Cyclonic Storm "FENGAL" over the Bay of Bengal (23th November– 02nd December, 2024): A Report

Typical (a) INSAT 3D imagery at 0245 IST of 30th November and (b) Doppler Weather Radar Chennai imagery at 0310 IST of 30th November during cyclonic storm "FENGAL"

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1. Life History of "FENGAL":

- A low pressure area formed over east Equatorial Indian Ocean (EIO) and adjoining Southeast Bay of Bengal (BoB) in the morning (0830 hours IST/0300 UTC) of 23rd November.

- Moving west-northwestwards, it became well marked low pressure area and lay centred in the morning (0830 hours IST/0300 UTC), of 24th November over southeast BoB and adjoining East EIO.

- It moved west-northwestwards, intensified into a depression and lay centred in the morning (0830 hours IST/0300 UTC) of 25th November over central parts of south Bay of Bengal and adjoining East Equatorial Indian Ocean.

- Moving west-northwestwards, depression over central parts of south Bay of Bengal and adjoining East Equatorial Indian Ocean intensified into a Deep Depression over Southwest Bay of Bengal and lay centred in the morning (0830 hours IST /0300 UTC), of 26th November over the same region.

- Continuing to move west-northwestwards, it intensifies into a cyclonic storm "FENGAL" [pronounced as FEINJAL] over Southwest Bay of Bengal in the afternoon (1430 hours IST/ 0900 UTC) of 29th November. It moved northwestwards and lay centred in the morning (830 hours IST/ 0300 UTC) of 30th November over the same. Region.

- It then initially moved westwards then west-southwestwards and crossed North Tamil Nadu & Puducherry coasts close to Puducherry, between (2230 hours IST/ 1700 UTC) and 2330 hours IST/1800 UTC) of 30th November as a cyclonic storm with a wind speed of 70-80 kmph gusting to 90 kmph.

- Thereafter, it remained practically stationary, weakened into a deep depression and lay centered in the forenoon (1130 hours IST/ 0600 UTC) of 1st December over the same region.

- Continuing to move further west-northwestwards, it weakened into a depression over the same region in the evening (1730 hours IST/ 1200 UTC) of 1st December.

- Thereafter, it moved nearly westwards and weakened into a Well-Marked Low Pressure Area over North Interior Tamil Nadu in the early morning (0530 hours IST/ 0000 UTC) of 2nd December.

- The best track parameters are presented in **Table 1**. The observed track of the severe cyclonic storm "FENGAL" is presented in **Fig.1**. **(All Figures and Tables are given Annexure-1)**

2. Monitoring of CS, "FENGAL"

India Meteorological Department (IMD) maintained round the clock watch over the north Indian Ocean and the cyclone was monitored since 14th November in Extended range outlook with low probability and with High probability on 21st November, about 11 days prior to formation of depression on 25nd November. First information about likely formation of a cyclonic circulation over south Andaman Sea with an advisory for continuous watch was issued in the Daily Report under Tropical Cyclone Forecasting Programme dated 19th November (about 2 days ahead of formation of cyclonic circulation on 21st November). Subsequently, the extended range outlook issued on 21th November (about 4 days ahead of formation of depression over the Bay of Bengal and 9 days ahead of landfall) indicated with high confidence (67-100% probability) likelihood of the formation of a depression over the central parts of south Bay of Bengal around 25th November and movement towards cross north Sri Lanka coast and south Tamil Nadu Coast (**Fig. 2**). Actually, the depression formed over southeast Bay of Bengal on 25th November.

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 3rd cyclone of the year 2024 over the Bay of Bengal. Climatologically, Tracks of cyclones crossing TN coast during 20-30 November (1965-2023). Total 15 developed in November and out of these 6 during 20-30 November (**Fig.4**). The severe cyclonic storm (50 kt) in 1985 formed over eastcentral BoB on 13th October and crossed North Odisha coast to the south of Balasore around 2300 UTC of 15th October, 1985 as a severe cyclonic storm (50 kt). Other storm in 1999, developed over eastcentral BoB on 15th October and

crossed Odisha coast near Gopalpur in the early morning of 18th October, 1999 (0230 hrs IST of 18th October/ 2100 UTC of 17th 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 29th 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 12th October, 2013.

(ii)   Movement:
Fengal had a recurving track. It changed its path 7 times during its life period. The six hourly average translational speed of "FENGAL" was 7.9 kmph against the normal speed of 12.9 kmph for CS 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 30th November, it moved further slowly. As a result, the landfall process which commenced in the midnight (1900 hours IST) of 30th November, continued for 6.5 hours till morning (01:30 hours IST) of 1st December. After landfall, it remained practically stationary for almost 15 hours and then moved slowly west-northwestwards and weakened into a well-marked low pressure area over North Tamil Nadu by 0530 hrs IST.

(iii)   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 (0830 hours IST of 23rd November) to well-marked low pressure area (0830 hours IST/0300 UTC of 24st November) to depression (0830 hours IST/0300 UTC of 25th November), deep depression (0830 hours IST /0300 UTC of 26th November) and cyclonic storm (1430 hours IST/ 0900 UTC of 29th November). 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 45 kts in the early morning of 30th November (0530 hours IST/ 0000 UTC) (Fig. 6) over northwest BoB when the system entered into an area of high sea surface temperature (≥ 300C). Thereafter, due to land interactions and cold dry air incursion from northwest, it weakened gradually and crossed coast with wind speed of 40 knots (70-80 gusting to 90 kmph). After landfall, it rapidly weakened in the forenoon (1130 hours IST/ 0600 UTC) of 1st December and to a

well-marked low pressure area over North Interior Tamil Nadu in the early morning (0530 hours IST/ 0000 UTC) of 2nd December.

(iv) Track length:
The total track length of severe cyclonic storm "FENGAL" was 1235 km.

(v) Life Period:
The total life period (depression to depression) of "FENGAL" was 6 days and 6 hours against the normal of 3 days & 16 hours for cyclonic storm category over the BoB in post-monsoon season based on the data of 1990-2013.

(vi) 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 2.8×10^2 knots, 1.09×10^4 knots^2 and $.44 \times 10^6$ knots^3 respectively against normal of 1.00×10^4 knots, 0.40×10^6 knots^3 for CS during post monsoon season over BoB based on the data during 1990-2020.

(vii) Cyclone Warnings:
- ❖ **Cyclone Alert** (Orange Message) for North Tamil Nadu, Puducherry and adjoining south Andhra Pradesh Coasts was issued at 0530 hours IST of 29th November with the formation of Deep Depression over Southwest BoB (about 1 day and 18 hours ahead of landfall).

- ❖ The landfall close to close to Puducherry during early hours of 30th November was first indicated in the first bulletin issued at 2330 hrs IST of 28th November in the graphical track forecast issued by IMD (about 2 days ahead of landfall).

- ❖ **Cyclone Warning** (Red Message) North Tamil Nadu, Puducherry and adjoining south Andhra Pradesh Coasts was issued on 1430 hours IST of 29th November on formation of Deep Depression over southwest BoB (about 24 hours ahead of landfall)

- ❖ **Post Landfall Outlook** (Red Message) for Red Message for North Tamil Nadu, Puducherry and adjoining south Andhra Pradesh was issued at 0830 hours IST of 30th November (about 15 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 south Andaman Sea around 21st November was issued in the daily report on 19th November 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 2 days ahead of the formation of upper air cyclonic circulation over south Andaman Sea on 21st November).

❖ First information about likelihood of cyclogenesis (formation of Depression) with High confidence (67-100%) was issued in the extended range outlook issued on 21st November (about 4 days ahead of formation of depression on 25th 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) 24th November when the system lay as a Well marked low pressure area southeast Bay of Bengal and adjoining East Equatorial Indian Ocean, depression by 25th and cyclonic storm by 27th November over Southwest Bay of Bengal. It was also indicated that the system would reach Tamil Nadu-Puducherry coasts between Karaikal and Mahabalipuram close to Puducherry as a cyclonic storm during evening of 30th November.

❖ 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 0830 hrs IST of 24th November.

ii) Track, intensity and landfall forecast performance

❖ With the intensity of Deep Depression on 29th November (1100 IST), it was indicated that system will cross north Tamil NaduPuducherry coasts between Karaikal and Mahabalipuram close to Puducherry as a cyclonic storm with a wind speed of 70-80 kmph gusting to 90 kmph during afternoon 30th November.

❖ The warnings were regularly updated every six hourly and three hourly at the depression and cyclonic storm stage respectively with track, intensity & landfall forecast.

❖ The landfall point forecast errors for 24, 48 and 60 hrs lead period were 5.5, 22.3 and 15.3 km respectively against the long period average errors of 18, 42 and 56.2 km based on data of 2019 - 23 (**Fig. 7a**). The landfall time forecast errors for 24, 48 and 60 hrs lead period were 7, 13 and 13 hours respectively against the long period average error of 2.8, 4.6 and 7.7 hours respectively based on the data of 2019-23 (**Fig. 7b**). **The operational landfall point & time forecast errors were markedly less than the LPA errors for all lead periods. There was 10-20km error in landfall point prediction for all lead periods upto 60 hours.**

❖ The track forecast errors for 24, 48 and 72 hrs lead period were 86, 124 and 151 km against the long period average errors of 72, 112 and 156 km respectively based on the data of 2019-23 (**Fig. 8a**). The track forecast skills calculated against Climatology & Persistence (CLIPER) forecast for 24, 48 and 72 hrs lead period were 40.6, 64 and 76.1 % respectively against the long period average skills of 66, 75 and 76% respectively based on the data of 2019-23 (**Fig. 8b**).

❖ The absolute errors (AE) in intensity (wind) forecast for 24, 48 and 72 hrs lead period were 4.2, 7.3 and 5.5 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. 9a**). The skills in intensity forecast based on AE

calculated against the persistence-based forecasts for 24, 48 and 72 hours lead period were 15.8, 33.3 and 72.1 % against the long period average skills of 57.2, 70.6 and 77% based on data of 2019-23 respectively (**Fig. 9b**). **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 5.4, 11 and 8.5 knots against the long period average errors of 9.2, 12.8 and 16.5 knots based on data of 2019-23 respectively (**Fig.10a**). The skills in intensity forecast based on RMSE calculated against persistence-based forecast for 24, 48 and 72 hrs lead period were 62.9, 73.4 and 80.6% against the long period average skills of 62.9, 73.4 and 80.6% based on data of 2019-23 respectively (**Fig. 10b**). **For all lead periods, the operational intensity forecast errors were less and the skills were more than the** long period average**.**

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 24th November morning till the system weakened into a 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) ≥28 and ≥34 knots wind in four geographical quadrants of cyclone were issued along with graphics, commencing from 24th November 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 "FENGAL" the advisories for winds & sea condition for fishermen over Bay of Bengal were also provided to WMO and WMO/ESCAP Panel countries.

- **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 18 bulletins under 3 stage warnings system were issued including 3 cyclone alert, 11 cyclone warnings for North Tamil Nadu, Puducherry and adjoining south Andhra Pradesh Coasts and 4 post-landfall outlook for interior districts of Odisha were issued during cyclone "FENGAL".
- **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 20th November by IMD HQ and Cyclones Warning Centres of IMD. Typical example of fishermen warning graphics issued on 29th November is presented in **Fig. 11**.
- **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 "FENGAL". 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 25th November 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.

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	40 & 1 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 Andaman & Nicobar Islands, Tamil Nadu, Andhra Pradesh, Puducherry and Odisha.

2.	Special bulleting by DGM IMD	3	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	41	1. IMD's website 2. WMO/ESCAP member countries through GTS, E-mail and Whats App
4	Flash Flood Guidance Bulletin	17	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	27	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	18	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	20	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	33 each	Issued to Port Authorities, Coast Authorities, offshore/onshore industries, Indian Oil Corporation, Indian Air Force and Indian Coast Guard, Nuclear Power Plants by email to concerned stake holders

9	Press Release	9	Disaster Managers, Media persons by email and uploaded on website
10	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
11	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).
12	Warnings through WhatsApp	Every 3 hourly	Warnings and bulletins were shared through WhatsApp with Disaster managers, media, WMO/ESCAP Panel member countries
13	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		
		ACWC Chennai	CWC Thiruvananthapuram	CWC VZG
1.	Coastal Weather Bulletins	26	21	30
2.	Fishermen Warnings issued	32	47	42
3.	Port Warnings	10	25	23
4.	Death reported (along with source)	4	-	3

8. Realized Weather

8.1. Realised rainfall

The system caused heavy to extremely heavy rainfall activity over Tamil Nadu, Puducherry & Karaikal southern states of India including Kerala. It is seen that light to moderate rainfall occurred at many places over Tamil Nadu, Puducherry & Karaikal with heavy rainfall at isolated places over Andaman & Nicobar Islands on 26th November.

Light to moderate rainfall occurred at many places with heavy to very heavy rainfall at isolated places on 27th November and heavy rainfall at a few places over on 30th November over Tamil Nadu, Puducherry & Karaikal.

Light to moderate rainfall occurred at most places with extremely heavy rainfall at many places over Tamil Nadu, Puducherry & Karaikal and heavy rainfall at isolated places over Kerala on 01st December.

Light to moderate rainfall occurred at most places with extremely heavy rainfall at many places over Tamil Nadu, Puducherry & Karaikal, heavy to very rainfall at a few places over Kerala and heavy rainfall at isolated places over Coastal Andhra Pradesh & Yanam on 02nd December.

NCMRWF IMD satellite gauge merged data plot showing 24 hours accumulated rainfall ending at 0300 UTC of dates during 21st – 27th November presented in Fig. 12a and 28th November – 04th December, 2024 presented in Fig 12b.

NCMRWF IMD satellite gauge merged data plot showing 24 hours accumulated rainfall ending at 0300 UTC of 21st November to 27th November and 0300 UTC of 28th November – 4th December is presented in **Fig. 12a and 12b** respectively.

24hours cumulative rainfall (≥ 7 cm) ending at 0830 hours IST of date:

26th November, 2024:

Andaman & Nicobar Islands: Car Nicobar (Nicobar) 7,

27th November, 2024

Tamil Nadu, Puducherry &Karaikal: Nagapattinam (Nagapattinam) 19, Kodiayakarai (Nagapattinam), Nagapattinam (Nagapattinam), Velankanni (Nagapattinam) 18 each, Tirupoondi (Nagapattinam) 14, Manali (Chennai), Thirukuvalai (Nagapattinam) 13 each, Tiruvarur (Thiruvarur), Vedaranyam (Nagapattinam) 12 each, Mahabalipuram (Chengalpattu), Cheyyur (Chengalpattu), Thalaignayer (Nagapattinam), Sirkali (Mayiladuthurai), Kathivakkam (Chennai), Marakkanam (Villupuram), Vadakuthu (Cuddalore), Mahabalipuram (Chengalpattu), Tarangambadi (Mayiladuthurai) 11 each, Mayiladuthurai (Mayiladuthurai), Thiruthuraipoondi (Thiruvarur), Kollidam (Mayiladuthurai), Tiruvarur (Thiruvarur), Cuddalore Collector Office (Cuddalore), Cuddalore (Cuddalore), Karaikal (Karaikal), Nannilam (Thiruvarur) 10 each, Muthupet (Thiruvarur), Mannudi (Thiruvarur), Ayyampettai (Thanjavur), Needamangalam (Thiruvarur), Karaikal (Karaikal), Madukkur (Thanjavur), NIOT_Pallikaranai (Chennai) 9 each, Bahour (Puducherry), Manalmedu (Mayiladuthurai), Nctpl M ECR (Chengalpattu), Mayiladuthurai (Mayiladuthurai), Manalmedu (Mayiladuthurai), Adiramapattinam (Thanjavur), Ayinkudi (Pudukkottai), Red Hills (Tiruvallur), Pattukottai (Thanjavur), Mylam (Villupuram), Thirukalukundram (Chengalpattu), Puducherry (Puducherry), Vettikadu (Thanjavur), Ennore (Tiruvallur), Orthanad (Thanjavur), Annamalai Nagar (Cuddalore), Puducherry Town (Puducherry) 8 each, Chidambaram (Cuddalore), Puducherry (Puducherry), Puzhal (Chennai), Kodavasal (Thiruvarur), Valangaiman (Thiruvarur), NeivasalThenpathi (Thanjavur), Lower Anaicut (Thanjavur), Manjalaru (Thanjavur), Perungudi (Chennai), Taramani (Chennai), Puzhal (Tiruvallur), Nagudi (Pudukkottai), Madhavaram (Chennai),

Thirukkanur (Puducherry), Thiruvottiyur (Chennai), Parangipettai (Cuddalore), Vanamadevi (Cuddalore), Royapuram (Chennai), Adyar Eco Park (Chennai), Adyar (Chennai), Vilupuram (Villupuram), Sholinganallur (Chennai), Peravurani (Thanjavur), Pandavaiyar Head (Thiruvarur), Avadi (Tiruvallur), Sembanarkoil (Mayiladuthurai) 7 each;

30th November, 2024

Tamil Nadu, Puducherry &Karaikal: Ennore AWS (Tiruvallur) 13, Kathivakkam (Chennai) 12, Thiruvottiyur (Chennai), Tondiarpet (Chennai), Sholinganallur (Chennai), CD Hospital Tondiarpet (Chennai), Basin Bridge (Chennai) 9 each, Ponneri (Tiruvallur), Manali (Chennai), Ice House (Chennai), Chennai (N) (Chennai), Chennai Central (Chennai) 8 each, Adyar (Chennai), Alandhur (Chennai), Kolathur (Chennai), YMCA Nandnam (Chennai), Madhavaram (Chennai), Anna University ARG (Chennai), Chennai Collector Office (Chennai), DGP Office (Chennai), Sholinganallur (Chennai), Puzhal (Chennai), Hindustan_University (Chengalpattu), Manali New Town (Chennai), Vadapalani (Chennai) 7 each;

1st December, 2024

Tamil Nadu: Mylam (Villupuram) 51, Puducherry(Puducherry) 49, Puducherry(Puducherry) 48, Patthukannu(Puducherry) 45, Thirukkanur(Puducherry) 43, Puducherry Town (Puducherry) 40, Tindivanam (Villupuram) 37, Nemoor (Villupuram) 35,Bahour (Puducherry), Vallam (Villupuram) 32 each, Semmedu (Villupuram) 31, Valavanur (Villupuram), Koliyanur (Villupuram) 28 each,Vilupuram (Villupuram) 27, Gingee (Villupuram), Kedar (Villupuram) 25 each, Valathy (Villupuram), Vanur (Villupuram), Soorapattu (Villupuram), Marakkanam (Villupuram) 24 each, Cuddalore (Cuddalore), Avalurpettai (Villupuram) 23 each, Tiruvannamalai (Tiruvannamalai), Chetpet (Tiruvannamalai) 22 each, Jamunamarathur (Tiruvannamalai), Cuddalore Collector Office (Cuddalore), Anandhapuram (Villupuram), Uthiramerur (Kancheepuram) 21 each, Maduranthagam (Chengalpattu), Keelpennathur (Tiruvannamalai), Gummidipoondi(Tiruvallur), Chengalpattu Chengalpattu) 20 each, Avadi (Tiruvallur), Thirukalukundram (Chengalpattu), Vanamadevi (Cuddalore)19 each, Tiruttani (Tiruvallur), Arani (Tiruvannamalai), Mugaiyur (Villupuram), Arcot(Ranipet) 18 each, Kudithangi (Cuddalore), Cheyyar (Tiruvannamalai) 17 each, Thirukoilur (Kallakurichi), Vandavasi (Tiruvannamalai), Thamaraipakkam (Tiruvallur), Kalasapakkam (Tiruvannamalai), Kanjanur (Villupuram),Tambaram (Chengalpattu) 16 each, Thandarampettai (Tiruvannamalai), Kallakurichi (Kallakurichi), Kancheepuram (Kancheepuram), Wallajah (Ranipet), Cheyyur (Chengalpattu), MGR Nagar (Chennai), Ayanavaram Taluk Office (Chennai), Mundiyampakkam

(Villupuram), Kalavai PWD (Ranipet) 15 each, Yercaud (Salem), Cheyyar (Tiruvannamalai), Arakonam (Ranipet), Sholingur(distRanipet), Vembakkam (Tiruvannamalai), Panruti (Cuddalore), Pallipattu (Tiruvallur), Kallakurichi (Kallakurichi), Mahabalipuram (dist Chengalpattu), JayaEngg College (Tiruvallur) 14 each,Koratur (Tiruvallur), PalarAnicut (Ranipet), Uthukottai (Tiruvallur), Chembarabakkam (Tiruvallur), Kaveripakkam (Ranipet), R.K.Pet (Tiruvallur), DSCL Madampoondi (Kallakurichi), Sriperumbudur (Kancheepuram),Panapakkam (Ranipet), Walajabad (Kancheepuram), Red Hills (Tiruvallur),Poondi (Tiruvallur), BASL Manampoondi (Villupuram), R.K.Pet (Tiruvallur),Minnal (Ranipet), Tiruvallur (Tiruvallur) 13 each, Meenambakkam (Chennai), Ambathur Rev (Chennai), Valasaravakkam(Chennai), Cholavaram (Tiruvallur), Thirupalapandal (Kallakurichi), Kalayanallur (distKallakurichi), Kolapakkam (Chengalpattu), Ayapakkam (Chennai), Ranipet (Ranipet), Tirukoilur (Kallakurichi), Maduravoyal (Chennai), Tiruttani (Tiruvallur), Ambattur MW (Chennai)12 each, Chennai (AP) (Chennai), Tiruttani (distTiruvallur), Alandur (dist Chennai), BASLManalurpet (Kallakurichi), Mill-1 Ariyalur (Kallakurichi), Vengur (Kallakurichi), Meenambakkam (Chennai), Valasaravakkam (Chennai), Anna Nagar (Chennai), Ammoor (Walajah Railway) (Ranipet), NctplMargECR (Chengalpattu), Vellore (Vellore), Thiru-Vi-Ka Nagar (Chennai),Ponneri (Tiruvallur), Chennai Collector Office (Chennai), Kattumayilur (Cuddalore), Sankarapuram (distKallakurichi), Perambur (dist Chennai), Chennai(N) AWS(dist Chennai), Kundrathur (distKancheepuram), Vadapalani (dist Chennai), ACSMedical College ARG (Kancheepuram), Ulundurpet (Kallakurichi), Sholinganallur(Chennai), Kodambakkam (Chennai), Virugavoor (Kallakurichi), Chennai(N) (Chennai) 11 each,Alangayam (Tirupathur), DGP Office (Chennai), Poonamallee (Tiruvallur), Ponnai Dam (Vellore), Tondiarpet (Chennai), Thiruvalangadu (Tiruvallur), Mugalivakkam (Chennai), Ariyalur Camp Area (Kallakurichi), DSCL Sulangurichi (Kallakurichi), Aminjikarai (Chennai), L Thiyagadurgam (Kallakurichi), DSCL Keelpadi (Kallakurichi), Basinbridge (Chennai), Ammundi (dist Vellore), Madipakkam Chennai) 10each,

Kerala: Ulanad (Pathanamthitta) 9, Enadimangalam (Pathanamthitta) 7

2nd December, 2024

Tamilnadu, Puducherry &Karaikal: Uthangarai (Krishnagiri) 50, Kedar (Villupuram) 42, Soorapattu (Villupuram) 38, Vilupuram (Villupuram) 35, Harur (Dharmapuri) 33, Mundiyampakkam (Villupuram), Koliyanur (Villupuram), Thirupalapandal (Kallakurichi) 32 each, Madampoondi (Kallakurichi) 31, Mugaiyur (Villupuram), Valavanur (Villupuram) 30 each, Nemoor (Villupuram), Manampoondi (Villupuram), Kanjanur (Villupuram) 29 each, Vengur (Kallakurichi) 27, Tirukoilur (Kallakurichi) 26, Jambukuttapatti (Krishnagiri), Pochampalli (Krishnagiri) 25 each, Yercaud (Salem) 24, Eraiyur (Kallakurichi), Jamunamarathur (Tiruvannamalai) 23 each, Pambar (Krishnagiri), Manalurpet (Kallakurichi) 21 each, Thandarampettai (Tiruvannamalai), Barur (Krishnagiri),

Pappireddipatti (Dharmapuri) 20 each, Penucondapuram (Krishnagiri), Sankarapuram (Kallakurichi) 19 each, Kallakurichi (Kallakurichi) 18, Anandhapuram (Villupuram), Kalayanallur (Kallakurichi) 17 each, Tiruvannamalai (Tiruvannamalai), Panruti (Cuddalore), Dharmapuri (Dharmapuri) 16 each, Moorarpalayam (Kallakurichi), Vanamadevi (Cuddalore), Keelpennathur (Tiruvannamalai), Moongilthuraipattu (Kallakurichi), Ulundurpet (Kallakurichi), Kariyakovil Dam (Salem), Sulangurichi (Kallakurichi), Rishivandhiyam (Kallakurichi), SCS Mill Pillaiyarkuppam (Kallakurichi), Keelpadi (Kallakurichi) 15 each, Virugavoor (Kallakurichi), Nedungal (Krishnagiri), Kattumayilur (Cuddalore) 14 each, Ariyalur (Kallakurichi), Ariyalur Camp Area (Kallakurichi), Kadavanur (Kallakurichi) 13 each, Vepur (Cuddalore), Me Mathur (Cuddalore) 12 each, Thiyagadurgam (Kallakurichi), Pennagaram (Dharmapuri), Semmedu (Villupuram), Manimutharu Dam PWD (Kallakurichi), SRC Kudithangi (Cuddalore), Krishnagiri (Krishnagiri), Kachirayaopalayam (Kallakurichi), Thirukkanur (Puducherry), Paiyur (Krishnagiri) 11 each, Sethiathope (Cuddalore), Anaimaduvu Dam (Salem), Omalur (Salem), Dam (Krishnagiri), Danishpet (Salem) 10 each, Kallakurichi (Kallakurichi), Gomugi Dam (Kallakurichi), Palacode (Dharmapuri), Pelandurai (Cuddalore), Hogenekal (Dharmapuri) 9 each, Vadapudupattu (Tirupathur), Bhuvanagiri (Cuddalore), Bahour (Puducherry), Palacode (Dharmapuri), Denkanikottai (Krishnagiri), TNAU CRI Yethapur (Salem), Vaniyambadi (Tirupathur) 8 each, Dharamapuri (Dharmapuri), Arasoor (Villupuram), Kuppanatham (Cuddalore), Gudalur Bazar (The Nilgiris), Thiruvennainal (Villupuram), Tirupattur (Tirupathur), Natrampalli (Tirupathur), Ambur (Tirupathur), Lakkur (Cuddalore), Kodanad (The Nilgiris), Tirupattur (Tirupathur), Avalurpettai (Villupuram), Mangalapuram (Namakkal), Kilacheruvai (Cuddalore), Kethandapatti (Tirupathur), Chengam(Tiruvannamalai), Chidambaram (Cuddalore), Vridhachalam (Cuddalore) 7 each,

Kerala: Kodungallur (Thrissur) 19, Kottayam18,Kurudamannil (Pathanamthitta)17, Konni (Pathanamthitta), Kanjirappally (Kottayam district) & Ranni (Pathanamthitta) 16 each, Kochi (Ernakulam), Haripad (Alappuzha) & Peerumedu (Idukki) 15 each, Perumbavur (Ernakulam) 14, Aluva (Ernakulam), Laha (Pathanamthitta) & Aluva (Ernakulam) 13 each, Cherthala (Alappuzha),Kunnathanam (Pathanamthitta) & Thycauttussery (Alapuzha) 12 each, Kalamassery (Ernakulam) 11, Kumarakom (Kottayam) & Konni(Pathanamthitta district) 8 each, Kozhikode, Vaikom (Kottayam) & Piravam (Ernakulam) 7 each.

Coastal Andhra Pradesh &Yanam: Yanam (Yanam) 8

Realised Wind:

❖ **Realised:** At the time of landfall, the estimated maximum sustained wind speed was about 70-80 kmph gusting to 90 kmph over Puducherry. Realised

estimated wind distribution in the tropical cyclone field during its life cycle is presented in **Fig.13.**

10. Damage report:

As per media reports, 20 death was reported including 11 from floods, 7 from landslides, and 2 from wall collapse and electrocution from Tamil Nadu due to cyclone. 20 people died from drowning and landslides. About 1,317 homes were damaged due to Cyclone Fengal, eight lakh people were evacuated to 6,210 cyclone relief centres in Odisha. 17,117 hectares of agricultural lands were damaged in Tamil Nadu, 5,527 hectares in Puducherry, and 6,825 hectares in Andhra Pradesh. A total of 69 lakh people in Tamil Nadu were impacted by cyclone Fengal and subsequent flooding in 14 districts of Tamil Nadu. The worst-hit districts were Villupuram, Kallakurichi, Cuddalore, and Tiruvannamalai (Indianexpress, 03 December).

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 CS FENGAL is also duly acknowledged.

All graphics are available in Annexure 1.

Table 1: Best track positions and other parameters of the Cyclonic Storm "FENGAL" over Southwest Bay of Bengal during 23rd November - 02th December, 2024

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

Date	Time	Latitude (N)	Longitude (E)	CI No.	Estimated Central Pressure(hPa)	Estimated Maximum Sustained surface wind (kt)	Estimated Pressure drop at the Centre (hPa)	Category
25.11.24	0300	5.0	85.3	1.5	1004	20	3	D
25.11.24	0600	5.1	84.5	1.5	1004	20	3	D
25.11.24	1200	5.2	83.5	1.5	1003	25	4	D
25.11.24	1800	5.5	83.2	1.5	1003	25	4	D
26.11.24	0000	6.0	82.9	1.5	1003	25	4	D
26.11.24	0300	6.3	82.8	2.0	1002	30	5	DD
26.11.24	0600	6.6	82.8	2.0	1002	30	5	DD
26.11.24	1200	7.0	82.7	2.0	1001	30	5	DD
26.11.24	1800	7.5	82.6	2.0	1001	30	5	DD
27.11.24	0000	8.2	82.4	2.0	1001	30	5	DD
27.11.24	0300	8.5	82.3	2.0	1001	30	5	DD
27.11.24	0600	8.7	82.2	2.0	1001	30	5	DD
27.11.24	1200	8.9	82.2	2.0	999	30	6	DD
27.11.24	1800	9.0	82.2	2.0	999	30	6	DD
28.11.24	0000	9.0	82.2	2.0	999	30	6	DD
28.11.24	0300	9.1	82.3	2.0	999	30	6	DD
28.11.24	0600	9.3	82.4	2.0	999	30	6	DD
28.11.24	1200	9.6	82.7	2.0	1000	30	6	DD

28.11.24	1800	10.1	82.8	2.0	1000	30	6	DD
29.11.24	0000	10.4	82.7	2.0	999	30	6	DD
29.11.24	0300	10.6	82.6	2.0	999	30	6	DD
29.11.24	0600	10.9	82.5	2.0	999	30	6	DD
29.11.24	0900	11.2	82.2	2.5	998	35	7	CS
29.11.24	1200	11.5	81.9	2.5	998	35	7	CS
29.11.24	1500	11.6	81.7	2.5	998	35	7	CS
29.11.24	1800	11.8	81.7	2.5	997	35	7	CS
29.11.24	2100	11.9	81.5	2.5	996	40	8	CS
30.11.24	0000	12.2	81.2	3.0	994	45	10	CS
30.11.24	0300	12.3	80.9	3.0	994	45	10	CS
30.11.24	0600	12.3	80.7	3.0	994	45	10	CS
30.11.24	0900	12.3	80.5	3.0	992	45	12	CS
30.11.24	1200	12.3	80.3	3.0	993	40	11	CS
30.11.24	1500	12.2	80.1	2.5	994	40	10	CS
	Crossed North Tamil Nadu and Puducherry coast near lat. 12.05N and long 79.9E close to Puducherry between 1700-1800 UTC of 30th November 2024.							
30.11.24	1800	12.0	79.8	-	994	40	10	CS
30.11.24	2100	12.0	79.8	-	993	35	11	CS
01.12.24	0000	12.0	79.8	-	993	35	10	CS
01.12.24	0300	12.0	79.8	-	996	35	7	CS
01.12.24	0600	12.0	79.8	-	997	30	6	DD
01.12.24	1200	12.1	79.6	-	998	25	4	D
01.12.24	1800	12.1	79.2	-	999	25	3	D
02.12.24	0000	Weaken into Well Marked low Pressure Area over North Interior Tamil Nadu						
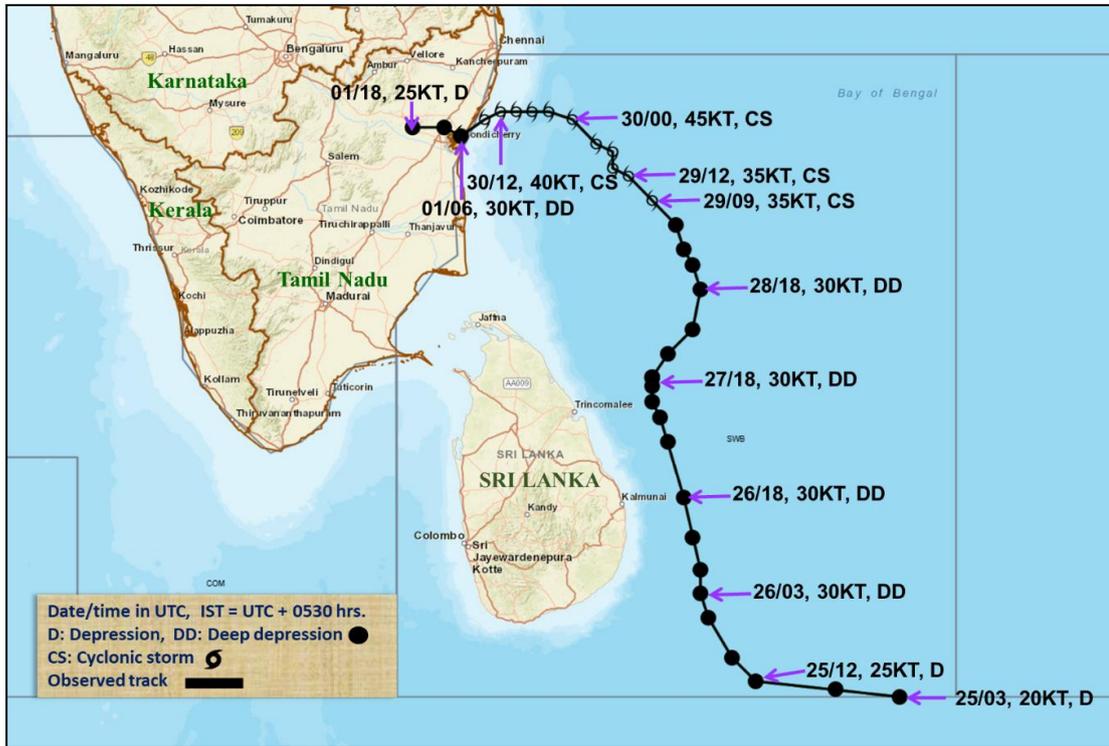
Fig. 1: Observed track of severe cyclonic storm "FENGAL" over Southwest Bay of Bengal during 24th November- 02th December, 2024
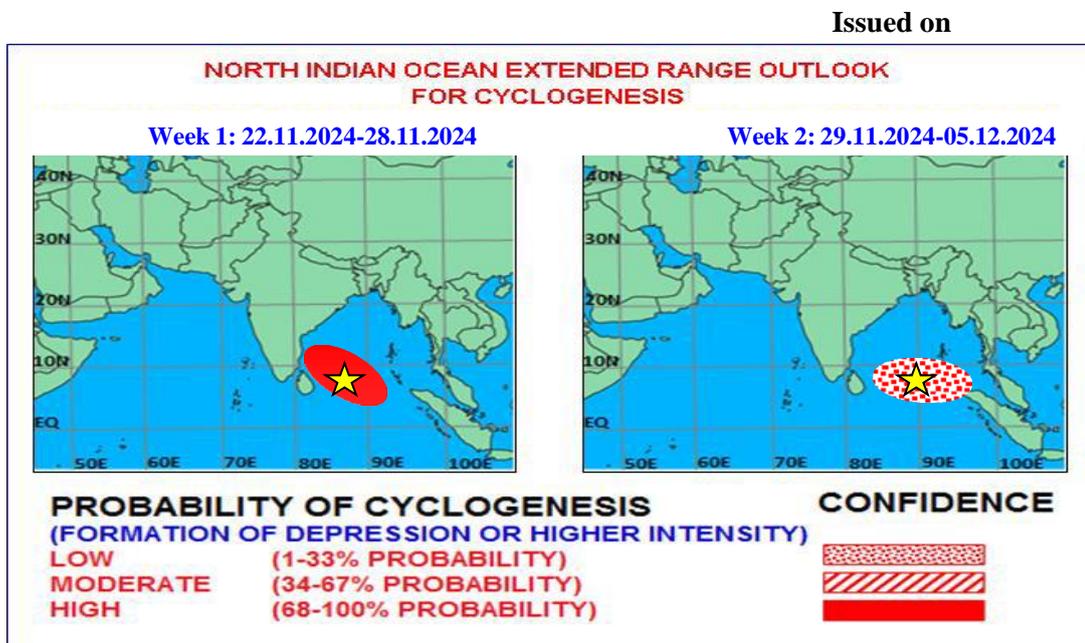
Fig. 2: Extended Range Outlook issued on 21st November, indicating probable area of genesis (formation of depression) and likely movement towards Tamil Nadu Coast with High confidence.

🔴 : Probable Area of cyclogenesis, ⭐: Actual Point of genesis
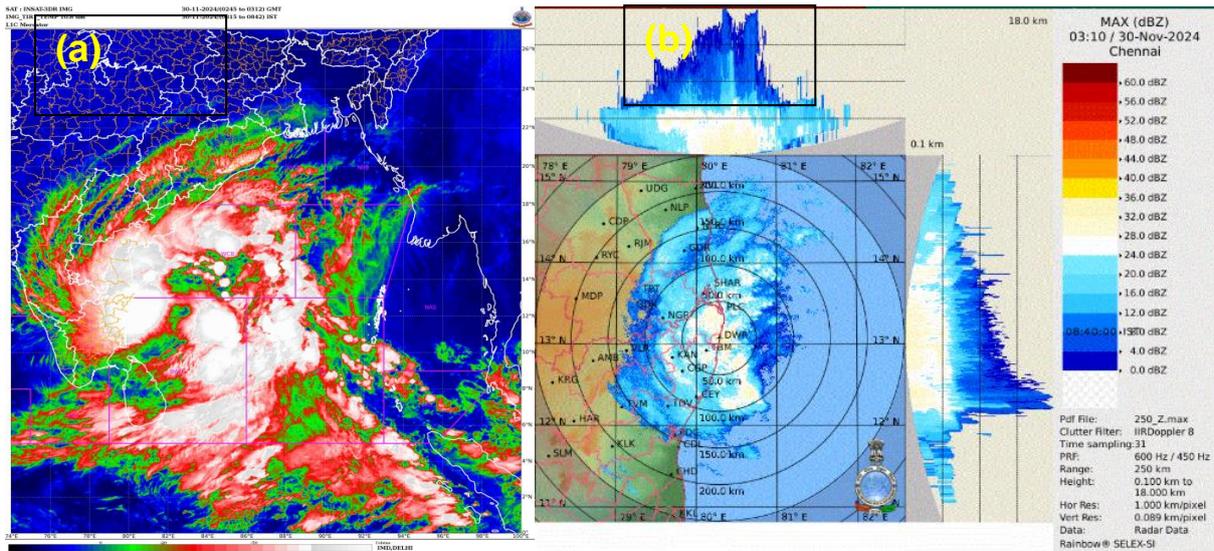
Fig. 3: Typical (1) INSAT 3D imagery at 0245 IST of 30th November and (b) Doppler Weather Radar Chennai imagery at 0310 IST of 30th November during cyclonic storm "FENGAL"
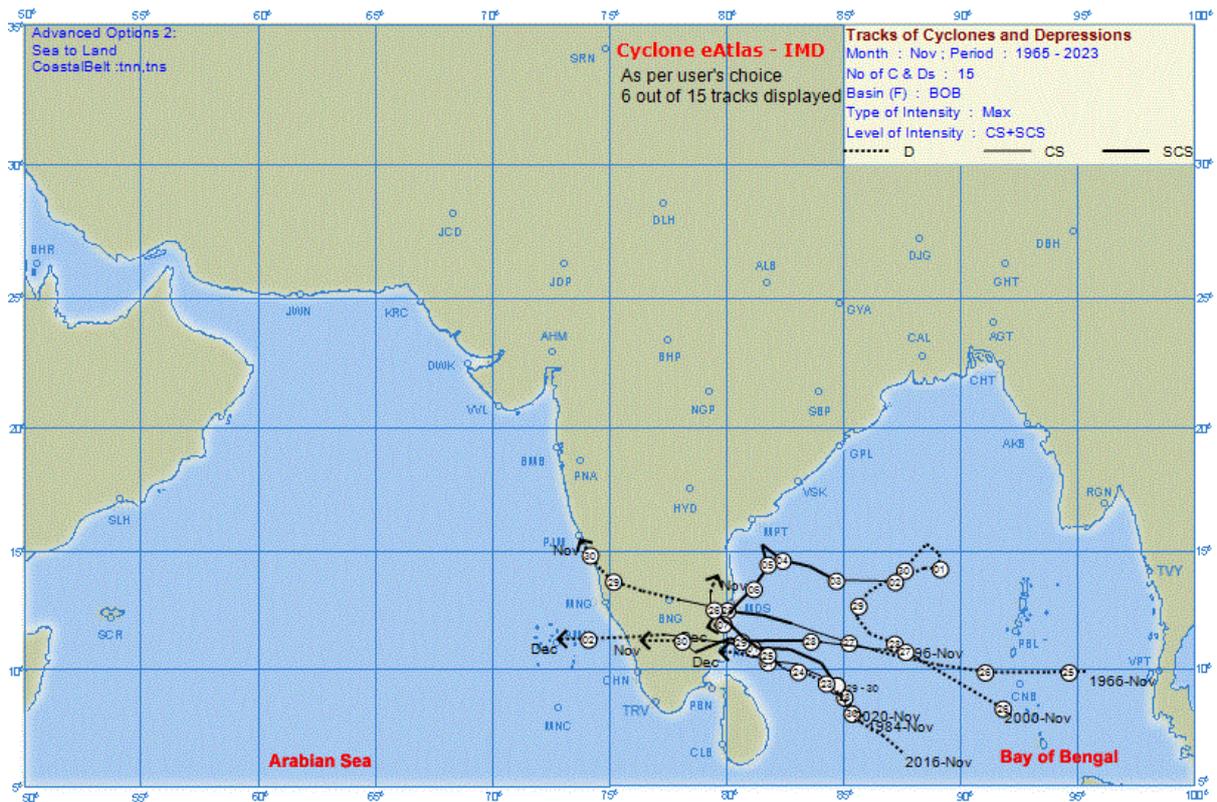
Fig. 4: Tracks of cyclonic storms developing from a depression in the grid (12-17N and 90-100 E) crossing Tamil Nadu (North) coast in the month of November during the period 1965-2023
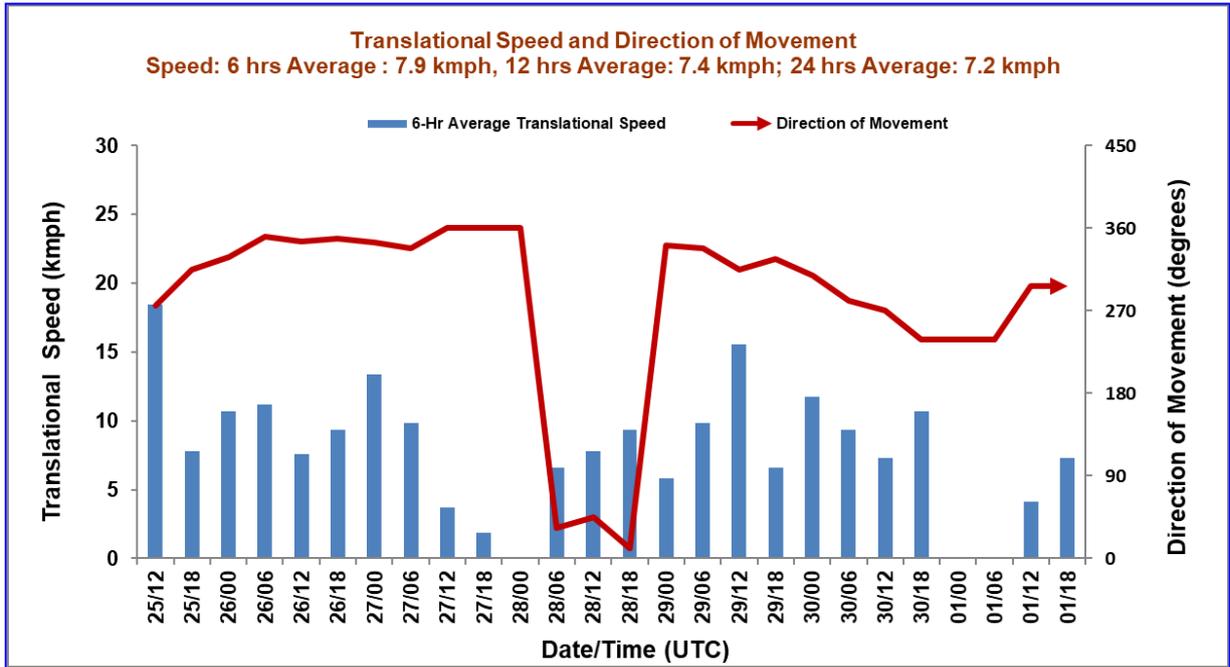
**Fig. 5: Six hourly average translational speed and direction of movement during life cycle of "CS FENGAL"**
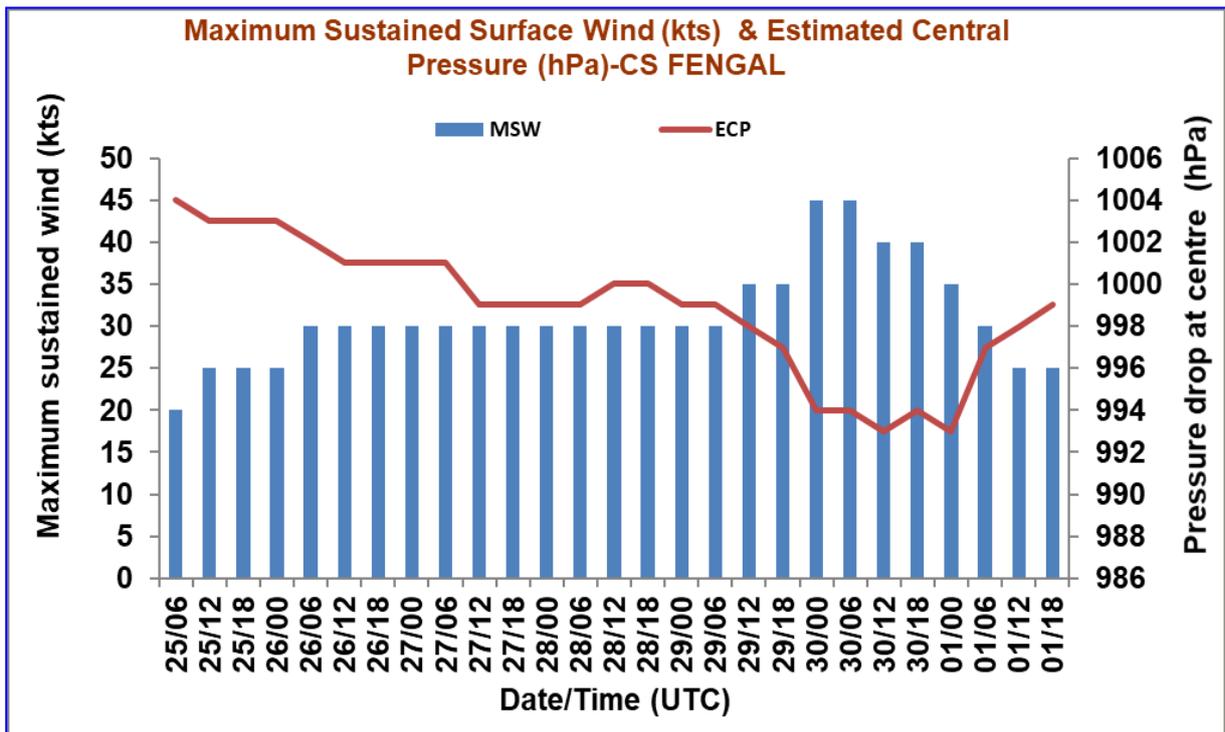
Fig. 6: Six hourly Maximum sustained wind speed and estimated central pressure during life cycle of "CS FENGAL"

(a)

Landfall Point Forecast Errors of CS FENGAL in comparison to Long Period Average Errors (2019-23)

(b)

Landfall Time Forecast Errors of CS FENGAL in comparison to Long Period Average Errors (2019-23)
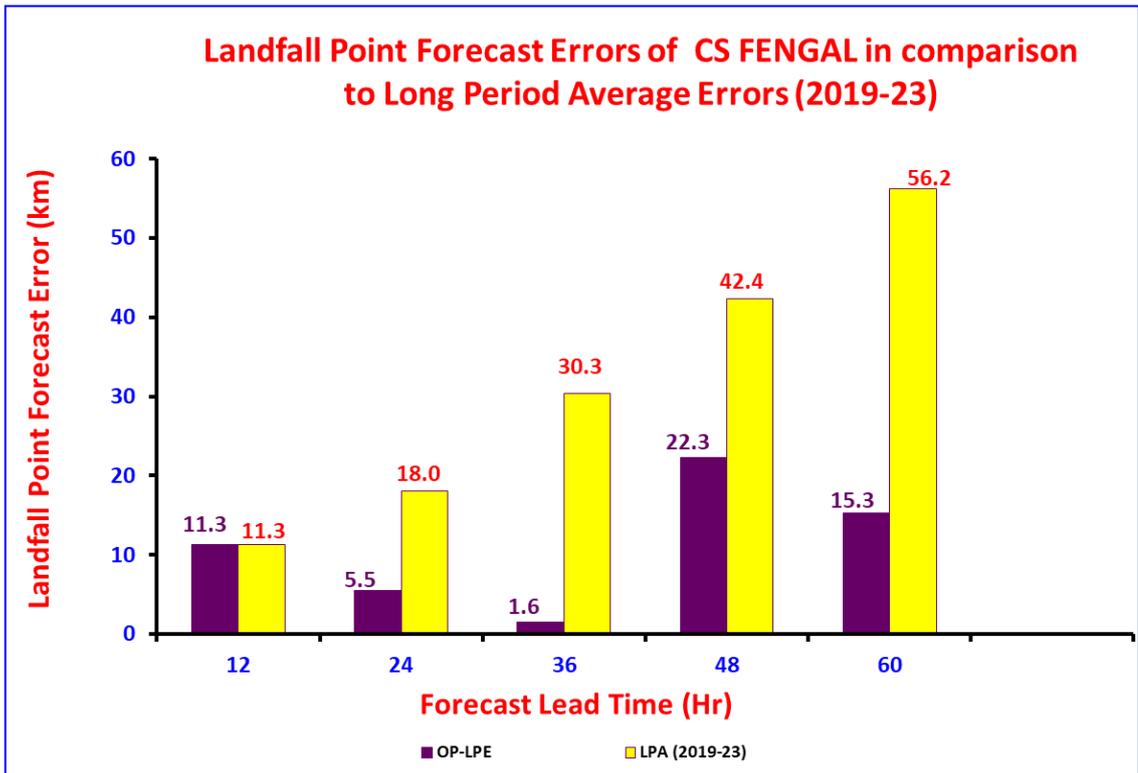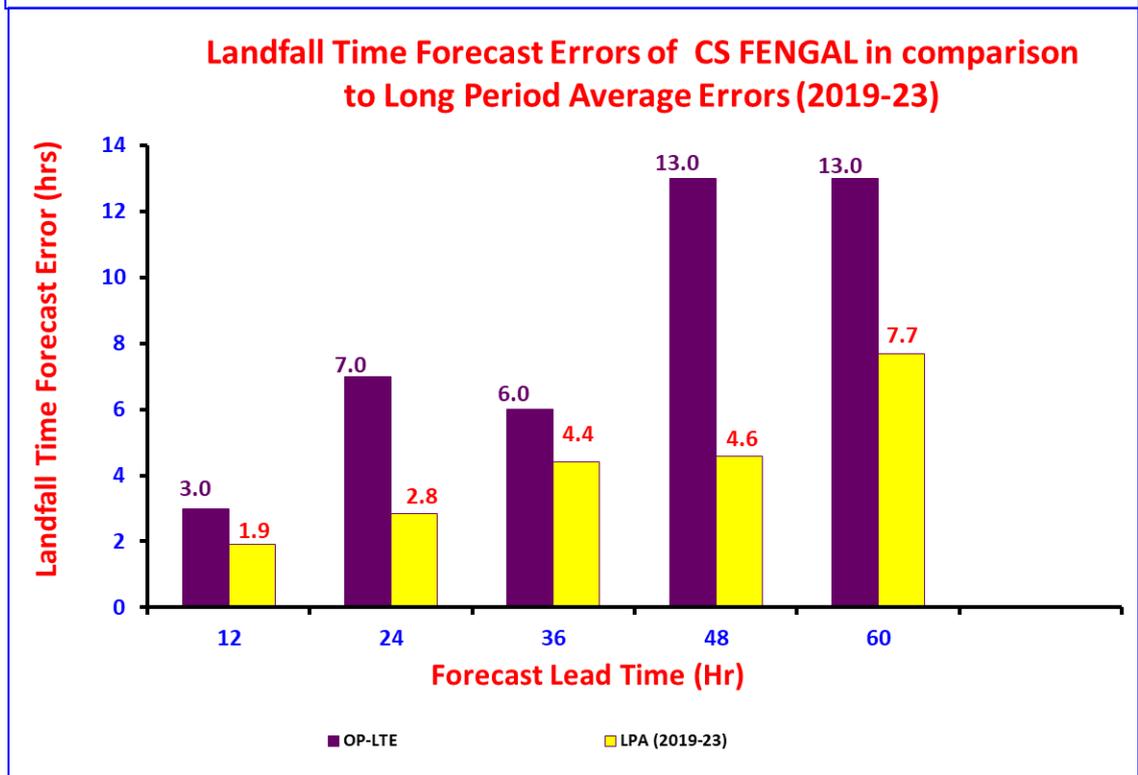
Fig. 7: (a) Landfall point and (b) time errors against the long period average (LPA) errors based on 2019-2023

(a) Track Forecast Errors of CS FENGAL in comparison to Long Period Average Errors (2019-23)

(b) Track Forecast Skill of CS FENGAL in comparison to Long Period Average Skill (2019-23)
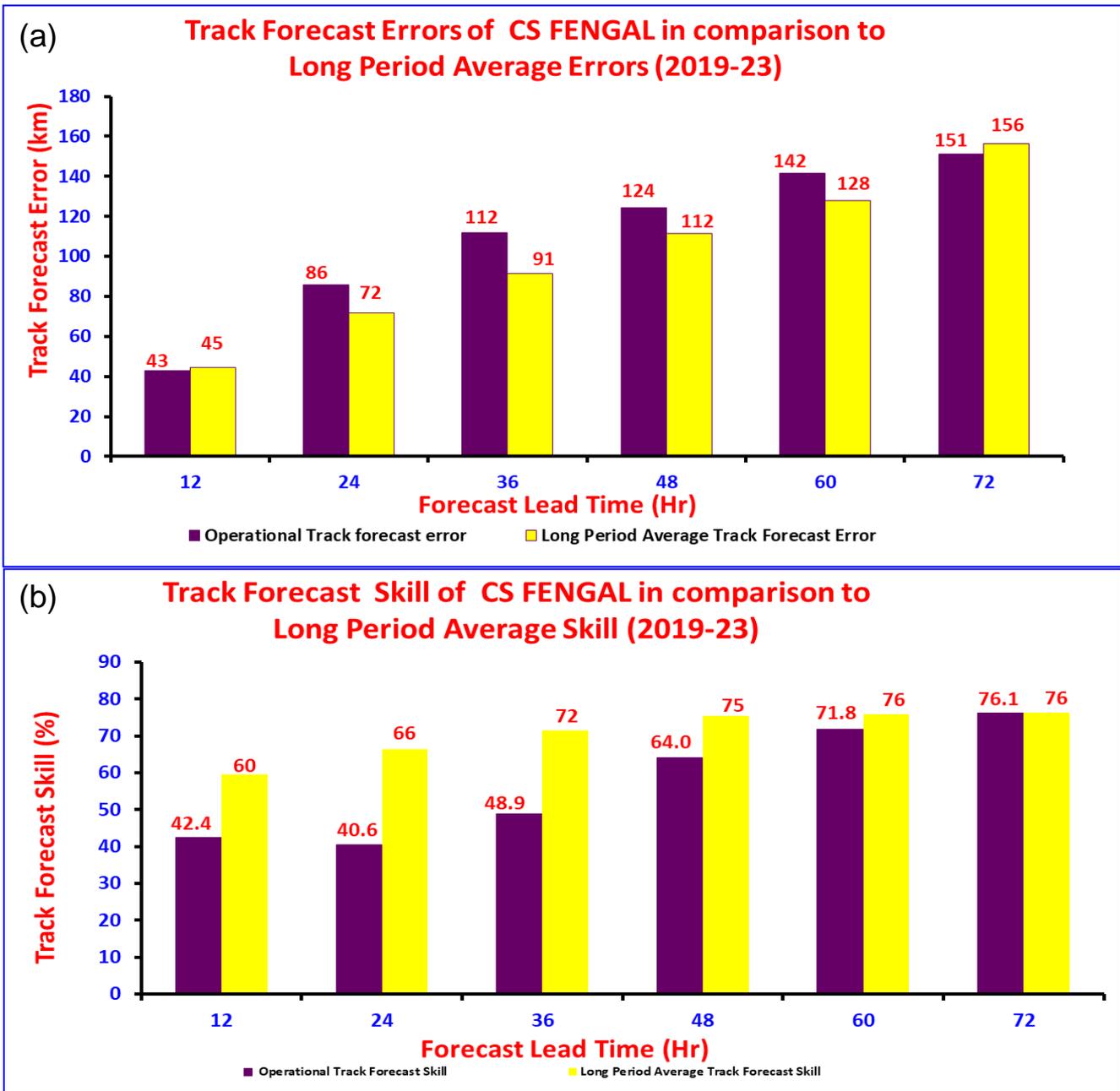
Fig. 8: Track forecast errors and (b) skills against Climatology & Persistence (CLIPER) compared to long period average (LPA) errors & skills respectively based on 2019-2023

Intensity Forecast Errors based on AE of CS FENGAL and Long Period Average Errors (2019-23)

Intensity Forecast Skill based on AE of CS FENGAL and Long Period Average Skill (2019-23)
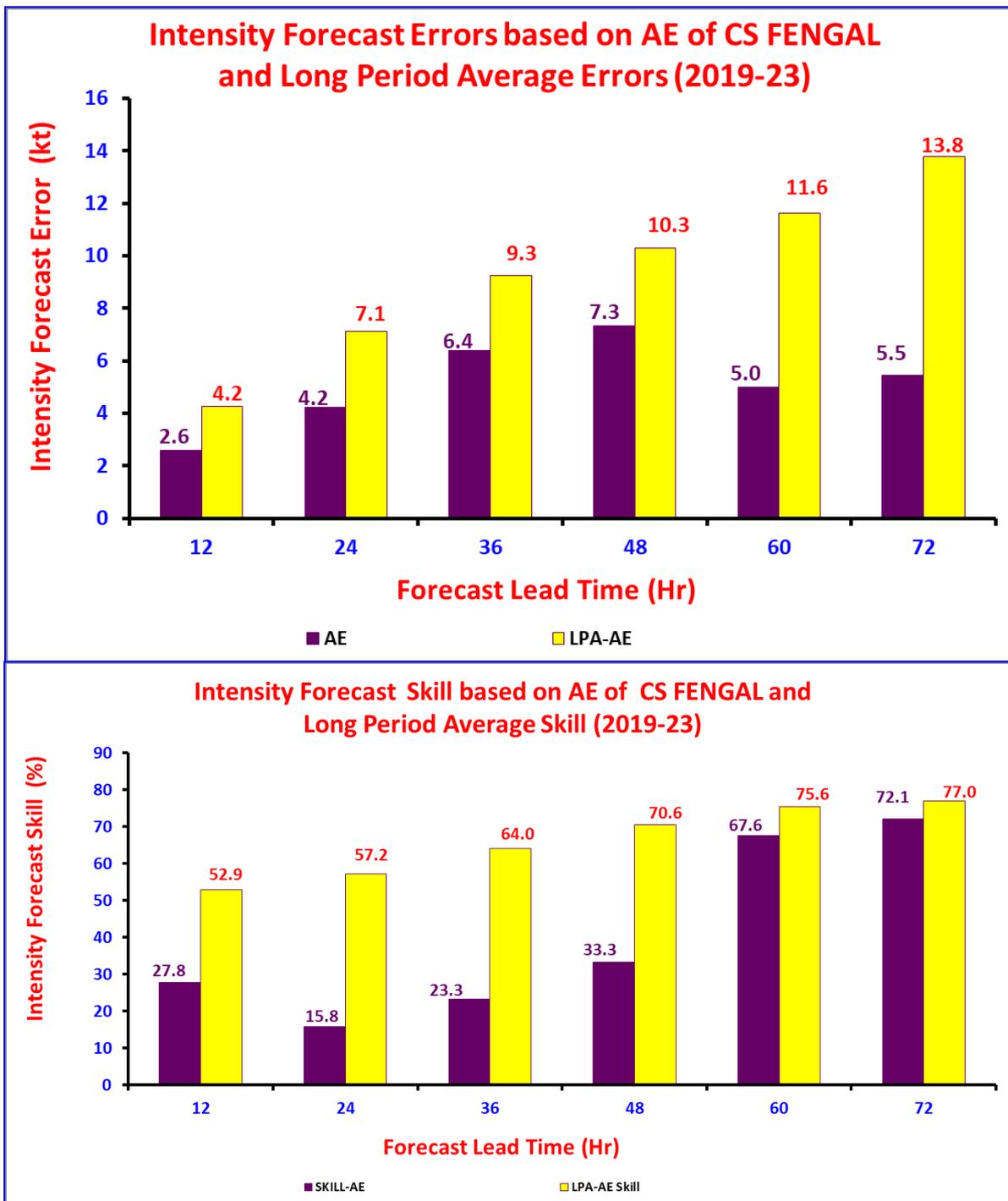
Fig. 9: Intensity forecast errors (AE) and (b) skills against Persistence compared to long period average (LPA) errors & skills respectively based on absolute error (AE).

(a)

Intensity Forecast Errors based on RMSE of CS FENGAL and Long Period Average Errors (2019-23)

(b)

Intensity Forecast Skill based on RMSE of CS FENGAL Long Period Average Skill (2019-23)
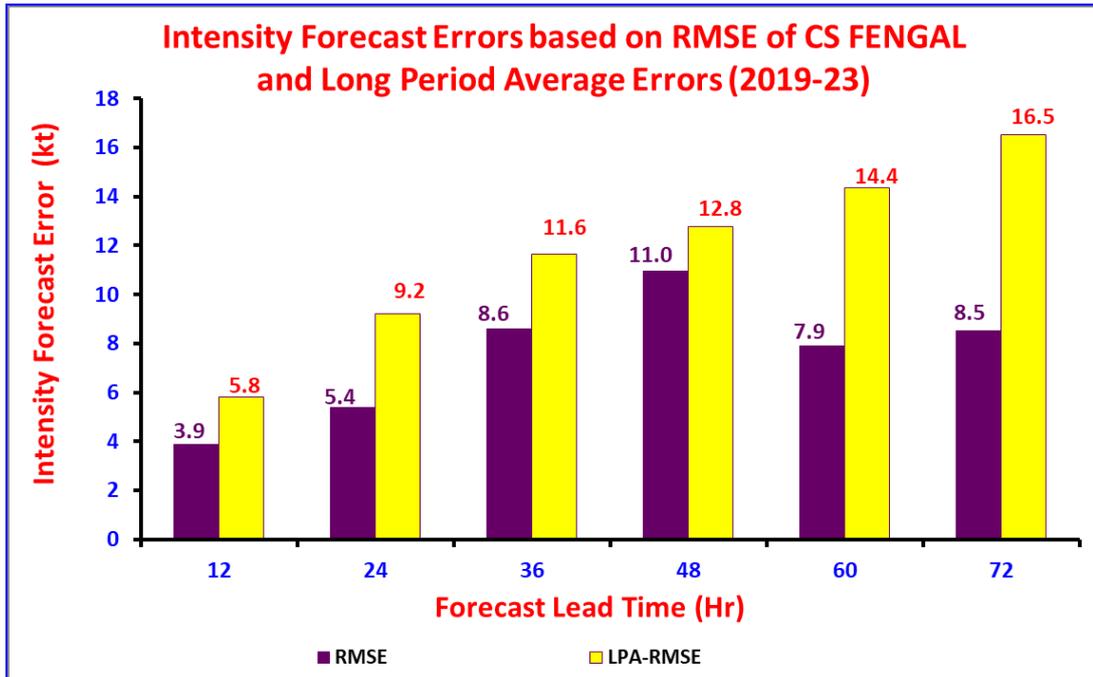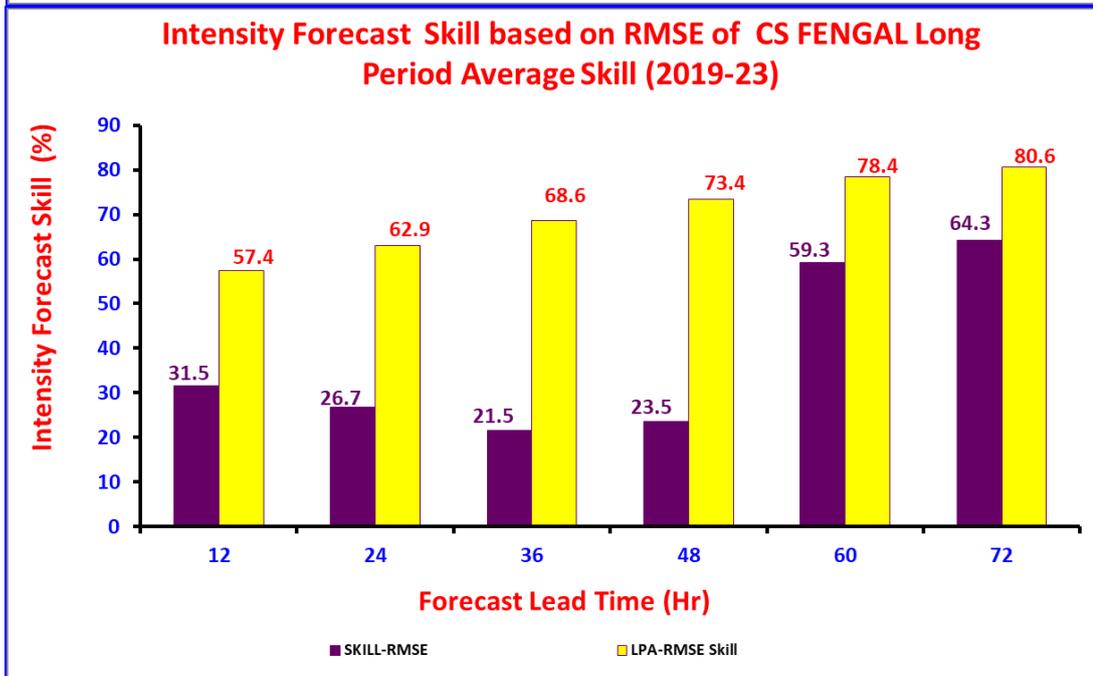
Fig. 10 (a): Intensity forecast errors (RMSE) and (b) skills against Persistence forecast compared to long period average (LPA) errors & skills respectively
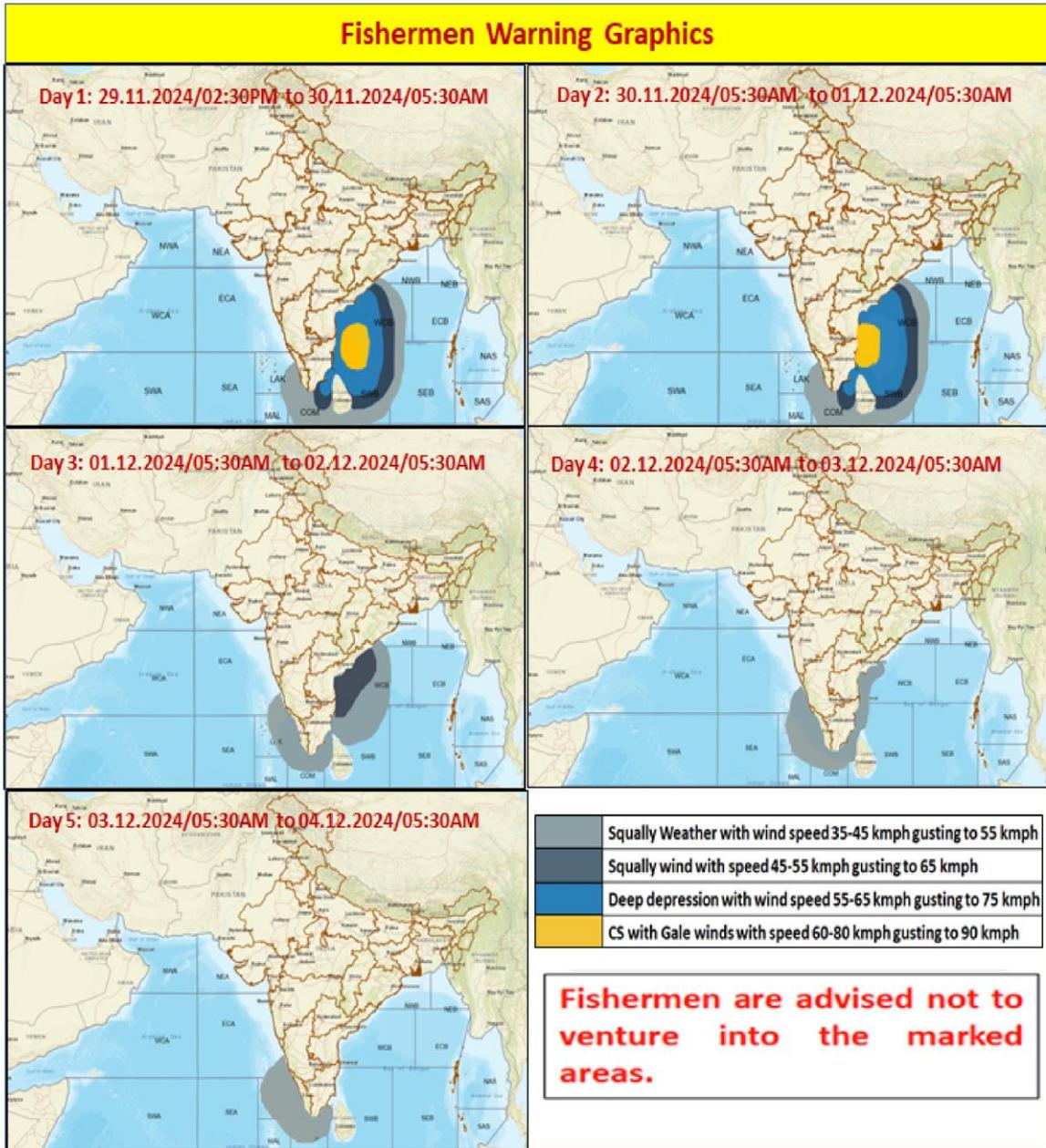
**Fig. 11: Typical Fishermen Warning graphics issued on 29th November 2024**
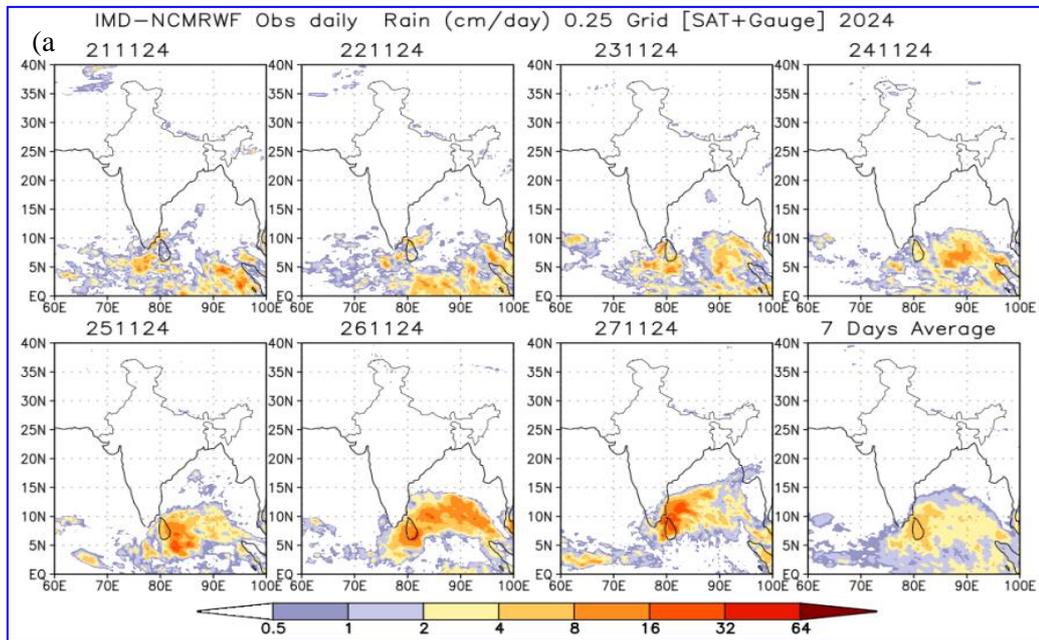
Fig. 12 a. NCMRWF-IMD satellite gauge merged data plots of 24 hours accumulated realized rainfall during 21st November to 27th November, 2024
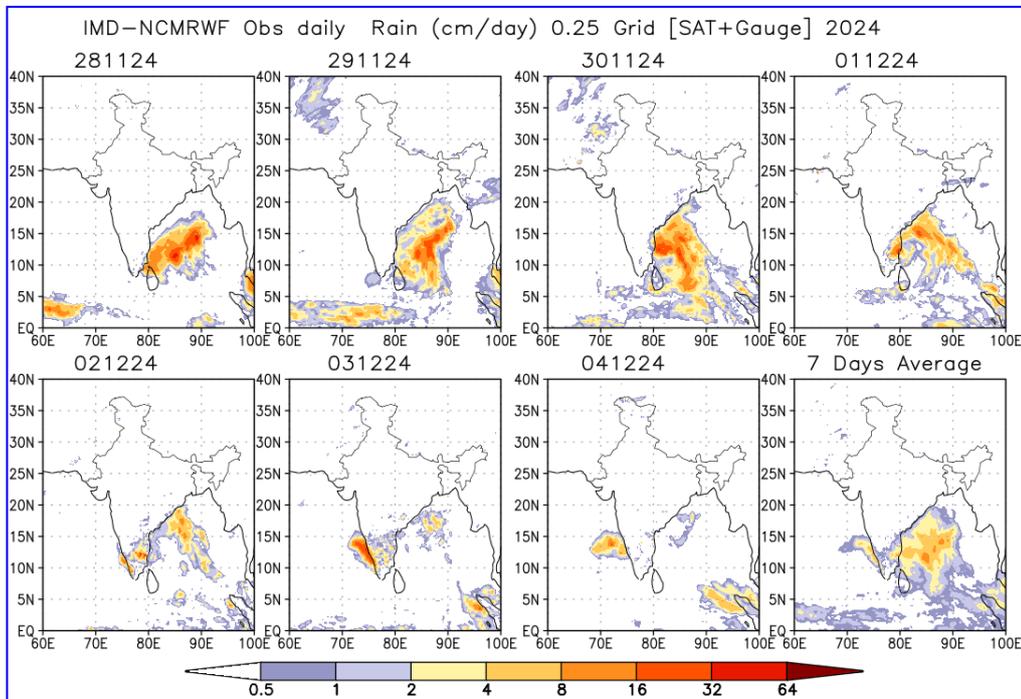

Fig. 12 b: NCMRWF-IMD satellite gauge merged data plots of realized 24 hours accumulated rainfall from 28th November – 04th December, 2024.
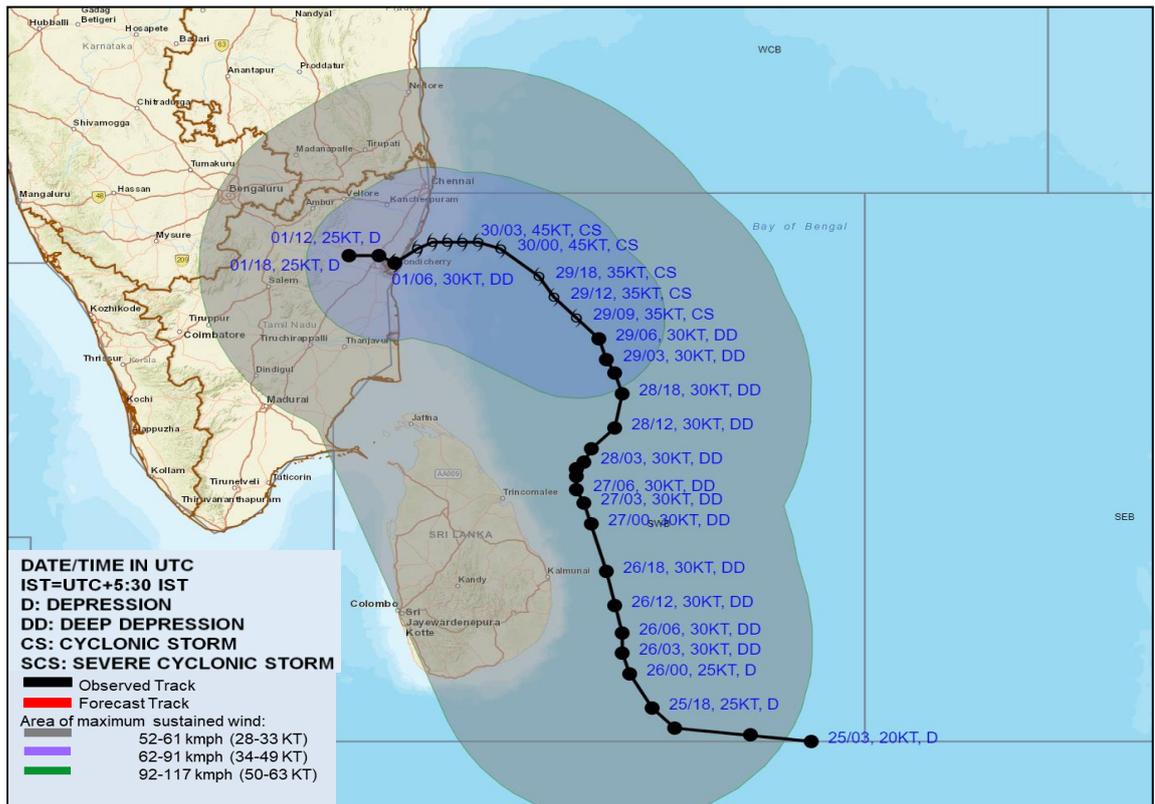
Fig. 13: Estimated maximum sustained wind during the life cycle of CS