) 8, Pakuria (dist Pakur) 7;

#### **Realised Wind:**

- ❖ **Realised:** At the time of landfall, the estimated maximum sustained wind speed was about 100-110 kmph gusting to 120 kmph over Kendrapara and Bhadrak districts of Odisha. Realised estimated wind distribution in the tropical cyclone field during the it's life cycle is presented in **Fig.16**.

#### **Realised Storm Surge:**

- ❖ Maximum estimated storm surge of height 1-2 m inundated low-lying areas of Kendrapara and Bhadrak districts of Odisha during landfall. Realised estimated storm surge is presented in **Fig. 17**.

#### **10. 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).

#### **11. Acknowledgements:**

We acknowledge the contribution of all sister organisations of Ministry of Earth Sciences including National Centre for Medium Range Weather Forecasting (NCMRWF), Indian National Centre for Ocean Information Services (INCOIS), National Institute of Ocean Technology (NIOT), Indian Institute of Tropical Meteorology (IITM) Pune. The support from various Divisions/Sections of IMD including Area Cyclone Warning Centre (ACWC) Kolkata & Chennai, Cyclone Warning Centres Bhubaneswar & Visakhapatnam, Meteorological Centre Port Blair, Doppler Weather Radar centres at Paradip & Gopalpur and various coastal observatories in Odisha & West Bengal is duly acknowledged. The contribution from Numerical Weather Prediction Division, Satellite and Radar Divisions, Surface & Upper Air Instruments Divisions, Agromet Advisory Services Division, Information System and Services Division, National Weather Forecasting Centre and Cyclone Warning Division at IMD is also duly acknowledged. India Meteorological Department (IMD) and RSMC New Delhi duly acknowledge contribution from WMO and WMO/ESCAP member countries for observational data. The contribution from all the stakeholders and disaster management agencies who contributed to the successful monitoring, prediction and early warning service of SCS DANA is also duly acknowledged.

**All graphics are available in Annexure 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)

Date	Time (UTC)	Lat.	Long.	CI No.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained surface wind (kt)	Estimated Pressure drop at the Centre (hPa)	Grade
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						

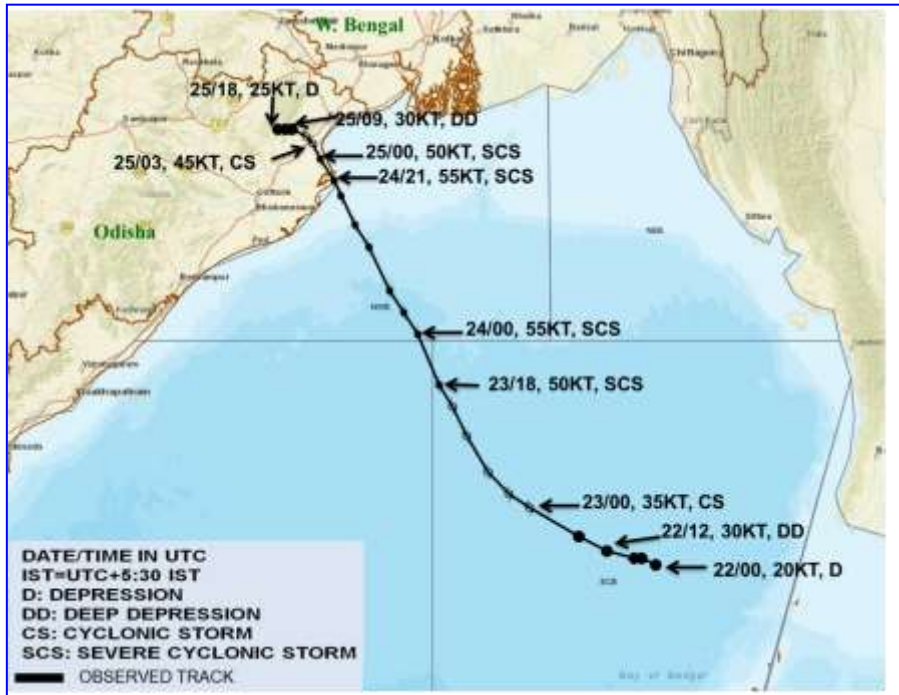


Fig. 1: Observed track of severe cyclonic storm “DANA” over eastcentral Bay of Bengal during 22-26 October, 2024

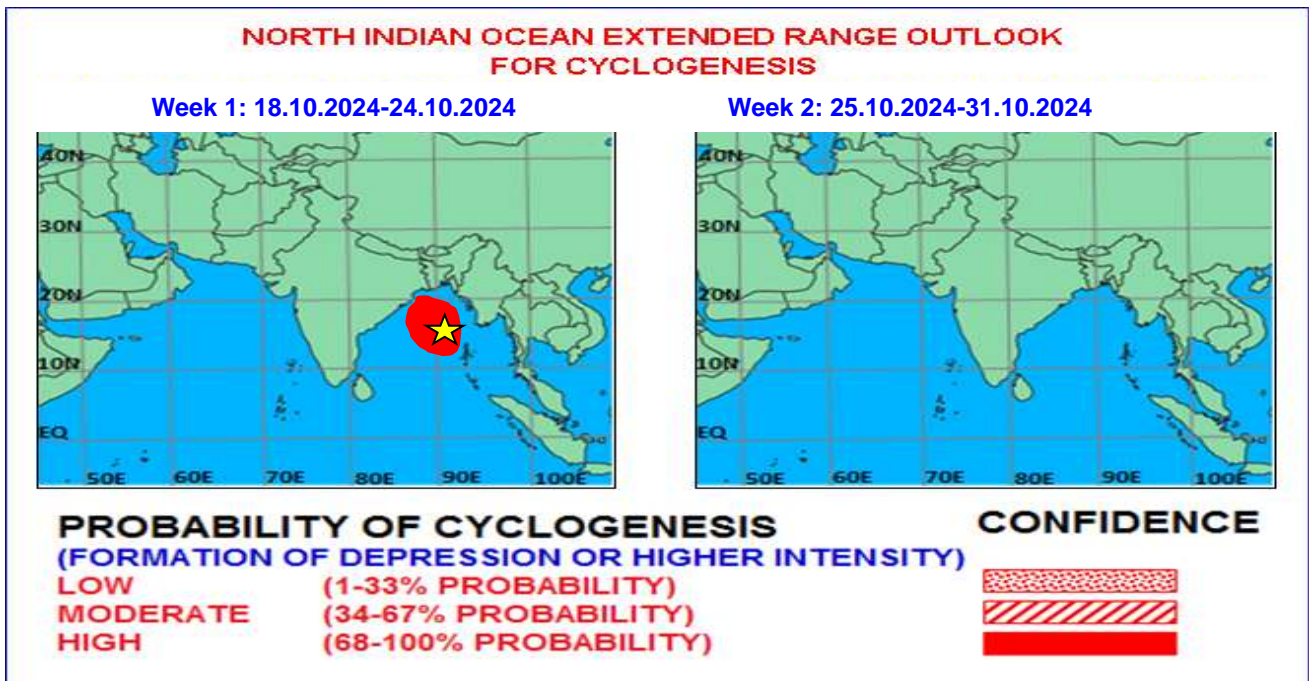


Fig. 2: Extended Range Outlook issued on 17<sup>th</sup> October, indicating probable area of genesis (formation of depression) and likely movement towards Odisha coast with High confidence.

: Probable Area of cyclogenesis, : Actual Point of genesis



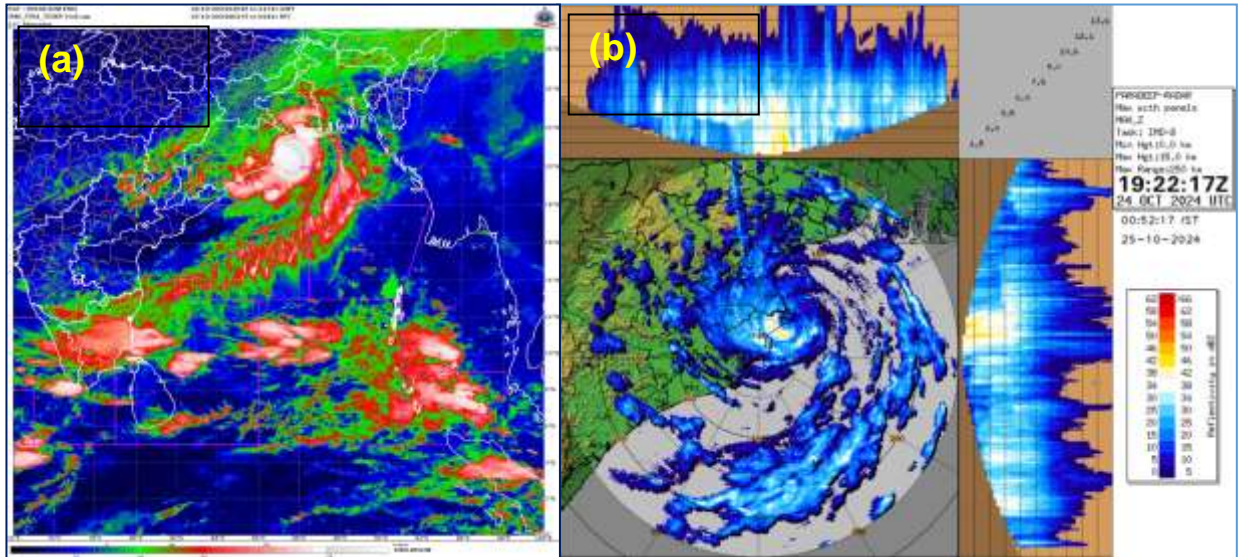


Fig. 3: Typical (1) INSAT 3D imagery at 0215 IST of 25<sup>th</sup> October and (b) Doppler Weather Radar Paradip imagery at 0052 IST of 25<sup>th</sup> during severe cyclonic storm “DANA”

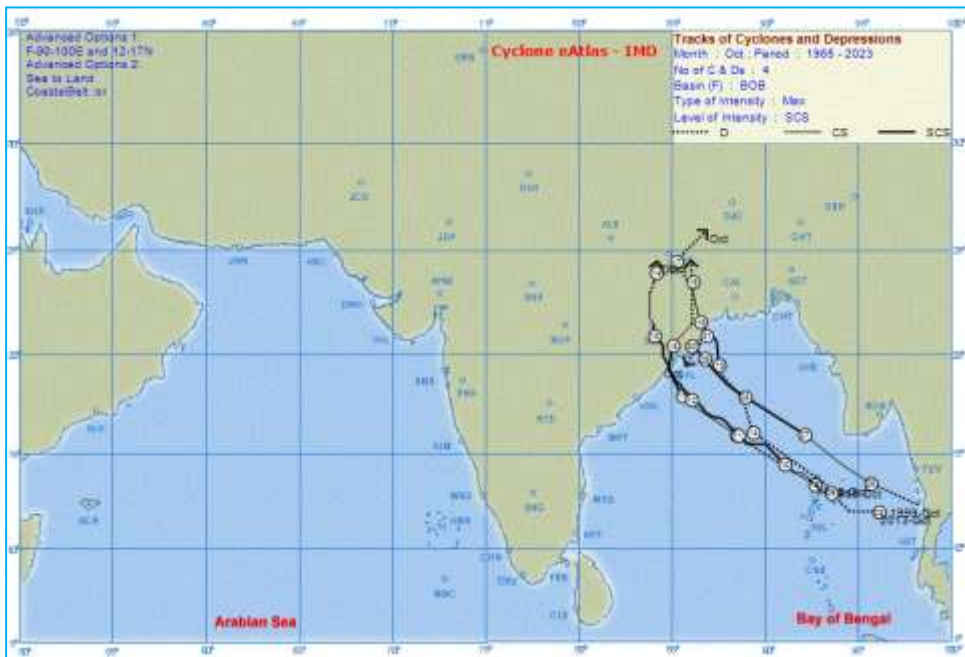


Fig. 4: Tracks of cyclonic storms developing from a depression in the grid (12-17N and 90-100 E) crossing Odisha coast in the month of October during the period 1965-2023

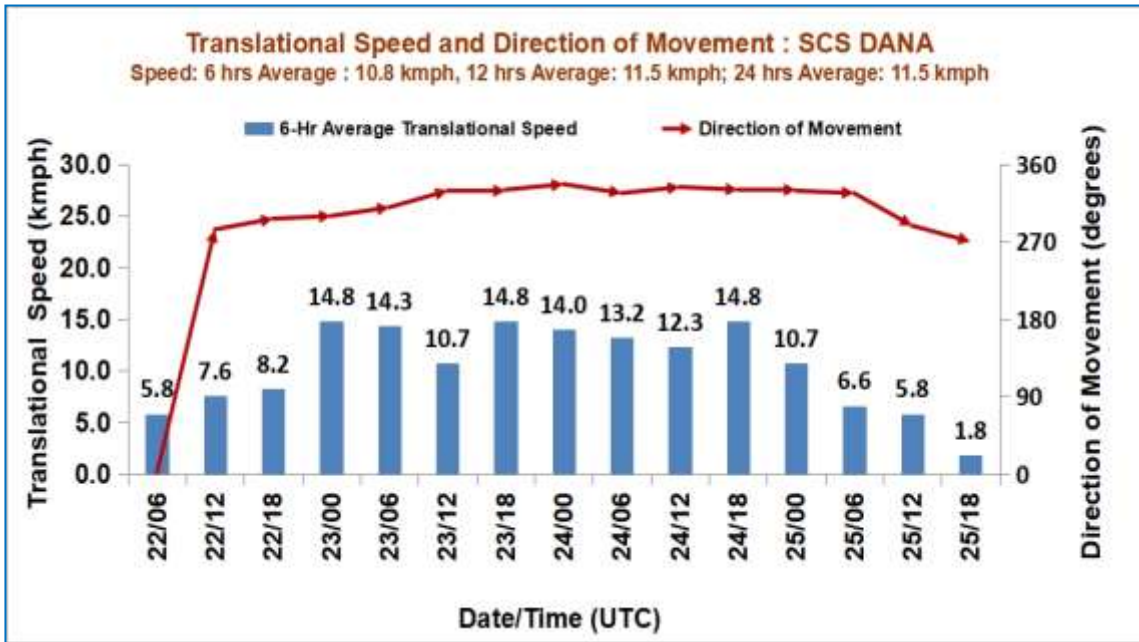


Fig. 5: Six hourly average translational speed and direction of movement during life cycle of “SCS DANA”

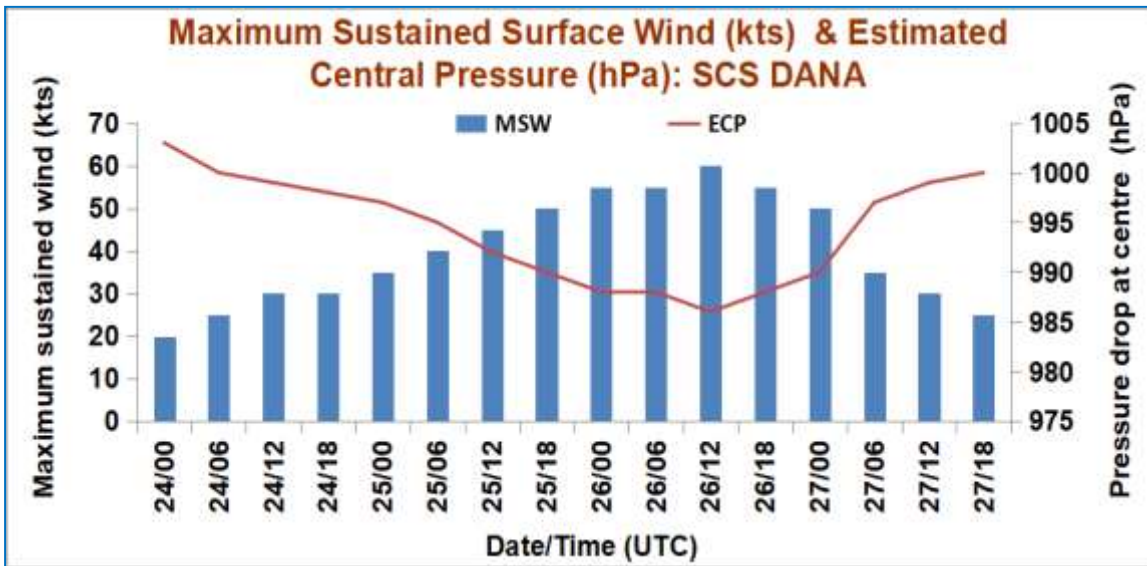
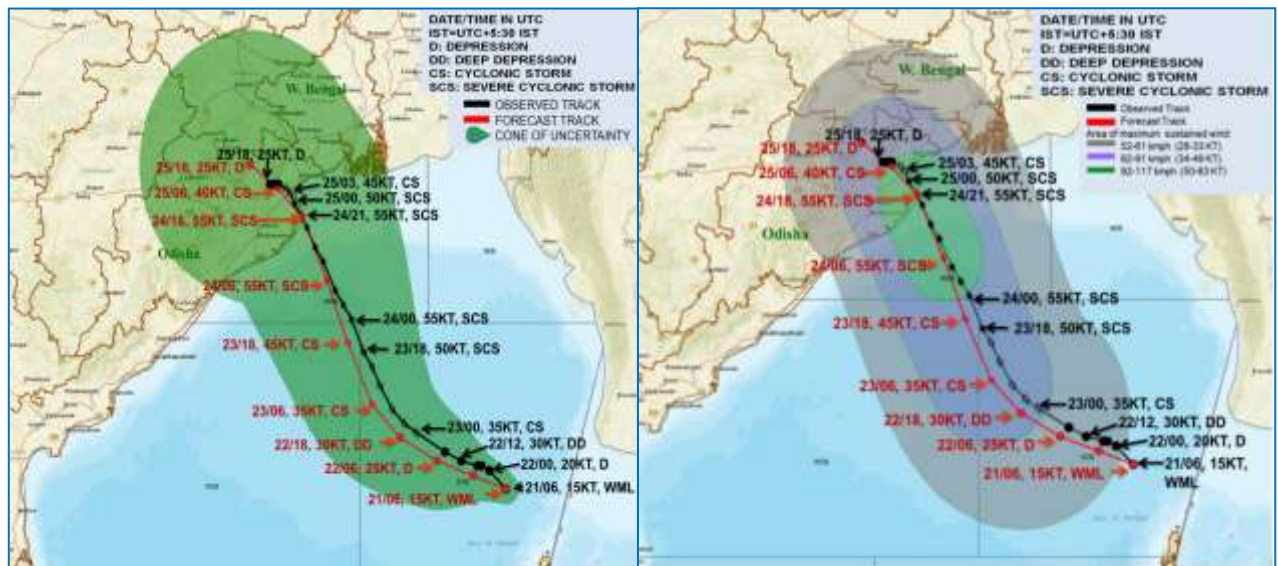
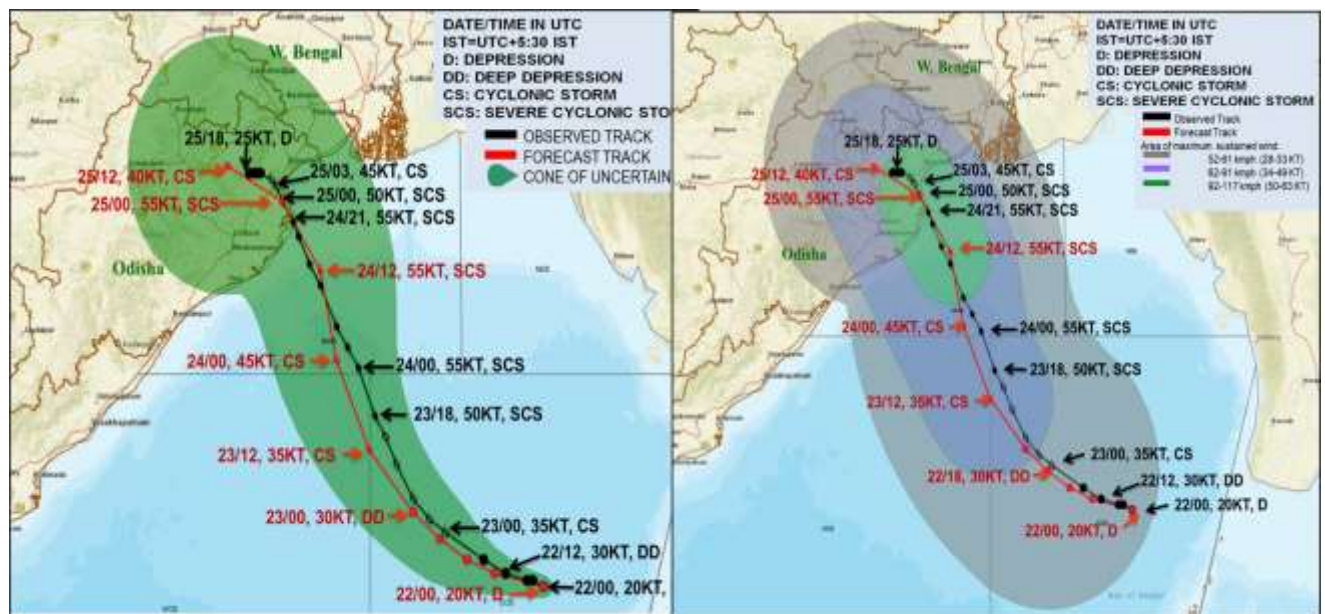


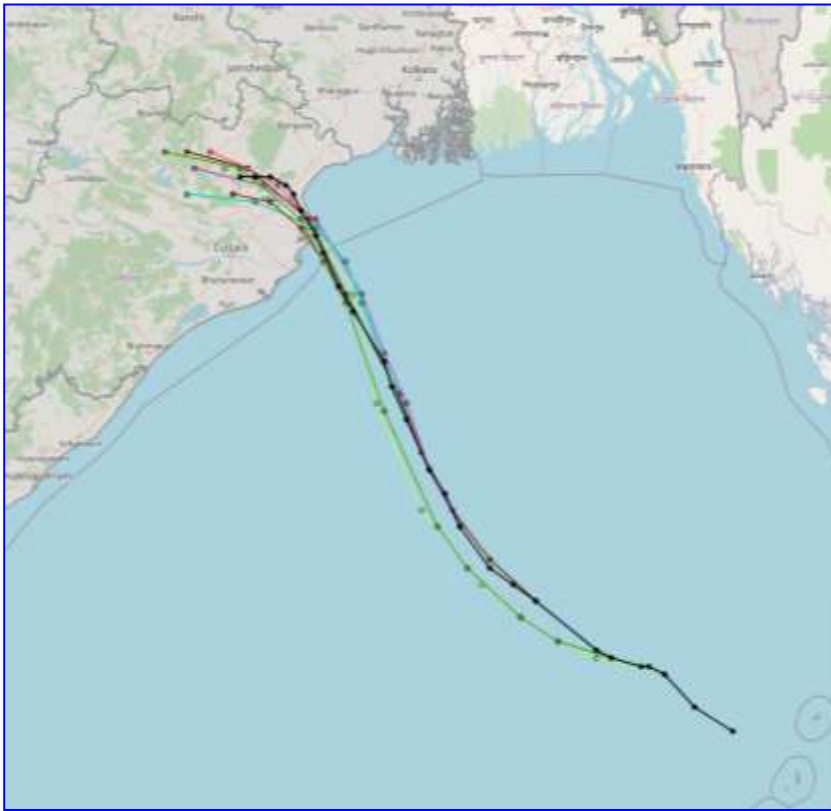
Fig. 6: Six hourly Maximum sustained wind speed and estimated central pressure during life cycle of “SCS DANA”



**Fig. 7: 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**



**Fig. 8: 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**



- Forecast Track of 22/00
- Forecast Track of 22/12
- Forecast Track of 23/00
- Forecast Track of 23/12
- Forecast Track of 24/00
- Forecast Track of 24/12
- Forecast Track of 25/00
- Forecast Track of 25/12
- OBSERVED**

**Fig. 9: 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**

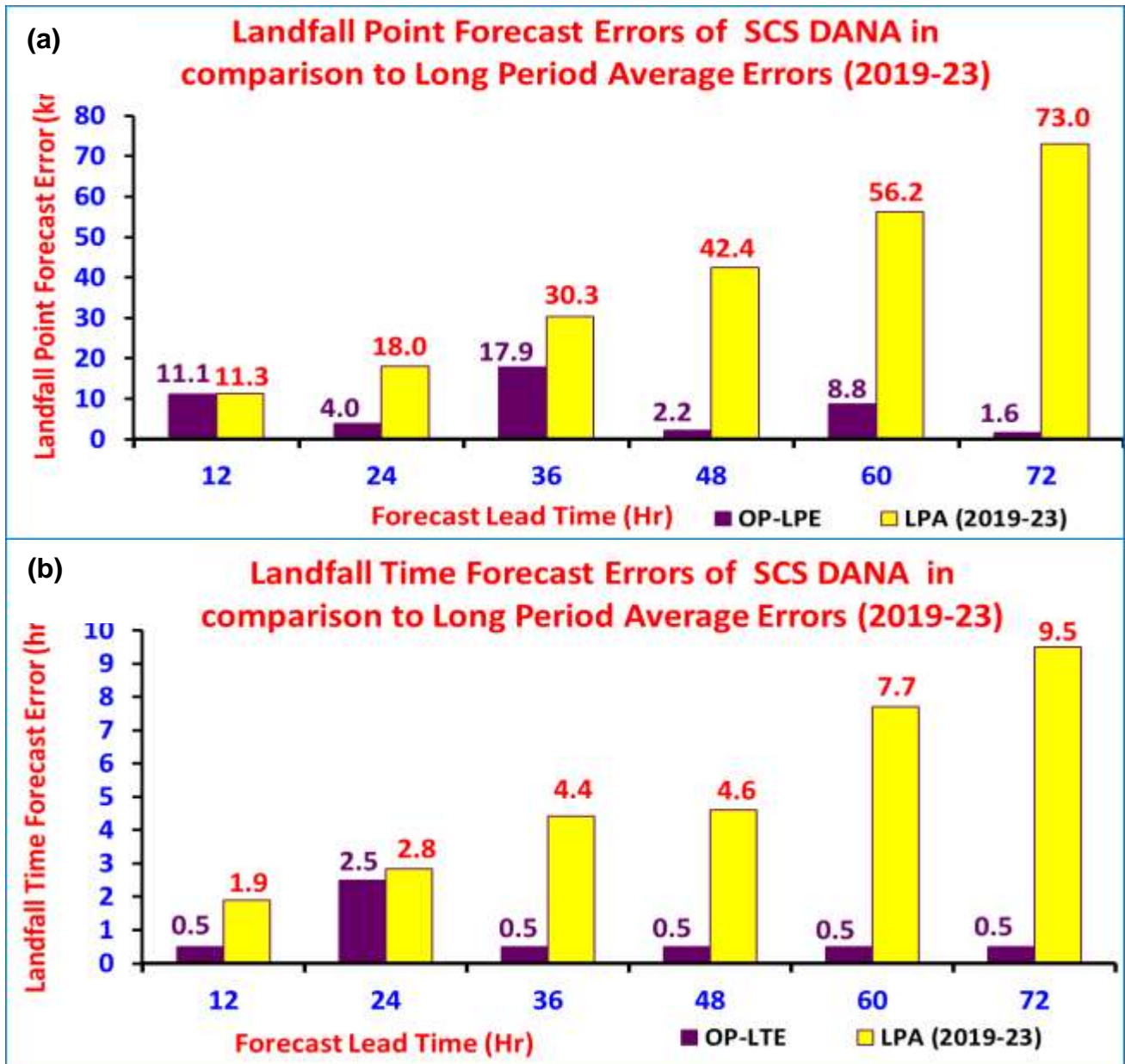


Fig. 10: (a) Landfall point and (b) time errors against the long period average (LPA) errors based on 2019-2023

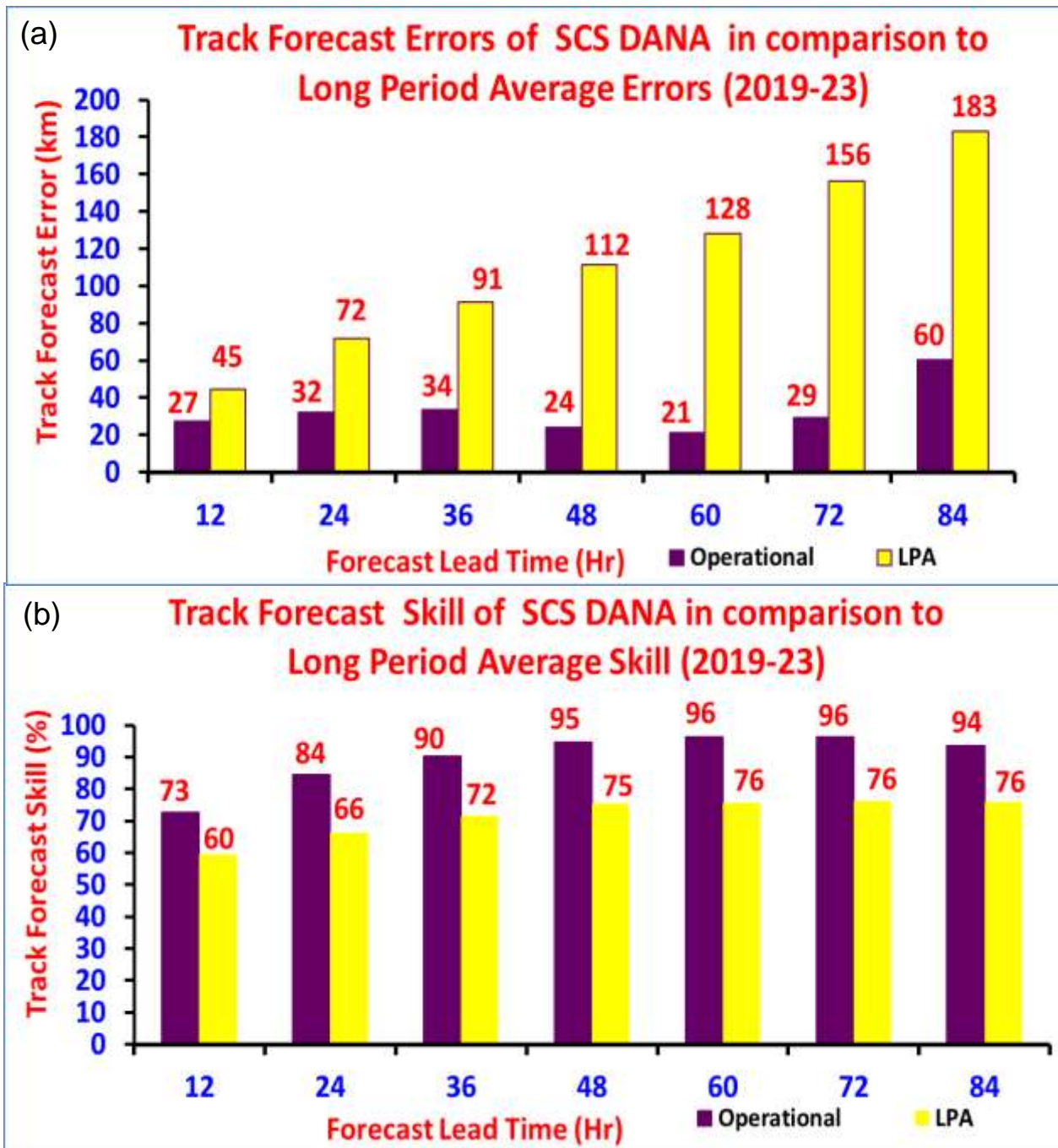


Fig. 11: Track forecast errors and (b) skills against Climatology & Persistence (CLIPER) compared to long period average (LPA) errors & skills respectively based on 2019-2023

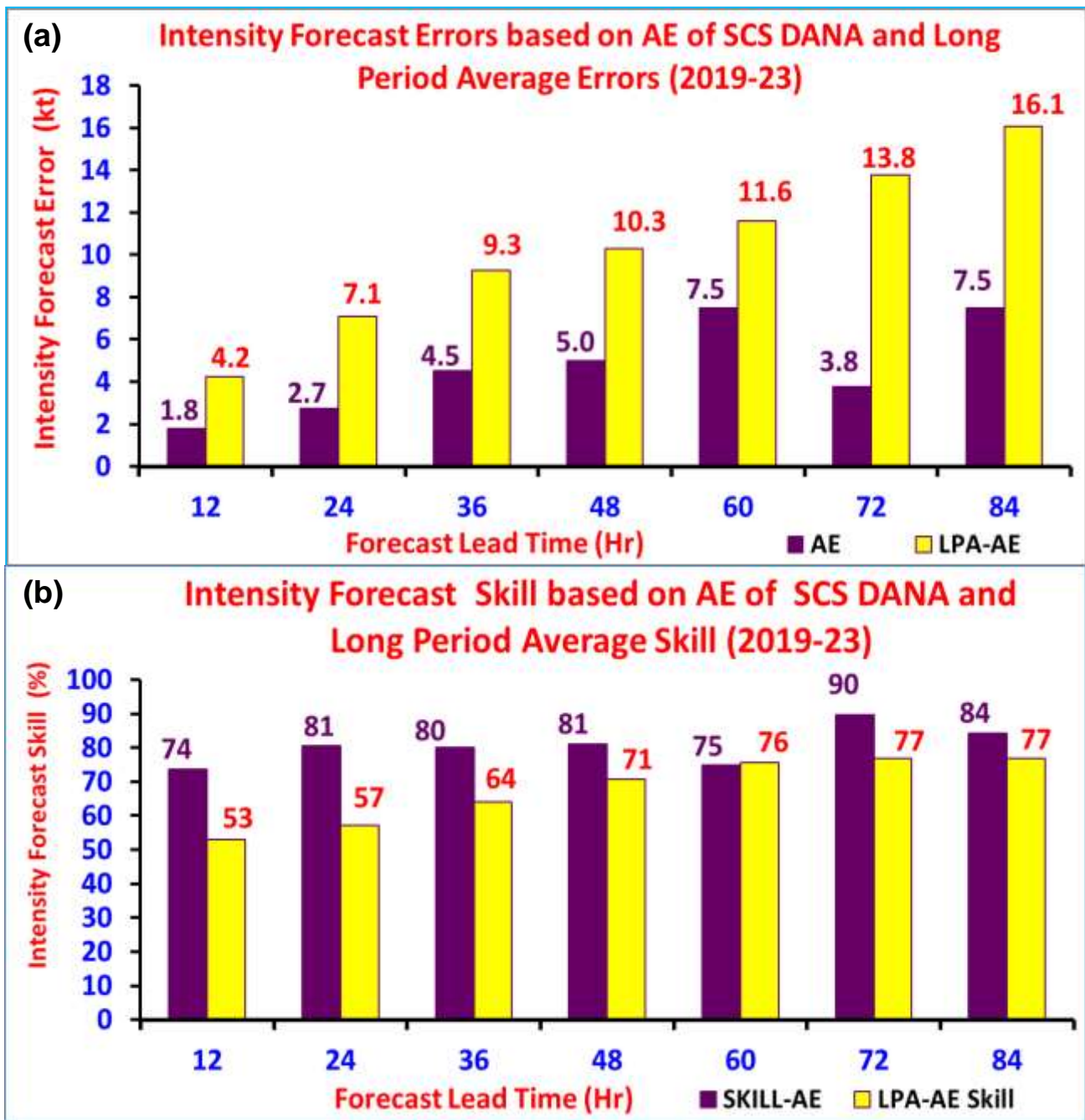


Fig. 12: Intensity forecast errors (AE) and (b) skills against Persistence compared to long period average (LPA) errors & skills respectively based on absolute error (AE).

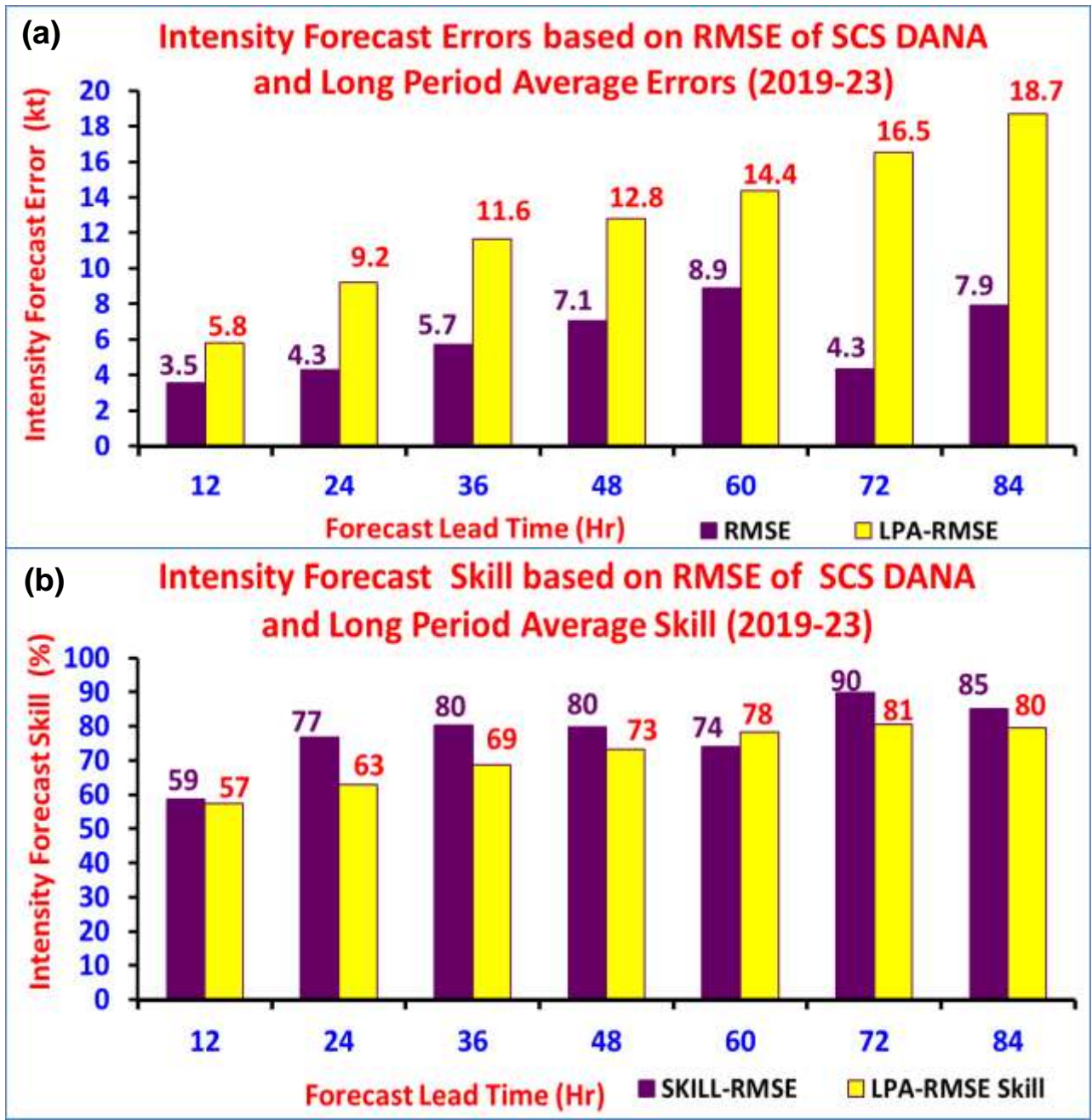
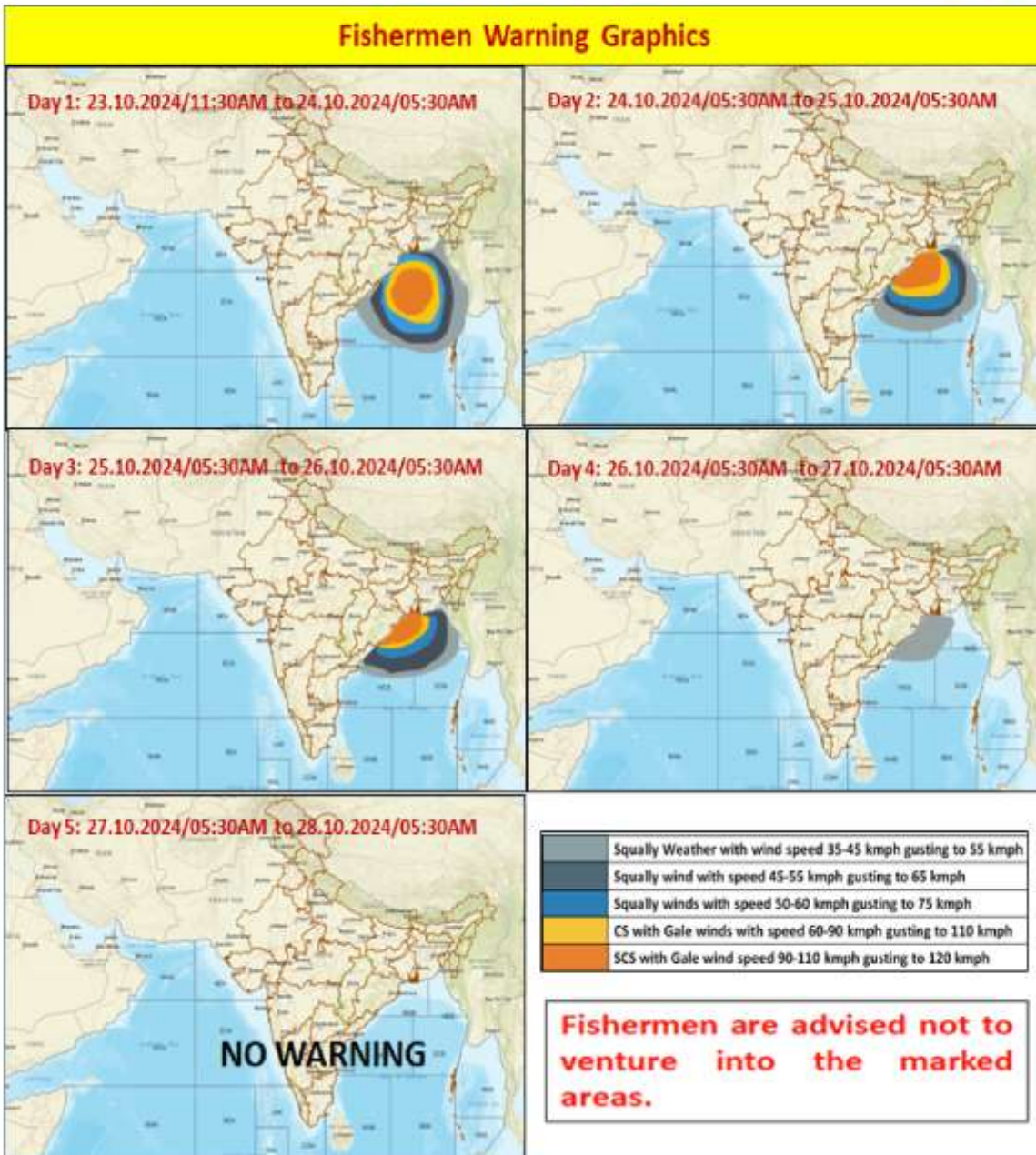
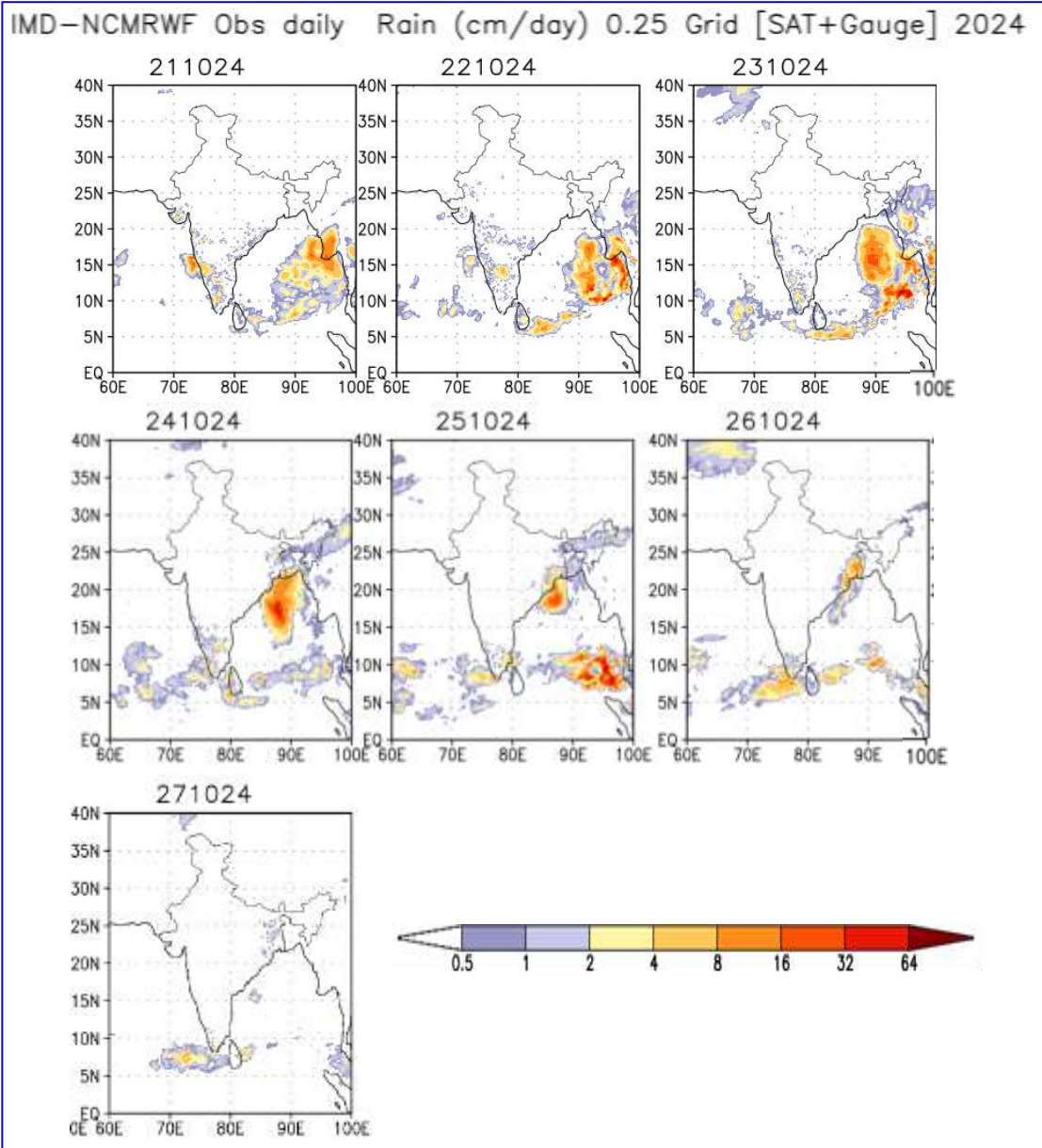


Fig. 13 (a): Intensity forecast errors (RMSE) and (b) skills against Persistence forecast compared to long period average (LPA) errors & skills respectively





**Fig. 14: Typical Fishermen Warning graphics issued on 23<sup>rd</sup> October 2024**



**Fig. 15: 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**

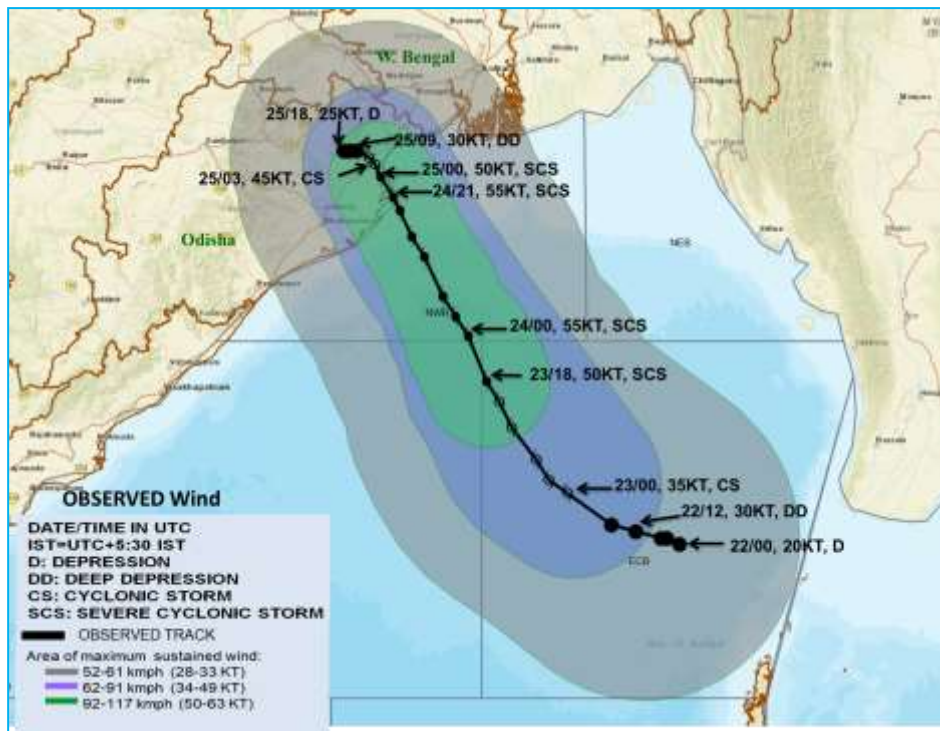


Fig. 16: Estimated maximum sustained wind during the life cycle of SCS DANA

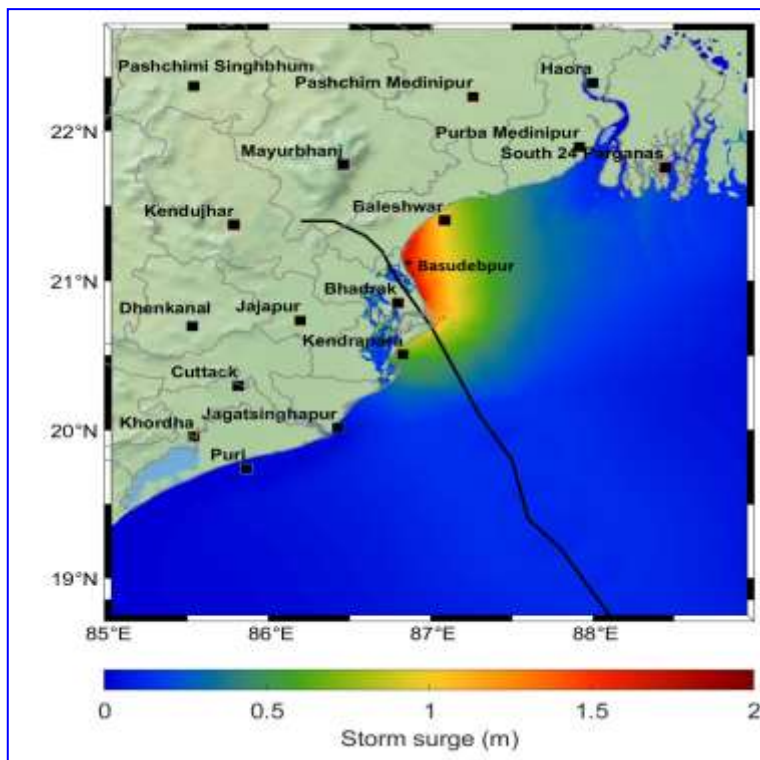


Fig.17: Estimated storm surge based on best track parameters of SCS DANA