



Extremely Severe Cyclonic Storm “FANI” over eastcentral equatorial Indian Ocean and adjoining southeast Bay of Bengal (26 April – 04 May, 2019): Summary

1. Brief Life History:

- Extremely Severe Cyclonic Storm (ESCS) “FANI” originated from a low pressure area (LPA) which formed over east Equatorial Indian Ocean (EIO) and adjoining southeast Bay of Bengal (BoB) in the early morning (0530 IST) of 25th April. It lay as a well marked low pressure area (WML) over the same region in the same morning (0830 IST).
- Under favourable environmental conditions, it concentrated into a Depression (D) over the same region in the morning (0830 IST) of 26th April. Moving nearly northwestwards, it intensified into a deep depression (DD) over the same region in the early morning (0530 IST) and further into a cyclonic storm (CS) “FANI” around noon (1130 IST) of 27th April over southeast BoB and adjoining east EIO.
- It then moved north-northwestwards and intensified, into a severe cyclonic storm (SCS) in the evening (1730 IST) of 29th over central parts of south BoB.
- It then moved nearly northwards and further intensified into a very severe cyclonic storm (VSCS) in the early morning (0530 IST) of 30th over southwest BoB.
- It then moved west-northwestwards and further intensified into an extremely severe cyclonic storm (ESCS) in the night (1730 IST) of 30th over westcentral and adjoining southwest BoB.
- It started recurving north-northeastwards from 1st early morning (0530 IST).
- It temporarily intensified during evening (1430 IST) of 2nd May to early hours (0230 IST) of 3rd May reaching the peak intensity of 115 knots. Thereafter from 3rd early morning (0530 IST) it weakened slightly.
- It continued to move north-northeastwards and crossed Odisha coast close to Puri as an ESCS with maximum sustained wind speed of 175-185 kmph (100 knots) gusting to 205 kmph between 0800 to 1000 hrs IST of today, the 03rd May, 2019.
- Continuing to move north-northeastwards across coastal Odisha, it weakened into a VSCS over coastal Odisha around noon (1130 IST) of 3rd May and lay close to east of Bhubaneswar. At 1430 IST, it lay close to Cuttack.
- Moving further north-northeastwards it weakened into an SCS over north coastal Odisha at night (2030 hrs IST) of 3rd May and lay centered about 20 km west of Balasore.
- Thereafter, it weakened into a CS in the early morning (0530 hrs IST) of 4th May over western parts of Gangetic West Bengal and lay centered about 60 km northwest of Kolkata.

- It weakened into a deep depression in the morning (0830 hrs IST) over Bangladesh & adjoining Gangetic West Bengal about 40 km east-northeast of Krishna Nagar and into a depression over Bangladesh about 120 km north-northwest of Dhaka around noon (1130 hrs IST) of 4th May.
- Moving further northeastwards, it became a well marked low pressure area over Meghalaya and neighbourhood during the night (2330 IST) of 4th May. It further weakened into a low pressure area over north Myanmar and adjoining areas of northeastern states of India in the early morning (0530 IST) and became insignificant in the morning (0830 IST) of 5th May. The observed track of the system during 26th April-5th May is presented in **Fig.1**. Best Track parameters associated with the system are presented in Table1.

2. Salient Features:

The salient features of the system were as follows:

- i. It developed near the equator (near 2.7⁰N and 88.7⁰E). Genesis of the cyclonic disturbance in such a lower latitude is very rare, last such activity was observed over the north Indian Ocean in January, 2005.
- ii. It was the most intense cyclone to cross Odisha coast after Phailin in 2013 which crossed coast with a maximum sustained wind speed of 215 kmph.
- iii. Climatologically, Fani was the most intense cyclonic storm crossing Odisha coast during pre-monsoon season during satellite era (1965 onwards). Last ESCS to cross Odisha coast in May was 1982 cyclone (31 May-05 June) which developed over southeast BoB near Andaman Islands on 31st May. It crossed Odisha coast between Paradip and Chandbali during midnight of 3rd June with MSW of 80 kts. Maximum intensity of this storm over sea was 120 kts. Tracks of severe cyclonic storms and above intensity storms crossing Odisha coast during May is presented in **Fig.2**.
- iv. It had one of the longest track. The track length of the cyclone was 3030 km.
- v. It had a clockwise recurving track as it moved north-northwestwards initially and later moved north-northeastwards upto northeastern states across coastal Odisha and West Bengal. It was mainly steered by an anticyclonic circulation in middle & upper tropospheric levels to the northeast of the system centre.
- vi. It had rapid intensification during 29th afternoon to 30th April evening over westcentral Bay of Bengal, mainly due to higher Ocean heat content, with increase in maximum sustained wind speed (MSW) from 45 knots at 1430 IST of 29th to 95 knots at 2030 IST of 30th April.
- vii. The peak MSW of the cyclone was 200-210 kmph (115 knots) gusting to 230 kmph during 0900 UTC to 2100 UTC of 2nd May over the westcentral BoB. The lowest estimated central pressure was 932 hPa 0900 UTC to 1200 UTC of 2nd May (**Fig.3a**).

- viii. The system crossed Odisha coast close to Puri with maximum sustained wind speed of 175-185 kmph (100 knots) gusting to 205 kmph between 0800 to 1000 hrs IST of today, the 03rd May, 2019.
- ix. The system maintained the cyclonic storm intensity for almost 21 hours even after landfall till 0000 UTC of 4th.
- x. The life period (D to D) of the system was 204 hours (8 days & 12 hours) against long period average (LPA) (1990-2013) of 134 hours (5 days & 14 hrs) for VSCS/ESCS categories over BoB during pre monsoon season.
- xi. It moved with 12 hour average translational speed of 14.6 kmph against LPA (1990-2013) of 14.7 kmph for VSCS category over north Indian Ocean (Fig.3b). However, after landfall it moved fast with an average speed of 24.0 kmph under the influence of upper tropospheric westerly trough lying to the west of system.
- xii. The Velocity Flux, Accumulated Cyclone Energy (a measure of damage potential) and Power Dissipation Index (a measure of loss) were 20.30×10^2 knots, 16.72×10^4 knots² and 15.12×10^6 knots³ respectively against long period average during 1990-2013 of 5.28×10^2 knots, 8.6×10^4 knots² and 2.8×10^6 knots³ respectively.

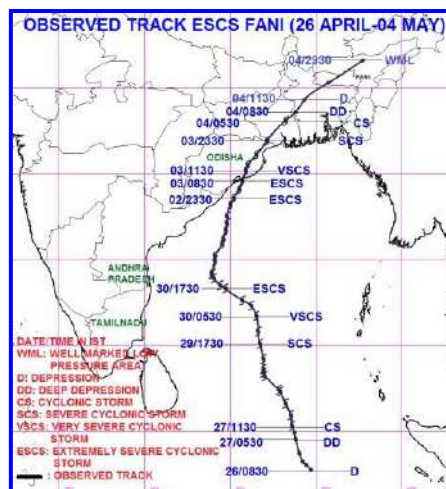


Fig.1: Observed track of ESCS FANI over east EIO and adjoining southeast BoB (26 April-04 May, 2019)

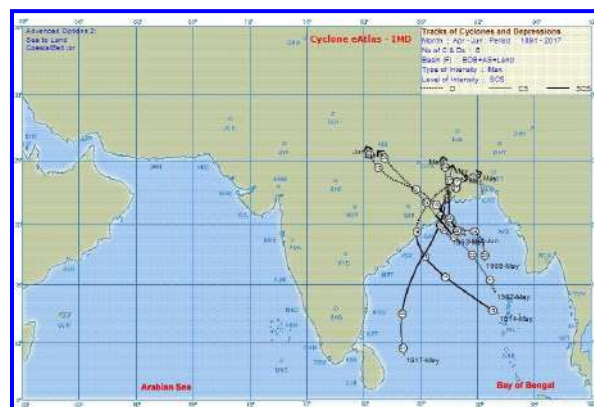


Fig.2: Tracks of severe cyclonic storms and above intensity storms crossing Odisha coast during pre monsoon season (1891-2017)

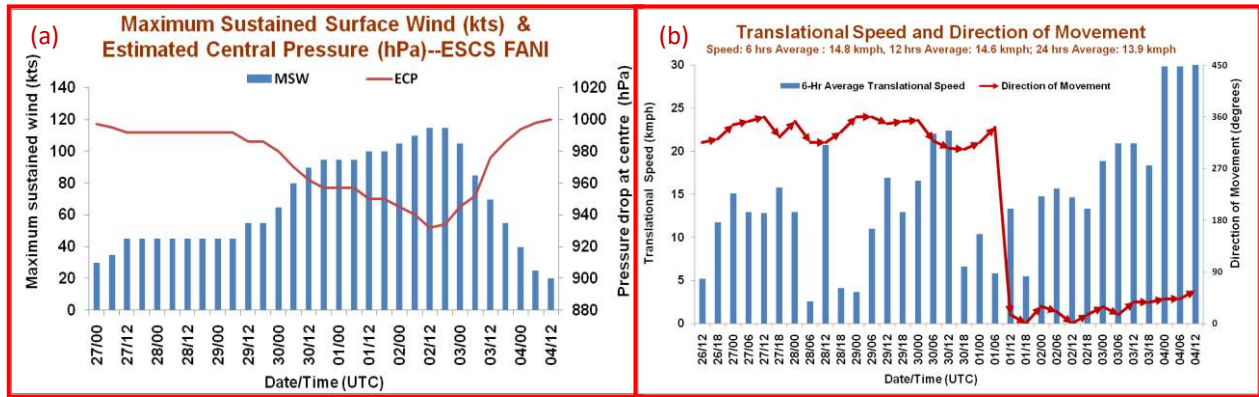


Fig. 3: (a) Translational speed & direction of movement and (b) Maximum sustained surface winds (kts) & Estimated Central Pressure

Table 1: Best track positions and other parameters of the Extremely Severe Cyclonic Storm “FANI” over east EIO and adjoining southeast BoB during 26th April – 4th May, 2019

Date	Time (UTC)	Centre lat. ^o N/ long. ^o E		C.I. NO.	Estimated Maximum Sustained Surface Wind (kt)	Estimated Central Pressure (hPa)	Estimated Pressure drop at the Centre (hPa)	Grade
26/04/2019	0300	2.7	89.7	1.5	25	998	4	D
	0600	3.0	89.4	1.5	25	998	4	D
	1200	3.2	89.2	1.5	25	998	4	D
	1800	3.7	88.8	1.5	25	998	4	D
27/04/2019	0000	4.5	88.8	2.0	30	997	5	DD
	0300	4.9	88.7	2.0	30	996	6	DD
	0600	5.2	88.6	2.5	35	995	7	CS
	0900	5.4	88.5	2.5	40	994	8	CS
	1200	5.9	88.5	3.0	45	992	10	CS
	1500	6.3	88.5	3.0	45	992	10	CS
	1800	6.6	88.2	3.0	45	992	10	CS
28/04/2019	2100	6.9	87.9	3.0	45	992	10	CS
	0000	7.3	87.9	3.0	45	992	10	CS
	0300	7.3	87.9	3.0	45	992	10	CS
	0600	7.4	87.8	3.0	45	992	10	CS
	0900	7.7	87.5	3.0	45	992	10	CS
	1200	8.2	87.0	3.0	45	992	10	CS
	1500	8.3	86.9	3.0	45	992	10	CS
	1800	8.4	86.9	3.0	45	992	10	CS
29/04/2019	2100	8.5	86.9	3.0	45	992	10	CS
	0000	8.6	86.9	3.0	45	992	10	CS
	0300	8.7	86.9	3.0	45	992	10	CS
	0600	9.2	86.9	3.0	45	992	10	CS
	0900	9.7	86.8	3.0	45	992	10	CS
	1200	10.1	86.7	3.5	55	986	16	SCS
	1500	10.4	86.7	3.5	55	986	16	SCS

	1800	10.8	86.6	3.5	55	986	16	SCS	
	2100	11.1	86.5	3.5	60	986	16	SCS	
30/04/2019	0000	11.7	86.5	4.0	65	980	22	VSCS	
	0300	12.3	86.2	4.5	75	974	28	VSCS	
	0600	12.6	85.7	4.5	80	970	32	VSCS	
	0900	13.0	85.3	4.5	85	966	36	VSCS	
	1200	13.3	84.7	5.0	90	962	40	ESCS	
	1500	13.4	84.5	5.0	95	957	45	ESCS	
	1800	13.5	84.4	5.0	95	957	45	ESCS	
	2100	13.6	84.2	5.0	95	957	45	ESCS	
01/05/2019	0000	13.9	84.0	5.0	95	957	45	ESCS	
	0300	14.1	83.9	5.0	95	957	45	ESCS	
	0600	14.2	83.9	5.0	95	957	45	ESCS	
	0900	14.5	84.1	5.0	95	955	45	ESCS	
	1200	14.9	84.1	5.5	100	950	50	ESCS	
	1500	15.1	84.1	5.5	100	950	50	ESCS	
	1800	15.2	84.1	5.5	100	950	50	ESCS	
	2100	15.5	84.2	5.5	100	950	50	ESCS	
02/05/2019	0000	15.9	84.5	5.5	105	945	55	ESCS	
	0300	16.2	84.6	5.5	105	945	55	ESCS	
	0600	16.7	84.8	5.5	110	940	60	ESCS	
	0900	17.1	84.8	6.0	115	932	66	ESCS	
	1200	17.5	84.8	6.0	115	932	66	ESCS	
	1500	17.8	84.9	6.0	115	934	66	ESCS	
	1800	18.2	85.0	6.0	115	934	66	ESCS	
	2100	18.6	85.2	6.0	115	934	66	ESCS	
03/05/2019	0000	19.1	85.5	6.0	105	945	55	ESCS	
	0300	19.6	85.7	5.5	100	950	50	ESCS	
		Crossed Odisha coast close to Puri (near lat. 19.75⁰N and Long. 85.7⁰E) between 0230 to 0430 UTC of 3rd May							
	0600	20.2	85.9	-	85	952	46	VSCS	
	0900	20.5	86.0	-	75	970	28	VSCS	
	1200	21.1	86.5	-	70	976	22	VSCS	
	1500	21.5	86.7	-	60	980	18	SCS	
	1800	21.9	87.1	-	55	986	16	SCS	
	2100	22.5	87.9	-	50	990	12	SCS	
	04/05/2019	0000	23.1	88.2	-	40	994	8	CS
0300		23.6	88.8	-	30	996	6	DD	
0600		24.3	89.3	-	25	998	5	D	
1200		25.2	90.7	-	20	1000	4	D	
1800		Weakened into well marked low pressure area over central Assam & neighbourhood							

3. Monitoring and Prediction:

India Meteorological Department (IMD) maintained round the clock watch over the north Indian Ocean and the cyclone was monitored one week prior to the formation of low pressure area over the Bay of Bengal and adjoining equatorial

Indian Ocean on 25th April. First information about formation of low pressure during week ending 25th and beginning of week ending at 2nd May with probability of intensification into cyclonic disturbance was indicated in the extended range outlook issued by IMD on 18th April. Thus the cyclone was monitored & predicted continuously from 18th April onwards by IMD.

The cyclone was monitored with the help of available satellite observations from INSAT 3D and 3DR, polar orbiting satellites, and available ships & buoy observations in the region. From 1st May onwards till 4th May, the system was tracked gradually by IMD Doppler Weather Radars at Chennai, Machillipatnam, Visakhapatnam, Gopalpur, Paradeep, Kolkata and Agartala as it moved from south to north. Various numerical weather prediction models developed by Ministry of Earth Sciences (MoES) institutions and dynamical-statistical models were utilized to predict the genesis, track, landfall and intensity of the cyclone. A digitized forecasting system of IMD was utilized for analysis and comparison of various model guidance, decision making process and warning product generation. Typical satellite and radar imageries are presented in **Fig. 4 (a & b)** respectively.

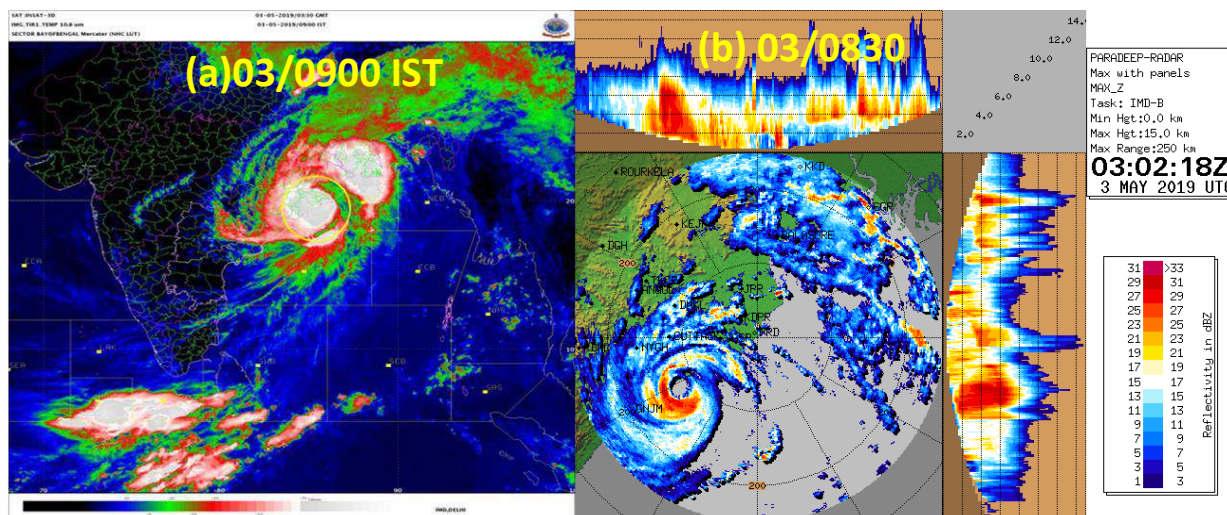


Fig.4: Typical (a) satellite imagery for ESCS FANI over Bay of Bengal and (b) Radar imagery from DWR Paradeep for ESCS FANI over Bay of Bengal near landfall time.

4. Realized Weather:

4.1. Realised rainfall

Rainfall associated with ESCS FANI based on IMD-NCMRWF GPM merged gauge 24 hours cumulative rainfall ending at 0830 IST of date is depicted in **Fig 5**.

It indicates occurrence of heavy to very heavy rainfall over coastal Odisha and Gangetic West Bengal on 3rd May, heavy rainfall at a few places over north coastal Odisha, Gangetic West Bengal and adjoining Bangladesh on 4th and heavy rainfall at a few places over Bangladesh and adjoining areas of northeastern states of Assam, Meghalaya & Arunachal Pradesh on 5th May.

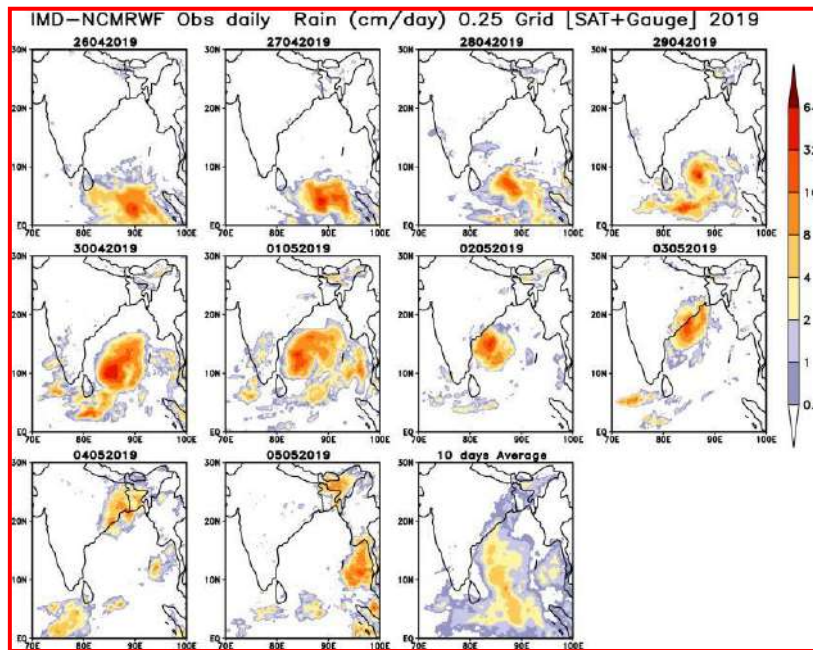


Fig.5: IMD-NCMRWF GPM merged gauge 24 hr cumulative rainfall (cm) ending at 0830 IST of date during 26th April - 5th May and 7 days average rainfall (cm/day)

Realized 24 hrs accumulated rainfall (≥ 7 cm) ending at 0830 hrs IST of date during the life cycle of the system is presented below:

3 May 2019

Arunachal Pradesh: Hawaii-8

Assam & Meghalaya: Gossaigaon-16, Kokrajhar-10, Hazuah-7

Sub-Himalayan West Bengal & Sikkim: Alipurduar & Alipurduar-7 each

Odisha: Berhampur-30, Gopalpur & Banki-17 each, Chhatrapur-15, Mundali-12, Purushottampur, Mohana, Puri, Ranpur, & R.Udaigiri-11 each, Rajghat-10, Nuagada-9, Tirtol, Digapahandi, Balasore, & Gania-8 each, Banpur, Aska, NH-5 Gobindpur, Khandapara, Narsinghpur, Naraj, & Niali-7 each

Bihar: Galgalia-14

Coastal Andhra Pradesh: Ichchapuram-18, Sompeta-17, Palasa-15, Mandasa-13, Tekkali-12, Kalingapatnam-9.

4 May 2019

Arunachal Pradesh: Tuting-9

Assam & Meghalaya: Williamnagar-8, Mawsynram-7

Nagaland, Manipur, Mizoram & Tripura: Arundhutinagar-9, Sonamura-8 and Agartala AERO, Amarapur & Kamalpur-7 each.

Gangetic West Bengal: Bankura-16, Kalaikunda-15, Kansabati Dam-14, Harinkhola & Phulberia-13 each, Hetampur & Suri -12 each, Bankura, Suri & Durgapur-11 each, Rampurhat-10, Sri Niketan, Jhargram, Simula, Kharidwar, Berhampore, Asansol, & Tantloi-9 each, Midnapore, Midnapore, Mohanpur, Asansol & Lalgah-8 each and Tusuma, Tilpara Barrage, Durgachack, Bagati, Purulia, Burdwan, Canning, Alipore, & Purihansa-7 each.

Odisha: Chandikhol-18, Bhuban & Bhubaneswar -16 each, Jajpur-15, Binjharpur & Samakhunta - 14 each, Cuttack & Jenapur-13 each, Hindol & Remuna -12 each, Korei & Kaptipada-11 each, Keonjhar, Sukinda & Rairangpur-10 each, Nilgiri & Jaleswar-9 each, Soro-8 and Dhenkanal, Joshipur, & Bari-7 each.

Jharkhand: Ghatsila, Messenjar, & Maheshpur-9 each, Dhanbad-8 and Maithon, Rajmahal, Jarmindi, & Moharo-7 each.

5 May 2019

Assam & Meghalaya: Cherrapunji-41, Mawsynram-33, Cherrapunji-28, Williamnagar-17, Shillong C.S.O.-13, Guwahati City-11, Kheronighat & Barapani-9 each, Guwahati, Dharamtul, Barpathar, & Kampur-8 each and Jia Bharali N T Xing, Bokajan, Karimganj, Shella, & Numaligarh-7 each.

Nagaland, Manipur, Mizoram & Tripura: Tamenglongi-13 and Sabroom-9

4.2. Realised wind:

Realised estimated maximum sustained surface wind was 175-185 kmph gusting to 205 kmph at the time of landfall close to Puri.

4.3. Realised storm surge:

Storm surge height is estimated to be about 1.5 m above the astronomical tide at the time of landfall.

5. Forecast performance:

5.1. Genesis Forecast

- First information about formation of LPA over EIO & adjoining south BoB during week ending 25th and beginning of week ending at 2nd May with probability of intensification into depression was indicated in the extended range forecast issued on 18th April.
- In the daily National Bulletin issued by IMD, likely formation of LPA over EIO & adjoining southwest BoB to the southeast of Sri Lanka around 26th April & intensification into D on 27th was predicted on 21st.
- The forecast was further modified on 22nd indicating an LPA over the same region on 25th April with likely intensification into a D during subsequent 48 hours.
- On 23rd, it was further informed that LPA is very likely to develop on 25th April, intensify into a depression on 26th and subsequently into a CS during next 48 hrs.
- On 25th, an LPA formed over EIO & adjoining southeast BoB. It was also predicted that it would intensify into a depression by 26th and into a CS during subsequent 48 hours. The LPA concentrated into D in morning of 26th April 2019. It was predicted that by 27th April morning it will intensify into a DD and into a CS by 27th April evening while moving northwestwards. Depression intensified into DD in early morning of 27th and into a CS by same afternoon.

5.2. Track, Intensity and Landfall Forecast

- First information issued at 1430 IST of 29th April (about 90 hrs prior to landfall) indicated that the system would move northwestwards till 1st May and recurve north-northeastwards towards Odisha coast.
- It was further indicated at 2100 hrs IST of 29th that the system would cross Odisha coast around Puri in the early morning of 4th May (about 84 hrs prior to landfall) as an extremely severe cyclonic storm with maximum sustained wind speed of 160-170 gusting to 190 kmph.
- The bulletin issued at 1520 hrs IST of 30th indicated that the system would cross Odisha coast between Gopalpur and Chandbali, to the south of Puri around 3rd May afternoon with wind speed of 175-185 kmph gusting to 205 kmph (about 66 hrs prior to landfall).
- The bulletin issued at 2030 hrs IST of 1st May (36 hrs prior to actual landfall) about indicated that the system would cross Odisha coast between Gopalpur and Chandbali, around Puri during 3rd May afternoon. The time of landfall was revised to 3rd May forenoon at 1600 IST of 2nd May.
- Observed & forecast track based on 0530 IST of 30th April (72 hrs prior to landfall) of ESCS FANI indicating accurate landfall prediction near Puri is presented in **Fig.6**.
- Typical observed and forecast tracks based on 0530 hrs IST of 30th April, 1st & 2nd May, 72 hrs, 48hrs & 24 hrs prior to landfall respectively indicating the consistency in track prediction and landfall near Puri is presented in **Fig.7**. IMD continuously predicted on 30th April, 1st & 2nd May that it will cross around Puri as an extremely severe cyclonic storm (ESCS) with wind speed of 175- 185 kmph gusting to 205 kmph on 3rd May.

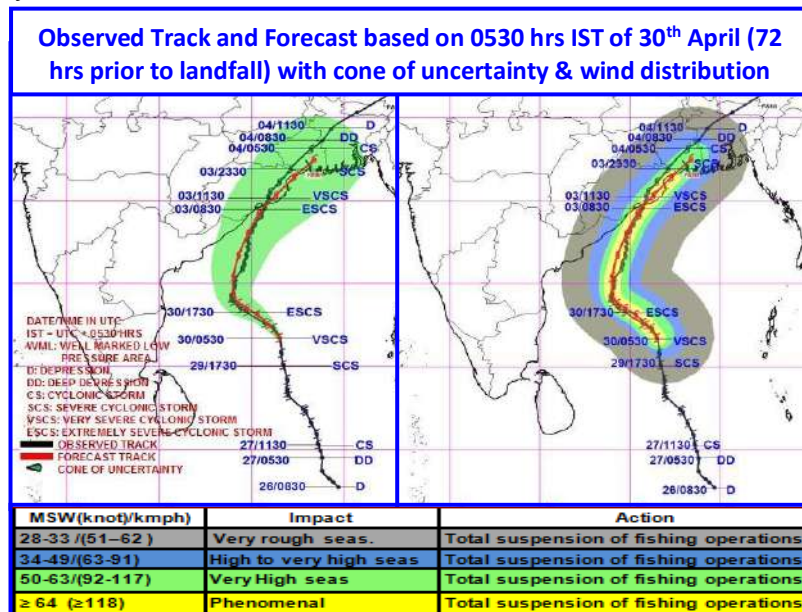


Fig.6: Observed and forecast track based on 0530 hrs IST of 30th April (72 hrs prior to landfall) of ESCS FANI indicating accuracy in landfall predictions near Puri (Odisha)

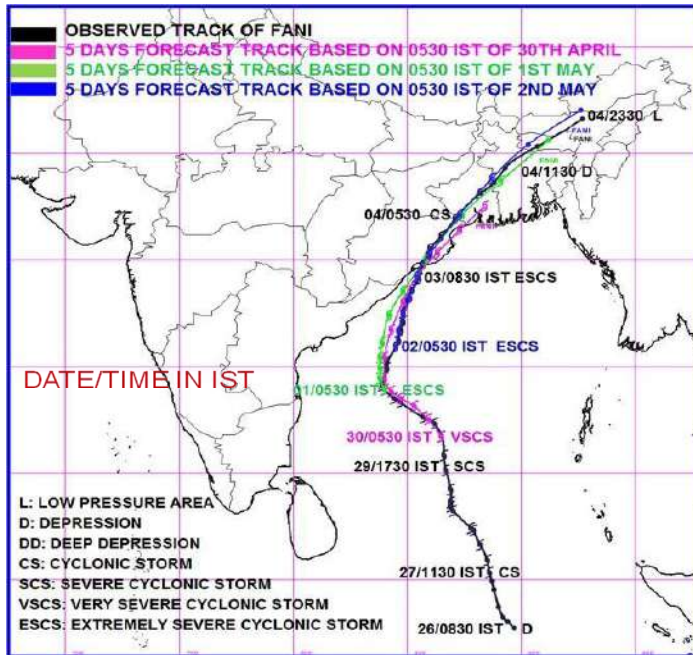


Fig. 7: Typical observed and forecast tracks based on 0530 hrs IST of 30th April, 1st & 2nd May, 72 hrs, 48hrs & 24 hrs prior to landfall indicating accuracy in landfall and track

5.3. Landfall Forecast Errors:

- The landfall point forecast errors for 24, 48 and 72 hrs lead period were 11, 11, and 15 km respectively against long period average errors of 47, 70 and 104 km during 2014-18 respectively (**Fig. 8**).
- The landfall time forecast errors for 24, 48 and 72 hrs lead period were 1.5, 5.5, and 14.5 hours respectively against long period average errors of 3, 5 and 6 hours during 2014-18 respectively (**Fig. 8**).

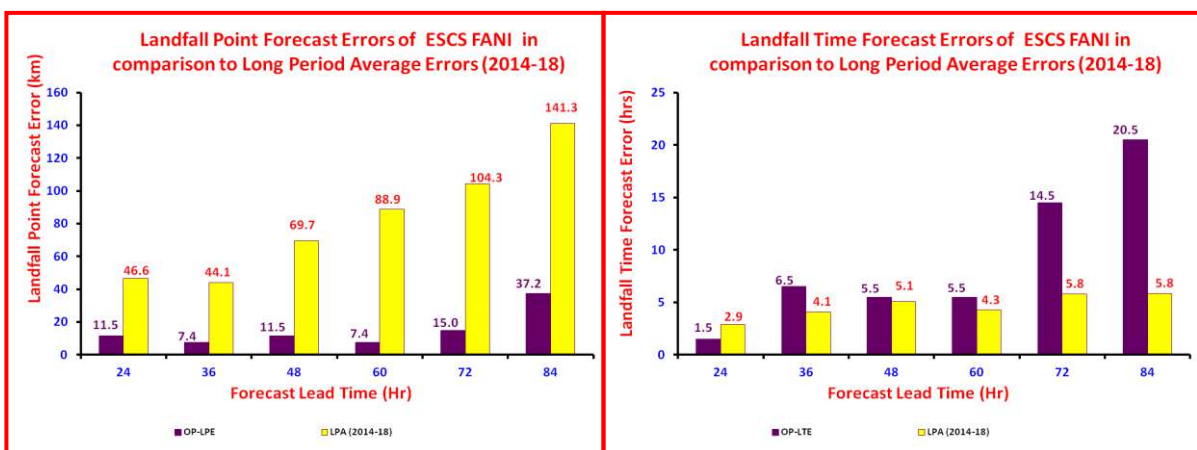


Fig. 8: Landfall forecast Errors and skill of ESCS FANI as compared to long period average (2014-18)

5.4. Track Forecast Errors:

- The track forecast errors for 24, 48 and 72 hrs lead period were 77.7, 137.3, and 182.6 km respectively against the average track forecast errors of 86.1, 132.3, and 177.7 km during last five years (2014-18) respectively (**Fig.9**).
- The track forecast skill was about 57%, 61%, and 58% against the long period average (LPA) of 58%, 70%, and 74% during 2014-18 for 24, 48 and 72 hrs lead period respectively (**Fig.9**).

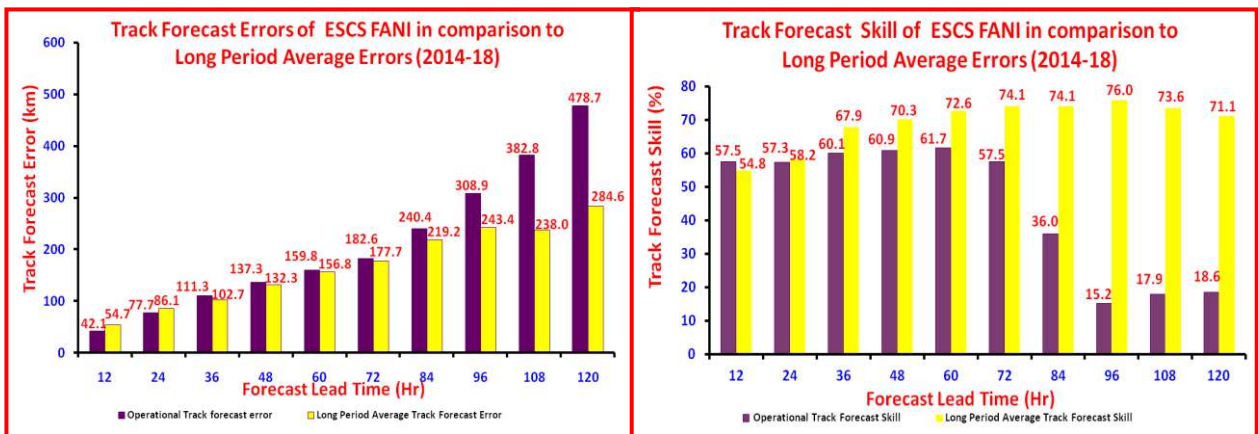


Fig. 9: Track forecast Errors and skill of ESCS FANI as compared to long period average (2014-18)

5.5. Intensity Forecast Errors:

- The absolute error (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 9.6, 12.6 and 13.8 knots against the LPA of 9.6, 14.1, and 14.3 knots respectively (**Fig. 10**).
- The root mean square error (RMSE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 11.3, 13.5 and 14.8 knots against the LPA of 12.5, 19.0, and 19.0 knots respectively (**Fig. 10**).

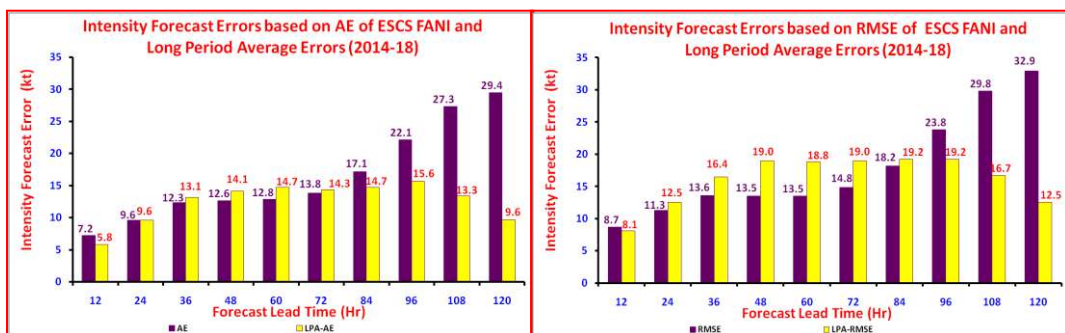


Fig. 10: Absolute errors (AE) and Root Mean Square errors (RMSE) in intensity forecast (winds in knots) based of ESCS FANI as compared to long period average (2014-18)

6. Warning Services

Bulletins issued by Cyclone Warning Division, New Delhi

- **Track, intensity and landfall forecast:** IMD continuously monitored, predicted and issued bulletins containing track, intensity, and landfall forecast for +06, +12, +18, +24, +36 and +48... +120 hrs lead period till the system weakened into a low pressure area. The above forecasts were issued from the stage of depression onwards along with the cone of uncertainty in the track forecast five times a day and every three hours during the cyclone period. The hourly updates were also provided 24 hours prior to landfall till the system maintained the intensity of cyclonic storm over West Bengal.
- **Cyclone structure forecast for shipping and coastal hazard management** The radius of maximum wind and radii of MSW ≥ 28 knots and ≥ 34 knots wind in four quadrants of cyclone was issued every six hourly giving forecast for +06, +12, +18, +24, +36 and +120 hrs lead period.
- **Four stage Warning:**
 - **Cyclone Watch:** Cyclone watch for Odisha and adjoining AP coasts was issued at 1430 IST of 29th April when the system was a CS over southwest BoB (90 hrs prior to landfall). It was extended to West Bengal coast at 1200 hrs IST of 30th April.
 - **Cyclone Alert:** 66 hrs prior to actual landfall issued for Odisha, West Bengal & Srikakulam and Vijayanagaram Districts of Andhra Pradesh coasts in the update issued at 1520 hrs IST of 30th April.
 - **Cyclone Warning:** Issued on 1st May 2030 IST (about 36 hrs prior to actual landfall) for Odisha, West Bengal and Srikakulam, Vijayanagaram & Visakhapatnam Districts of Andhra Pradesh Coasts:
 - **Post landfall Outlook** for interior districts of south coastal Odisha, north Odisha and interior districts of Gangetic West Bengal indicating expected winds, damage and action suggested after landfall of the system was issued at 2030 IST of 2nd May (about 12 hrs prior to actual landfall).
- **Adverse weather warning bulletins:** Adverse weather warning bulletins: The tropical cyclone forecasts alongwith expected adverse weather like heavy rain, gale wind and storm surge was issued with every three hourly update to central, state and district level disaster management agencies including MHA NDRF, NDMA for all concerned states along the east coast of India including Kerala, Tamil Nadu, Andhra Pradesh, Odisha, West Bengal, Assam & Meghalaya, Manipur, Mizoram & Tripura. The bulletins also contained the suggested action for disaster managers and general public in particular for fishermen. These bulletins were also issued to Defence including Indian Navy & Indian Air Force.
- **Warning graphics:** The graphical display of the observed and forecast track with cone of uncertainty and the wind forecast for different quadrants were disseminated by email and uploaded in the RSMC, New Delhi website

(<http://rsmcnewdelhi.imd.gov.in/>) regularly. The adverse weather warnings related to heavy rain, gale/squally wind & storm surge were also presented in graphics alongwith colour codes in the website.

- **Warning and advisory through social media:** Daily updates (every six hourly or whenever there was any significant change in intensity/track/landfall) were uploaded on face book and tweeter regularly during the life period of the system. From 2nd evening onwards, hourly updates were posted on facebook and tweeter till the system maintained the intensity of cyclonic storm.
- **Press release and press briefing:** Press and electronic media were given daily updates since inception of system through press release, e-mail, website and SMS.
- **Warning and advisory for marine community:** The three/six hourly Global Maritime Distress Safety System (GMDSS) bulletins were issued by the Marine Weather Services division at New Delhi and bulletins for maritime interest were issued by Area cyclone warning centres of IMD at Chennai, Kolkata and Cyclone warning centres at Bhubaneswar and Visakhapatnam to ports, fishermen, coastal and high sea shipping community.
- **Fishermen Warning:** Regular warnings for fishermen for deep sea of east equatorial Indian Ocean and adjoining south BoB and the states of West Bengal, Odisha, Andhra Pradesh, Tamil Nadu, Kerala, Andaman & Nicobar Islands were issued since 25th April.
- **Advisory for international Civil Aviation :** The Tropical Cyclone Advisory Centre (TCAC) bulletin for International Civil Aviation were issued every six hourly to all meteorological watch offices in Asia Pacific region for issue of significant meteorological information (SIGMET). It was also sent to Aviation Disaster Risk Reduction (ADRR) centre of WMO at Hong Kong.
- **Diagnostic and prognostic features of cyclone:** The prognostics and diagnostics of the systems were described in the RSMC bulletins.
- **Hourly Bulletin:** Hourly updates on the location, distance from recognised station, intensity and landfall commenced from 2nd evening onwards till the system maintained the intensity of cyclonic storm.

Statistics of bulletins issued by RSMC New Delhi and Area Cyclone Warning Centre Kolkata, Cyclone Warning Centre Bhubaneswar and Visakhapatnam in association with the ESCS FANI are given in **Table 2**.

Table 2 (a): Bulletins issued by RSMC New Delhi

S.N	Bulletin type	No. of Bulletins	Issued to
1	National Bulletin	65	1. IMD's website, RSMC New Delhi website 2. FAX and e-mail to Control Room Ministry of Home Affairs & National Disaster Management Authority, Cabinet Secretariat, Minister of Science & Technology, Headquarter Integrated Defence Staff, Director General Doordarshan, All India Radio, National Disaster Response Force, Chief Secretary, Government of Kerala, Tamil Nadu, Andhra Pradesh, Odisha, West Bengal, Assam, Meghalaya, Arunachal Pradesh.
2	RSMC Bulletin	64	1. IMD's website 2. WMO/ESCAP member countries through GTS and E-mail.
3	GMDSS Bulletins	33	1. IMD website, RSMC New Delhi website 2. Transmitted through WMO Information System (WIS) to Joint WMO/IOC Technical Commission for Ocean and Marine Meteorology (JCOMM)
4	Tropical Cyclone Advisory Centre Bulletin	30	1. Met Watch offices in Asia Pacific regions and middle east through GTS to issue Significant Meteorological information for International Civil Aviation 2. WMO's Aviation Disaster Risk Reduction (ADRR), Hong Kong through ftp 3. RSMC website
5	Tropical Cyclone Vital Statistics	29	Modelling group of IMD, National Centre for Medium Range Weather Forecasting Centre (NCMRWF), Indian National Centre for Ocean Information Services (INCOIS), Indian Institute of Technology (IIT) Delhi, IIT Bhubaneswar etc.
6	Warnings through SMS	Frequently	SMS to disaster managers at national level and concerned states (every time when there was change in track, intensity and landfall characteristics) (i) 4,29,357 SMS to General Public by IMD Headquarters (ii) 2,140 SMS to disaster managers by IMD Headquarters (iii) SMS to fishermen by INCOIS (iv) 59,37,365 SMS to farmers by Kisaan Portal
7	Warnings through Social Media	Daily	Cyclone Warnings were uploaded on Social networking sites (Face book, Tweeter and Whats App) since inception to weakening of system (every time when there was change in track, intensity and landfall characteristics).
8	Press Release	12	Disaster Managers, Media persons by email and uploaded on website
9	Press Briefings	Daily	Regular briefing daily
10	Hourly Updates	36	Hourly bulletins by email, website, social media

Table 2 (b): Statistics of bulletins issued by ACWC Kolkata and CWC Bhubaneswar & Visakhapatnam

S.No.	Type of Bulletin	No. of Bulletins issued		
		ACWC Kolkata	CWC Bhubaneswar	CWC Visakhapatnam
1.	Sea Area Bulletin	46	-	-
2.	Coastal Weather Bulletins	30	32	31
3.	Fishermen Warnings issued	74	32	29
4.	Port Warnings	53	34	20
5.	Heavy Rainfall warning	31	31	8
6.	Gale Wind Warning	23	25	8
7.	Storm Surge Warning	4	24	-
8.	Information & Warning issued to State Government and other Agencies	37	35	25
9.	SMS	10,000	22,150	396

7. Initiatives during ESCS FANI:

- (i) Rapid scanning of cyclone by INSAT-3DR was carried out during life cycle of ESCS FANI.
- (ii) The lightning data was superimposed on the satellite and radar image.
- (iii) The cyclone was continuously monitored and tracked by all the DWRs along the east coast commencing from radar at Chennai, Visakhapatnam, Gopalpur, Paradeep, Kolkata and Agartala. The DWR based specific products like wind speed at the height of 1 km was used to find out the intensity of cyclone.
- (iv) Both versions namely Princeton Ocean Model (POM) and Hybrid Co-ordinate Model (Hy-Com) of cyclone specific Hurricane Weather Research & Forecast Model (HWRF) were run simultaneously and six hourly forecast was provided with latest data assimilation tools.
- (v) HWRF model forecast products were made available through IMD website, RSMC website and also NCEP, USA website.
- (vi) IMD issued Extended Range Outlook giving 15 days probabilistic cyclogenesis forecast **(Fig. 11)**. The product is available at <http://www.rsmcnewdelhi.imd.gov.in/images/bulletin/eroc.pdf>
- (vii) Prediction of intensity of cyclone even prior to genesis. On 23rd April, it was predicted that the system would intensify into a cyclonic storm, while low pressure area formed on 25th April.
- (viii) Cone of uncertainty representing uncertainty in track was reduced by 20-30% for different lead periods due to reduction in track forecast errors during 2014-18 as compared to that during 2009-13. The last revision of COU was carried out in 2013 **(Fig.12)**.
- (ix) Impact over sea area and suggested action was given in the warning graphics alongwith wind distribution around the system centre **(Fig. 6)**.

- (x) Fishermen warning in graphical form was issued daily valid upto 5 days from 25th April, 2019 onwards (**Fig.13**). The product is available at <http://www.rsmcnewdelhi.imd.gov.in/images/bulletin/gfisherman.png>
- (xi) Hourly updates based on Radar observations were provided from 9:30 PM of 1st of May.
- (xii) Hourly bulletins were issued from 2nd morning (10:30 A.M.) till the system maintained the intensity of cyclonic storm. These bulletins were uploaded on facebook & tweeter hourly and SMS to disaster managers and general public were sent hourly.
- (xiii) To facilitate easy access to cyclone warning bulletins and graphics, the products were also uploaded on INCOIS website on 2nd & 3rd May.
- (xiv) Information and warning products on cyclone alongwith storm surge guidance were also provided to United Nations through WMO.
- (xv) During cyclone FANI the number of unique visitors and hits on IMD & RSMC website were exceptionally higher (**Fig.14**).

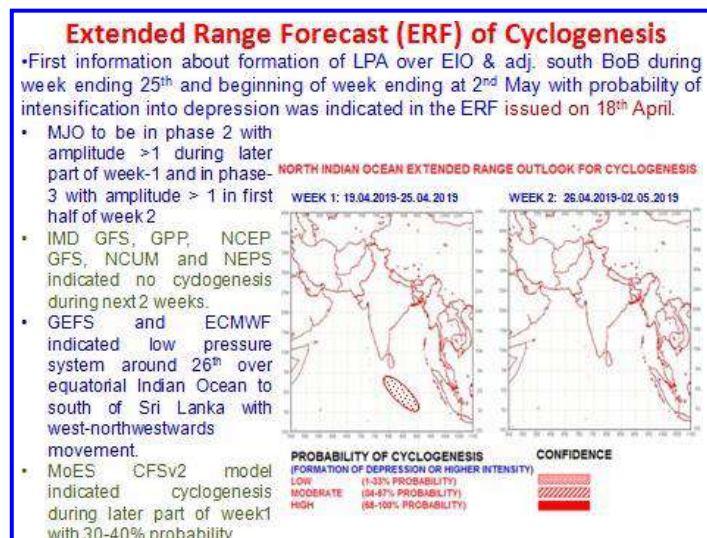


Fig.11: Extended Range Outlook issued on 18th April for next 15 days indicating cyclogenesis around 26th.

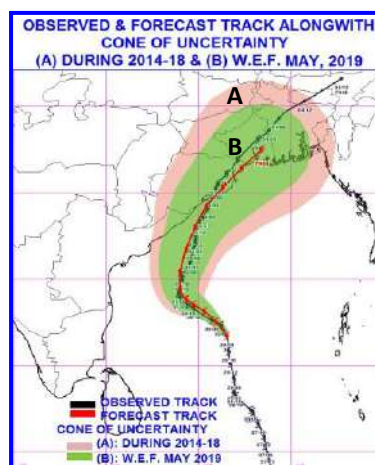


Fig. 12: Observed & Forecast Track alongwith cone of uncertainty (A) during 2014-18 and (B) w.e.f. May, 2019

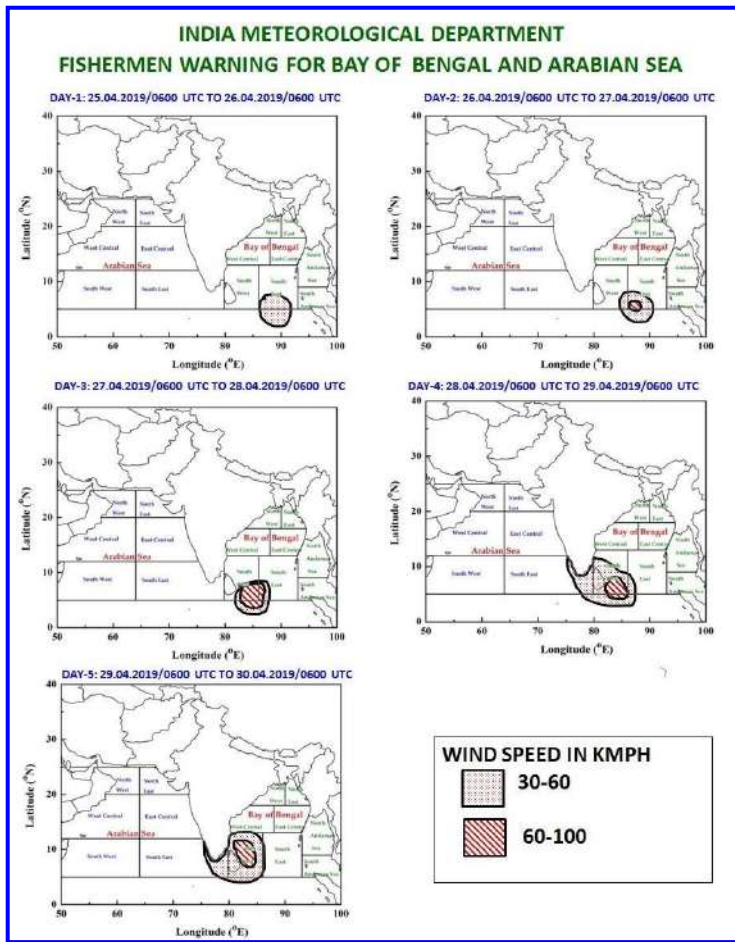


Fig. 13: 5 days fishermen warning in graphical form for entire north Indian Ocean issued at 0600 UTC (1130 IST) of 25th April 2019

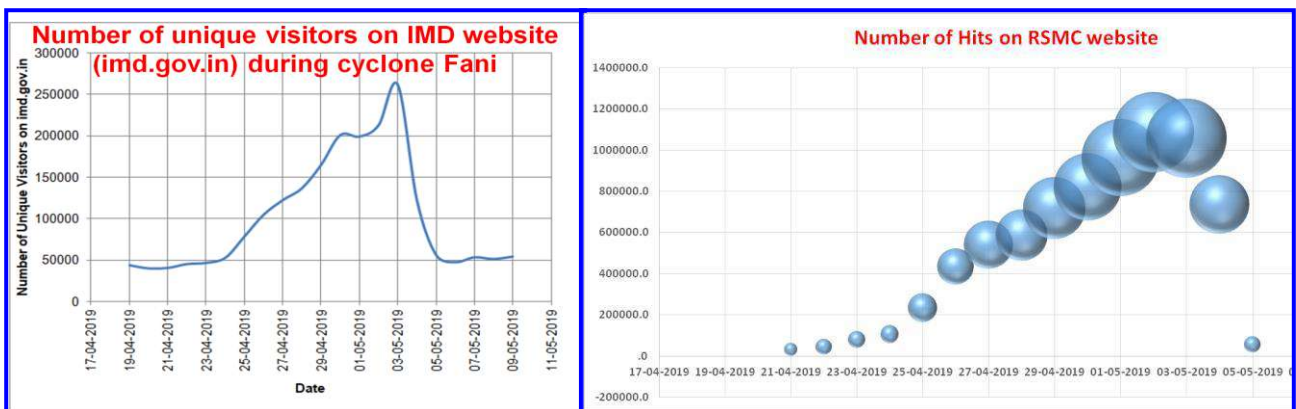
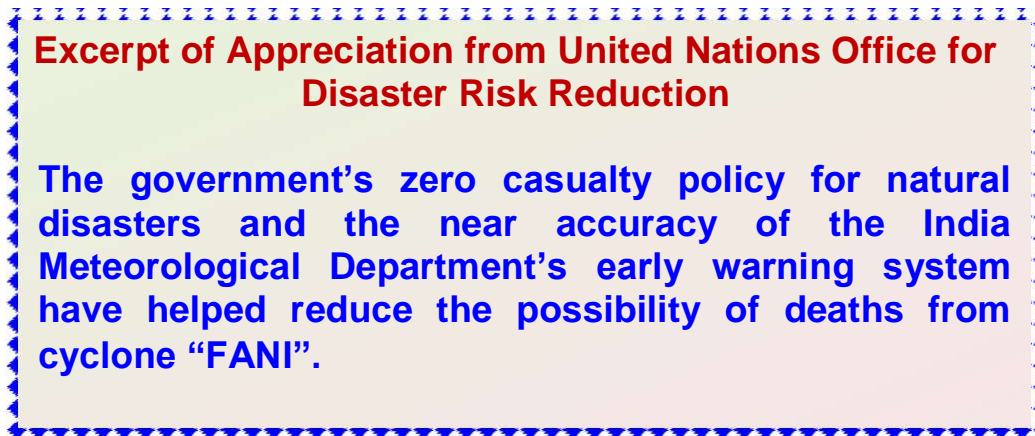


Fig. 14: No. of unique visitors in IMD website and No. of Hits on RSMC website during ESCS FANI

8. Appreciations earned for accurate forecast of ESCS FANI:

- ❖ Cyclone warning services of IMD have been appreciated world-wide by scientific, research and Govt. & non-governmental disaster management communities.

- ❖ IMD received appreciation from UNDRR, WMO and other national & international scientific community and media for pin point accuracy during recent cyclone FANI (26 April-04 May 2019).



9. Acknowledgement:

India Meteorological Department (IMD) and RSMC New Delhi duly acknowledges the contribution from all the stake holders and disaster management agencies who contributed to the successful monitoring, prediction and early warning service of ESCS FANI. We acknowledge the contribution of all sister organisations of Ministry of Earth Sciences including National Centre for Medium Range Weather Forecasting Centre (NCMRWF), Indian National Centre for Ocean Information Services (INCOIS), National Institute of Ocean Technology (NIOT), Indian Institute of Tropical Meteorology (IITM) Pune, research institutes including IIT Bhubaneswar, IIT Delhi and Space Application Centre, Indian Space Research Organisation (SAC-ISRO) for their valuable support. The support from various Divisions/Sections of IMD including Area Cyclone Warning Centre (ACWC) Chennai, Kolkata, Cyclone Warning Centre (CWC) Bhubaneswar, Visakhapatnam, Meteorological Centre (MC) Agartala, Doppler Weather Radar Stations at Chennai, Machillipatnam, Visakhapatnam, Gopalpur, Paradeep, Kolkata & Agartala and coastal observatories of Odisha & north Andhra Pradesh. The contribution from Numerical Weather Prediction Division, Satellite and Radar Division, Surface & Upper air instruments Divisions, New Delhi and Information System and Services Division at IMD is also duly acknowledged.
