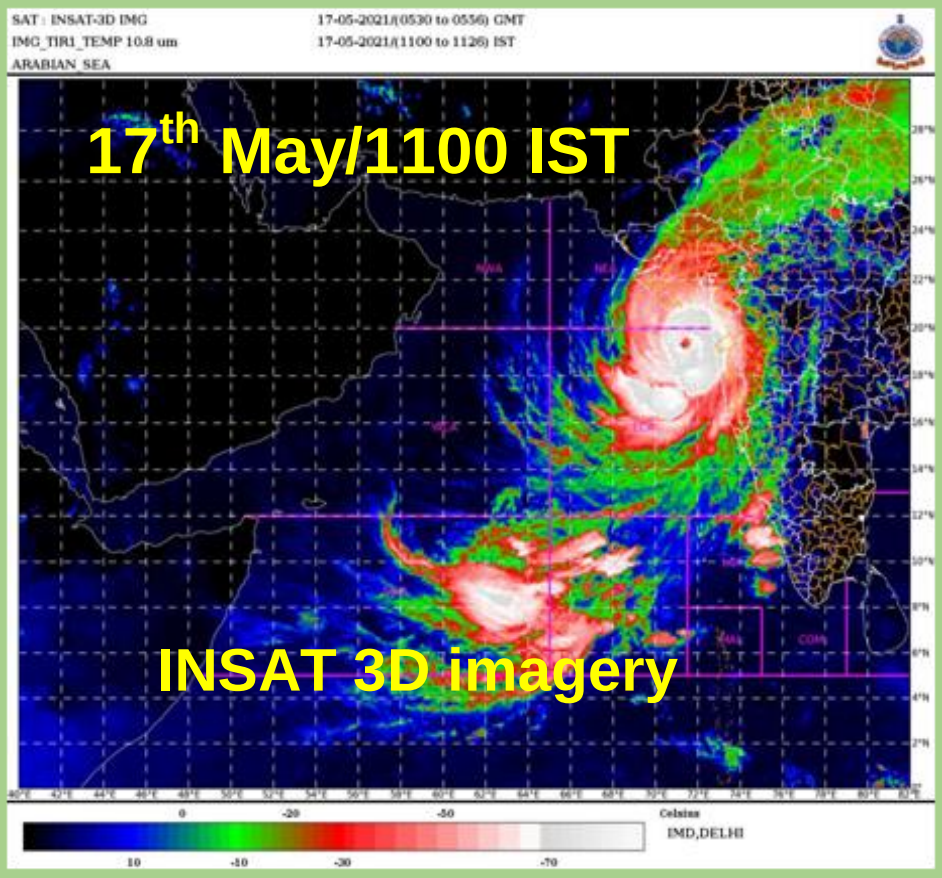
GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
INDIA METEOROLOGICAL DEPARTMENT

Extremely Severe Cyclonic Storm TAUKTAE over the Arabian Sea (14th-19th May, 2021): A Report



INSAT-3D enhanced colored IR imagery of 17th May, 2021

Cyclone Warning Division

India Meteorological Department

New Delhi

June, 2021

Extremely Severe Cyclonic Storm TAUKTAE over the Arabian Sea (14th-19th May, 2021): A Report

1. Life History of TAUKTAE:

- A low pressure area formed over southeast Arabian Sea & adjoining Lakshadweep area in the morning (0830 hrs IST/ 0300 UTC) of 13th May 2021. It lay as a well marked low pressure area over Lakshadweep area and adjoining southeast Arabian Sea in the same evening (1730 hours IST/1200 UTC of 13th May).
- Under favourable environmental conditions, it concentrated into a Depression (D) over Lakshadweep area in the morning (0830 hrs IST) of 14th May, 2021.
- It intensified into a Deep Depression (DD) over Lakshadweep area and adjoining southeast & eastcentral Arabian Sea (EC AS) in the same afternoon (1430 hrs IST/ 0900 UTC of 14th May) and into Cyclonic Storm (CS) **"TAUKTAE"** in the same midnight (2330 hrs IST/1800 UTC) over the same region.
- It moved nearly northwards and further intensified into a Severe Cyclonic Storm (SCS) in the evening (1730 hrs IST) of 15th May over EC AS.
- Continuing to move nearly northwards, it intensified into a Very Severe Cyclonic Storm (VSCS) over EC AS in the early hours (0230 hrs IST- 2100 UTC / 15th) of 16th May.
- It gradually started moving north-northwestwards from noon (1130 hours IST/0600 UTC) of 16th May and intensified rapidly into an Extremely Severe Cyclonic Storm (ESCS) in the early hours (0230 hrs IST/16th, 2100 UTC) of 17th May.
- Thereafter, it entered in a marginally unfavourable environment, weakened gradually and crossed Saurashtra coast near latitude 20.8°N and longitude 71.1°E, close to northeast of Diu (about 20 km northeast of Diu) during 2000-2300 hours IST of 17th May, 2021 with maximum sustained wind speed of 160-170 kmph gusting to 185 kmph.
- During the landfall, the system moved slowly nearly northwards, as it started re-curving. After landfall, it weakened into a VSCS over Saurashtra in the midnight (2330 hrs IST) of 17th May.
- Thereafter, it started moving north-northeastwards and weakened into an SCS in the morning (0300 UTC) over Saurashtra and further into a CS around noon (0600 UTC) of 18th May, 2021 over Saurashtra and adjoining Gujarat region.
- Continuing to move north-northeastwards, it weakened into a DD over Gujarat region in the evening (1730 hrs IST) and into a D over Gujarat region and adjoining South Rajasthan in the midnight (2330 hrs IST) of 18th May. The observed track of the system is presented in **Fig. 1.** The best track parameters of the system are presented in **Table 1**.

2. Salient features:

i. TAUKTAE was the first CS over the north Indian Ocean during the year 2021.

ii. During satellite era (1961-2021), Tauktae was the most intense cyclone after Kandla cyclone in 1998. During this period, 3 extremely severe cyclonic storms crossed Gujarat coast. Tracks of tropical cyclones (TCs) crossing Gujarat coast during 1961-2020 are presented in **Fig. 2**. Frequency of TCs crossing Gujarat coast is presented in **Fig.3**. The cyclone Tauktae had the same intensity as that of Kandla cyclone of June, 1998 at the

time of landfall as both had maximum sustained surface wind speed of 160-170 kmph gusting to 185 kmph at the time of landfall. However, life time maximum intensity was higher in case of Tauktae, as it had the maximum intensity of 180-190 gusting to 210 kmph over the east-central Arabian Sea during early morning to afternoon of 17th May 2021. **Table- 2** provides a comparison of salient features and damage potential of the two Extremely Severe Cyclonic Storms viz., Tauktae and Kandla Cyclone.

iii. Tauktae was a very rare cyclone causing adverse weather and damage over entire west coast states and Union Territories and Lakshadweep as it moved parallel to west coast and crossed Gujarat.

iv. It had a longer period of the impact of cyclone intensity over Gujarat (about 24 hrs from 1730 IST of 17th to 1730 IST of 18th May).

v. The track length of the cyclone was 1880 km.

vi. It had rapid intensification for about 24 hrs period during 16th morning (0530 IST/0000 UTC) to 17th morning (0530 IST/0000 UTC), with increase in maximum sustained wind speed (MSW) from 65 knots at 0530 IST of 16th to 100 knots at 0530 IST of 17th.

vii. The peak MSW of the cyclone was 180-190 kmph (100 knots) gusting to 210 kmph during 0530 IST (0000 UTC) 0f 17th to 1130 IST (0600 UTC) of 17th over the EC AS. The lowest estimated central pressure (ECP) was 950 hPa during the period with a pressure drop of about 50 hPa at the centre as compared to the surroundings (**Fig.8**).

viii. The life period (D to D) of the system was 129 hours (5 days & 9 hours) against long period average (LPA) (1990-2013) of 165 hours (6 days & 21 hrs) for VSCS categories over the Arabian Sea during pre-monsoon season.

ix. It moved with 12-hour average translational speed of 14.4 kmph against LPA (1990-2013) of 11.8 kmph for VSCS category over Arabian Sea during pre-monsoon season (**Fig.7**).

x. The Velocity Flux, Accumulated Cyclone Energy (a measure of damage potential) and Power Dissipation Index (a measure of loss) were 10.6 $X10^2$ knots, 7.7 X 10^4 $knots^2$ and 6.11 $X10^6$ $knots^3$ respectively.

xi. The operational track forecast errors for 24 and 48 hrs lead period were 73 and 113 km respectively against the average long period average (LPA) track forecast errors of 77 and 117 km during last five years (2016-20) respectively.

xii. The operational absolute error (AE) of intensity (wind) forecast for 24 and 48 hrs lead period were 4.4 and 8.9 kt against the LPA of 7.9 and 11.4 kt respectively.

xiii. The operational landfall point errors were 27 and 71 km for 24 and 48 hrs lead period against LPA of 32 and 62 km.

xiv. The operational landfall time errors were 3.5 hrs and 6.5 hrs for 24 and 48 hrs lead period against LPA of 2.5 hrs and 5.0 hrs.

xv. As the cyclone moved parallel to west coast, it caused heavy to extremely heavy rainfall activity, strong wind and tidal waves affecting Lakshadweep on 13th-14th, Kerala on 14th-15th, Karnataka on 15th, Goa and south coastal Maharashtra on 15th -16th, north Maharashtra on 16th -17th, Gujarat, Daman & Diu, Dadra & Nagar Haveli on 17th and 18th. It's remnant also impacted northwest India with heavy to very heavy rainfall activity at isolated places over Rajasthan, Haryana, Chandigarh, Delhi, Uttar Pradesh, Uttarakhand on 19th May 2021.

xvi. It also caused strong winds along the west coast of India as well as over Lakshadweep. Agathi reported maximum sustained wind speed of 45 kts on 14th May, Panaji reported 46 kts on 16th, Diu reported 85 kts on 17th.

xvii. A total of 41 national bulletins, 30 RSMC bulletins to WMO/ESCAP Panel member countries, 9 Press Releases, 15 hourly bulletins on the day of landfall, 18 bulletins for International Civil Aviation, 83 lakh SMS to fishermen, farmers & coastal population, very frequent updates on social networking sites were sent to trigger mass response and sensitize masses about the impending disaster in association with the system.

xviii. While 3 hourly bulletins were issued commencing from cyclone stage, hourly updates were provided on the day of landfall.

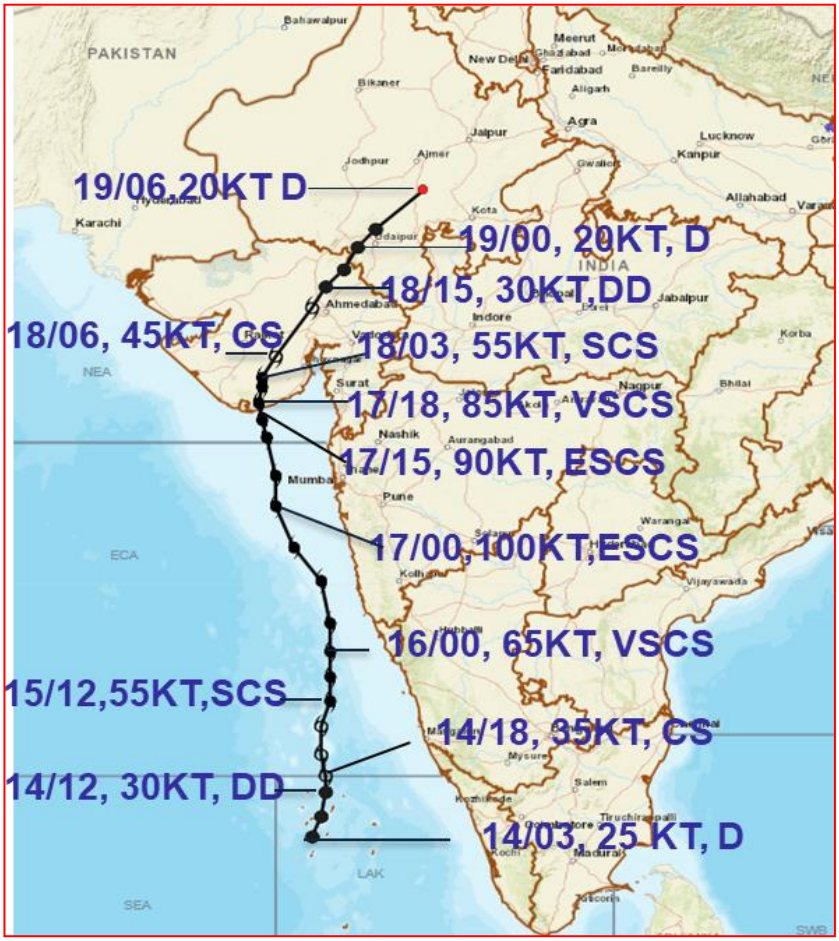


Fig.1: Observed track of ESCS TAUKTAE during 14th-19th May, 2021

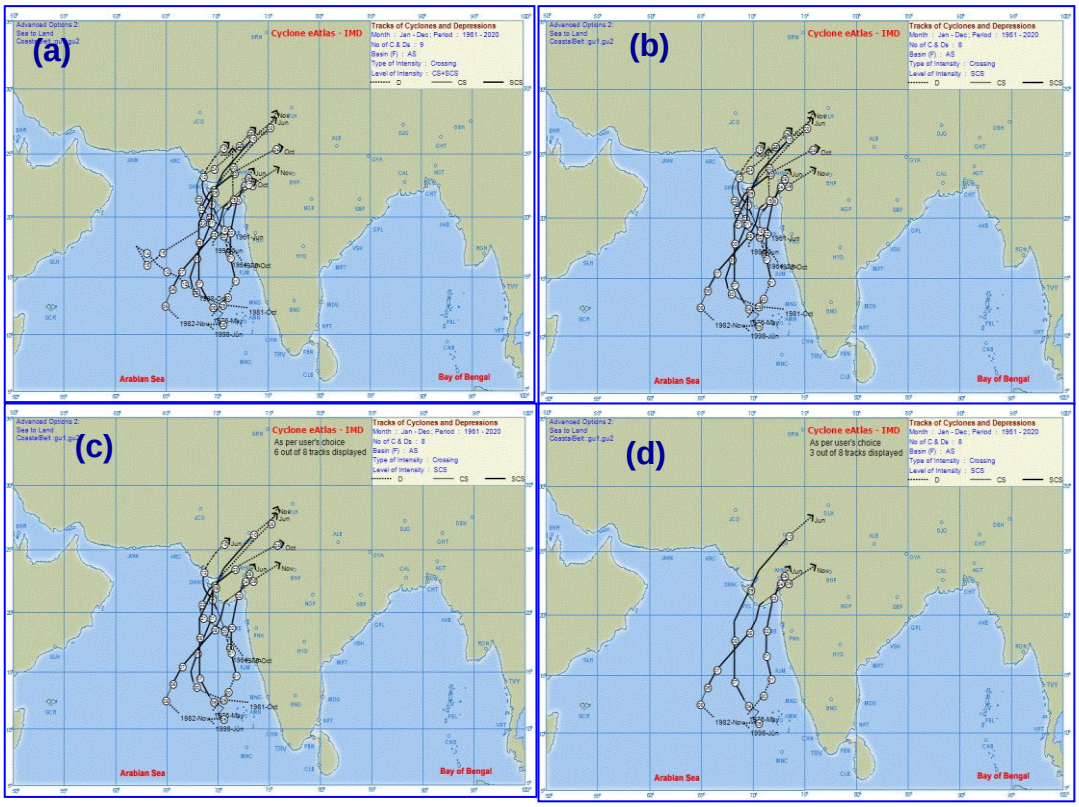


Fig.2: Tracks of (a) CS & above (Total 8), (b) SCS & above (Total 8), (c) VSCS & above (Total 6) and (d) ESCS & above (Total 3) category storms crossing Gujarat coast during 1961-2020

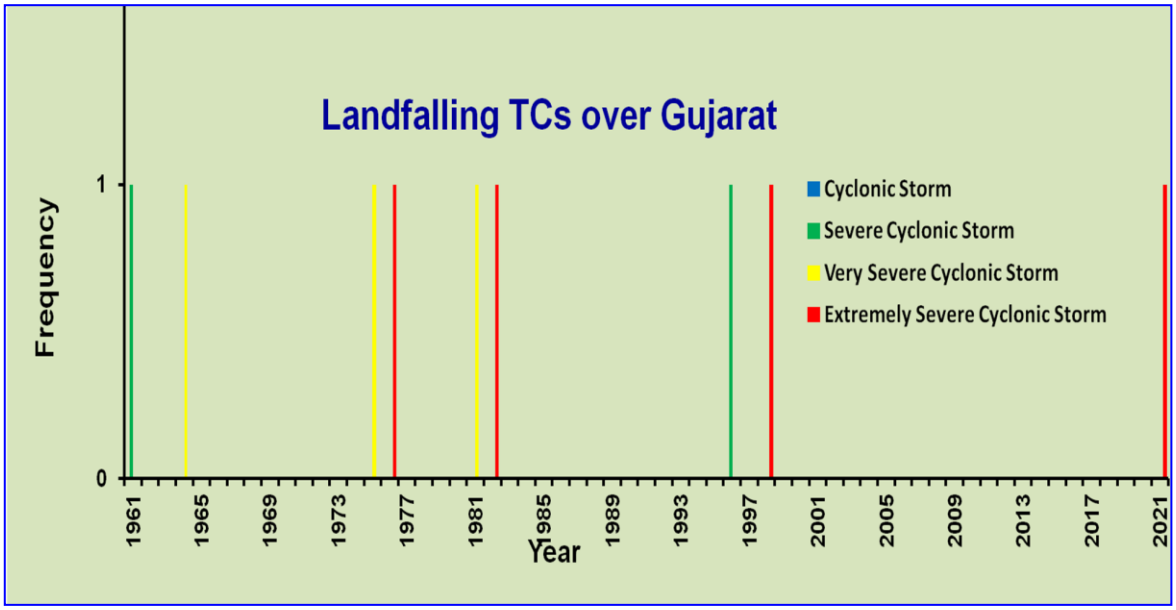


Fig.3: Frequency of landfalling TCs of Gujarat coast during 1961-2021

3. Monitoring of ESCS, 'TAUKTAE'

India Meteorological Department (IMD) maintained round the clock watch over the north Indian Ocean and the cyclone was monitored since 6th May, about 7 days prior to the formation of low pressure area over southeast Arabian Sea & adjoining Lakshadweep area on 13th May and 8 days prior to the formation of the D over Lakshadweep area. The cyclone was monitored with the help of available satellite observations from INSAT 3D and 3DR, SCAT SAT, polar orbiting satellites and available ships & buoy observations in the region. The system was also monitored by Doppler Weather RADARs (DWR) Thiruvananthapuram, Kochi and Goa. Various numerical weather prediction models run by Ministry of Earth Sciences (MoES) institutions, global models and dynamical-statistical models were utilized to predict the genesis, track, landfall and intensity of the cyclone. A digitized forecasting system of IMD was utilized for analysis and comparison of various models' guidance, decision making process and warning products generation. Typical satellite and radar imageries during ESCS TAUKTAE are presented in Fig. 4.

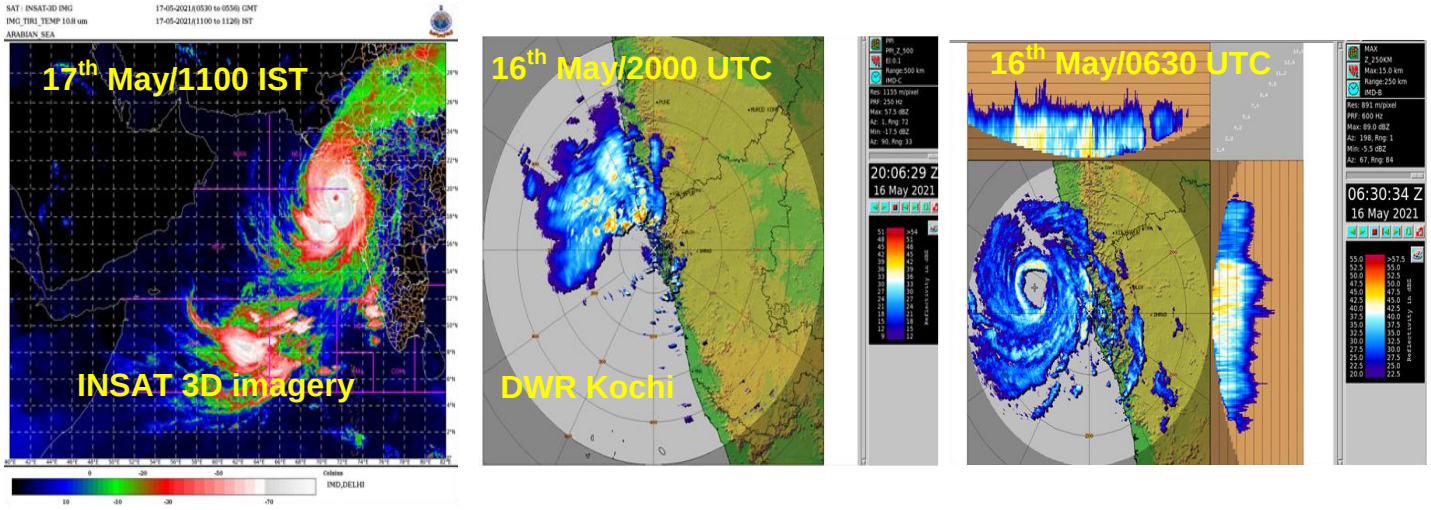


Fig. 4: Typical INSAT 3D satellite and radar imageries from Doppler Weather Radars Kochi and Goa

Table1: Best track positions and other parameters of the Extremely Severe Cyclonic Storm, "Tauktae" over the Arabian Sea during 14 May- 19 May, 2021

Date	Time (UTC)	Centre lat.^{0} N/ long.^{0} E		C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimated Pressure drop at the Centre (hPa)	Grade
14/05/2021	0300	10.5	72.3	1.5	997	25	3	**D**
	0600	11.0	72.5	1.5	996	25	4	D
	0900	11.5	72.5	2.0	995	30	5	D
	1200	11.6	72.6	2.0	995	30	6	**DD**

	1800	12.2	72.6	2.5	993	35	7	**CS**
	2100	12.2	72.6	2.5	992	40	8	CS
15/05/2021	0000	12.7	72.5	2.5	992	40	8	CS
	0300	12.8	72.5	2.5	992	40	8	CS
	0600	13.2	72.6	2.5	990	45	10	CS
	0900	13.5	72.7	2.5	990	45	10	CS
	1200	13.8	72.7	3.0	985	55	15	**SCS**
	1500	14.2	72.7	3.0	984	55	16	SCS
	1800	14.5	72.6	3.0	982	60	18	SCS
	2100	14.7	72.7	3.0	982	60	18	SCS
16/05/2021	0000	15.0	72.7	4.0	979	65	21	**VSCS**
	0300	15.3	72.7	4.0	976	70	24	**VSCS**
	0600	15.7	72.7	4.0	976	70	24	VSCS
	0900	16.2	72.6	4.0	976	70	24	VSCS
	1200	16.7	72.5	4.5	972	75	28	VSCS
	1500	17.2	72.3	4.5	978	80	32	VSCS
	1800	17.5	72.0	4.5	964	85	36	VSCS
	2100	18.0	71.7	5.0	960	90	40	**ESCS**
17/05/2021	0000	18.5	71.5	5.5	950	100	50	ESCS
	0300	18.8	71.5	5.5	950	100	50	ESCS
	0600	19.2	71.4	5.5	950	100	50	ESCS
	0900	19.6	71.4	5.5	950	100	50	ESCS
	1200	20.1	71.3	5.0	955	95	45	ESCS
	1500	20.5	71.2	5.0	960	90	40	ESCS
	Crossed Saurashtra coast about 20 km northeast of Diu, near Lat.20.8°N and Long. 71.1°E during 1530-1730 UTC of 17th May 2021 with maximum sustained wind speed of 90 knots gusting to 100 knots.							
	1800	20.9	71.1	-	964	85	36	**VSCS**
	2100	21.3	71.2	-	972	75	28	VSCS
18/05/2021	0000	21.5	71.2	-	978	65	22	VSCS
	0300	21.6	71.3	-	984	55	16	**SCS**
	0600	22.0	71.5	-	990	45	10	**CS**
	0900	22.5	71.8	-	992	40	8	**CS**
	1200	23.1	72.3	-	993	35	7	CS
	1500	23.6	72.6	-	994	30	6	**DD**
	1800	24.1	73.0	-	995	30	5	DD
19/05/2021	0000	24.5	73.3	-	996	25	4	**D**
	0300	24.9	73.7	-	997	20	3	D
	0600	25.8	74.8	-	997	20	3	D
	1200	Weakened into a Well-Marked Low Pressure Area over Northeast Rajasthan.						

Table-2: Comparison of salient features and damage potential of the two Extremely Severe Cyclonic Storms viz., Tauktae and Kandla Cyclone

S.N	Parameter	TAUKTAE, 2021	Kandla Cyclone, 1998
1.	Intensity Category	Extremely Severe Cyclonic Storm	Extremely Severe Cyclonic Storm
2.	Life time maximum	85 knots gusting to 100 knots	90 knots gusting to 100 knots

	intensity	(185 kmph)	(185 kmph)
3.	Intensity at the time of landfall	160-170 kmph gusting to 185 kmph	160-170 kmph gusting to 185 kmph
4.	Estimated Central Pressure Lowest Pressure drop	950 hPa 50 hPa	958 hPa 40 hPa
5.	Track length	1880 km	2750 km
6.	Life Period	5 days and 9 hours (0300 UTC of 14th – 1200 UTC of 19th)	6 days and 6 hours (0600 UTC of 4th June to 1200 UTC of 10th June)
7.	Accumulated Cyclone Energy (damaging potential)	7.72 X 10^4 kt^2	8.1 X 10^4 kt^2
8.	Power dissipation Index (measure of loss)	6.12 X 10^6 kt^3	6.12 X 10^6 kt^3
9.	Speed of movement at the time of landfall (slower speed causes more wind damage)	15 kmph	20 kmph
10	Duration of VSCS over land after landfall	12 hrs (17th/15 UTC to 18th/03 UTC)	12 hrs (9th/00 UTC to 9th/12 UTC)
11	Duration of SCS over land after landfall	3 hrs (18th/03 UTC to 18th/06 UTC)	6 hrs (9th/12 UTC to 9th/18 UTC)
12	Duration of CS over land after landfall	9 hrs (18th/06 UTC to 18th/15 UTC)	6 hrs (9th/18 UTC to 10th/ 00 UTC)
13	Duration of D & DD over land after landfall	21 hrs (18/15 UTC to 19th/12 UTC)	12 hrs (10th/00 UTC to 10th/12 UTC)
14	Total duration of cyclonic storm intensity over land	24 hrs	24 hrs
15	Duration from landfall till de-intensification into depression	Approx. 45 hrs	Approx. 36 hrs
16	Rainfall	23 cm in 24 hours over Gujarat	19 cm in 24 hours in Rajasthan & 12 cm in Bhuj
17	Storm Surge Warning	3-4m	2-3 m (above the astronomical tide of 6.6 m)
18	Major states and UTs affected	Lakshadweep, Kerala, Karnataka, Goa, Maharashtra, Gujarat & Rajasthan, Daman & Diu and Dadra & Nagar Haveli. Remnant also impacted northwest India with isolated heavy rainfall. **Large area was impacted at the time of landfall**	Gujarat & Rajasthan. Large area was impacted at the time of landfall. Also the system made double landfall, initially damaging Kandla port with High storm tides & gale force winds. After re-emerging into Gulf of Kutch, it made the second landfall near Bhuj.
19	Damages reported	Houses damaged-129297 In Gujarat due to effect of cyclone, power supply affected in coastal areas in around 9543	Houses damaged – more than 2.5 Lakhs The total extent of damage to Gujarat state was of the order

		villages/cities. Minor damage to electricity also reported in Daman & Diu.	of Rs. 190 crores (in 1998).
20	Death toll (in Gujarat)	67	Around 3,000

4. Anaysis of environmental features associated with the genesis, intensification & movement

4.1 Genesis

A near equatorial convergence zone developed over south AS from the beginning of the second week of May. Cross equatorial flow began strengthening over the region following the persistence & enhancement of convection since 10th May. As the cyclonic shear vorticity increased in the lower tropospheric levels, a low pressure area formed over southeast Arabian Sea & adjoining Lakshadweep area in the morning (0300 UTC) of 13th May. It became well marked over Lakshadweep area and adjoining southeast Arabian Sea in the same evening (1200 UTC of 13th May). Under favourable environmental conditions, it concentrated into a D over Lakshadweep area in the morning (0300 UTC) of 14th May. It intensified into a DD over Lakshadweep area and adjoining southeast & EC AS in the same afternoon (0900 UTC of 14th May) and into CS "TAUKTAE" in the same midnight (1800 UTC) over the same region.

4.2 Intensification and movement

CS 'Tauktae' moved nearly northwards and intensified into an SCS in the evening (1200 UTC) of 15th May over EC AS. Continuing to move nearly northwards, it further intensified into a VSCS over EC AS in the early hours (2100 UTC of 15th) of 16th May over EC AS. It gradually started moving north-northwestwards from noon (0600 UTC) of 16th May and intensified rapidly into an ESCS in the early hours (0000 UTC) of 17th May. Thereafter, it entered in a marginally unfavourable environment, weakened gradually and crossed Saurashtra coast near latitude 20.8°N and longitude 71.1°E, close to northeast of Diu (about 20 km northeast of Diu) during 1430 – 1730 UTC of 17th May, with maximum sustained wind speed of 160-170 kmph gusting to 185 kmph. During the landfall, the system moved slowly & nearly northward, as it started re-curving under the influence of a trough in mid-latitude westerlies. After landfall, it weakened into a VSCS over Saurashtra in the midnight (1800 UTC) of 17th May.

Thereafter, it started moving north-northeastwards and weakened into an SCS in the morning (0300 UTC) over Saurashtra and further into a CS around noon (0600 UTC) of 18th May over Saurashtra and adjoining Gujarat region. Continuing to move north-northeastwards, it weakened into a DD over Gujarat region in the evening (1200 UTC) and into a D over Gujarat region and adjoining South Rajasthan in the midnight (1800 UTC) of 18th May.

4.3 Environmental features associated with intensification & movement

The index of Madden Julian Oscillation (MJO) remained in Phase 2, though with amplitude less than 1 all through the life period of the system, thereby providing environment for enhanced convection over the Arabian Sea (AS). The Tropical Cyclone Heat Potential (TCHP) was more than 140 KJ/cm^2 over southeast AS. It was comparatively less over central & north AS. Sea Surface Temperature (SST) was around 30-31^{o}C over southeast AS and around 30^{0}C over the rest of the AS. These Oceanic

conditions also continued to prevail during the life Cycle of the system. The cross equatorial flow in the near equatorial belt was found to be enhanced in association with a westerly wind burst.

On 14th May morning, the low level cyclonic vorticity was getting further organised and was around 200 $x10^{-6}$ s^{-1} to the south-southwest of system centre over southeast AS. Low level convergence also increased (40 x10-5 s^{-1}) to the southwest of system centre. Positive upper level divergence (40 x 10^{-5} s^{-1}) was seen to the west-southwest of system centre. Upper tropospheric ridge ran along 12.5^{o}N. The system remained in a region of low to moderate Vertical Wind Shear (VWS) (10-15 KTS). Thus under favourable environment of MJO, high SST, high TCHP, good pole ward outflow, moderate VWS and westerly wind burst, the well marked Low pressure area concentrated into a D over Lakshadweep area at 0300 UTC of 14th May.

By 14th evening, the low level cyclonic vorticity was around 150 $x10^{-6}$ s^{-1} to the south of system centre. Low level convergence remained more or less the same (40 $x10^{-5}$ s^{-1}) to the southwest of system centre. Positive upper level divergence (40 x 10^{-5} s^{-1}) was seen to the southwest of the system centre. Upper tropospheric ridge ran along 12.5^{0}N. The system at this time remained in a region of moderate to high VWS (25-30 KTS). Thus under favourable environment of MJO, high SST, high TCHP, good pole ward outflow and westerly wind burst, the D over Lakshadweep area intensified into a DD at 1200 UTC of 14th May over the same region.

By the night of 14th May, the Convection over Lakshadweep and adjoining southeast Arabian Sea organized further and clouds became organized in a curved band pattern. The cross equatorial flow in the near equatorial belt was further enhanced due to westerly wind burst. The low level cyclonic vorticity was around 150 $x10^{-6}$ s^{-1} to the south of system centre. Low level convergence further increased and was (60 $x10^{-5}$ s^{-1}) to the west of system centre. Positive upper level divergence (30 x 10^{-5} s^{-1}) was seen around the system center. Upper tropospheric ridge ran along 12.5^{0}N. The system continued to remain in a region of moderate to high vertical wind shear (VWS) (25-30 KTS). Thus under favourable environment of MJO, high SST, high TCHP, good pole ward outflow, and westerly wind burst, the DD over Lakshadweep area intensified into a Cyclonic Storm At 1800 UTC of 14th May.

By the evening of 15th May, the satellite imagery indicated development of a CDO pattern. The low level cyclonic vorticity was about 250 $x10^{-6}s^{-1}$ around system centre. Low level convergence has been (40 $x10^{-5}$ s^{-1}) to the southwest of system centre. Positive upper level divergence was (30 x 10^{-5} s^{-1}) to the south-southwest of the system centre. Upper tropospheric ridge continued to run along 12.5^{0}N. At this period, the system entered to the region of moderate vertical wind shear (VWS) (15-20 KTS). Thus under favourable environment of MJO, high SST, high TCHP, good pole ward outflow, moderate VWS and westerly wind burst, the CS over EC AS intensified into an SCS at 1200 UTC of 15th May.

In the early morning of 16th May, the clouds organized further. The low level cyclonic vorticity was about 250 $x10^{-6}$ s^{-1} around system centre. Low level convergence was (40 $x10^{-5}$ s^{-1}) to the southwest of system centre. Positive upper level divergence remained to

be (20 x 10^{-5} s^{-1}) around the system centre. Upper tropospheric ridge shifted northwards and ran along 15 ^{0}N. The system at this period was found to be entering into a region of low VWS (05-10 KTS). Thus, under favourable environment like MJO, high SST, high TCHP, good pole ward outflow, low VWS and westerly wind burst, the SCS over eastcentral Arabian Sea rapidly intensified into a VSCS by 0000 UTC of 16th May and into an ESCS by 2100 UTC of 16th May.

On 17th morning, the low level cyclonic vorticity remained to be about 250 x10^{-6} s $^{-1}$ around system centre. Low level convergence had further increased and was (60 x10^{-5} s^{-1}) to the southeast of system centre. Positive upper level divergence has been (40 x 10^{-5} s^{-1}) to the south of the system centre. Upper tropospheric ridge ran along 21 ^{0}N. The system continued to remain in the region of low vertical wind shear (VWS) (10-15 KTS). The movement of the system became faster during past 12 hours due to strong steering from upper tropospheric winds. Thus, under favorable environment, the ESCS over east-central Arabian Sea moved north northwestwards maintaining its intensity.

At 1500 UTC of 17th May, just prior to the beginning of the landfall process, the low level cyclonic vorticity had reduced slightly and was about 200-250 x10^{-6} s $^{-1}$ around system centre. Low level convergence was (40 x10^{-5} s^{-1}) to the southeast of system centre. Positive upper level divergence was (30 x 10^{-5} s^{-1}) which lay to the south of the system centre. Upper tropospheric ridge continued to run along 21ºN.

The ESCS made landfall during 1530 – 1730 UTC of 17th May and started weakening further due to land interaction. Still, at 0000 UTC of 18th, the low level cyclonic vorticity continued to remain about 200-250 x10^{-6} s $^{-1}$ around system centre. Low level convergence was (40 x10^{-5} s^{-1}) to the south of system centre. Positive upper level divergence was (30 x 10^{-5} s^{-1}) which also lay to the south of the system centre. Upper tropospheric ridge ran along 22 ^{0}N to the east of the system. Under these environmental conditions, the system weakened in to a VSCS at 1800 UTC of 17th May.

Subsequently, on 18th morning, the low level cyclonic vorticity reduced and was about 200-250 x10^{-6}s $^{-1}$ around system centre. Low level convergence also reduced and was about (30 x10^{-5} s^{-1}) to the south of system centre. Positive upper level divergence remained to be (40 x 10^{-5} s^{-1}) to the south of the system centre. Upper tropospheric ridge ran along 23.5^{0}N to the east of the system centre. At 0300 UTC of 18th, the system further weakened into a severe cyclonic storm.

Around noon of 18th, the low level cyclonic vorticity further reduced and was about 200 x10^{-6} s-^{1} around system centre. Low level convergence was about (50 x$10^{-5}$$s^{-1}$) to the south of system centre. Positive upper level divergence has been (30 x 10^{-5} s^{-1}) to the south of the system centre. Upper tropospheric ridge ran along 23.0^0 N to the east of the system centre. At 0600 UTC of 18th, the severe cyclonic storm further weakened into a cyclonic storm.

During 18th night, he low level cyclonic vorticity remained to be about 200 x10^{-6} s^{-1} around system centre. Low level convergence was about (20 X$10^{-5}$$s^{-1}$) around the system centre. Positive upper level divergence reduced and was (10 x $10^{-5}$$s^{-1}$) to the south of the system centre. Upper tropospheric ridge ran along 23.0 ^{0}N to the east of the system center. At 1500 UTC of 18th, the cyclonic storm further weakened into a Deep Depression, into a

Depression by 0000 UTC of 19th and further into a Well Marked low by 1200 UTC of 19th May.

The total precipitable water (TPW) vapour imageries (Source: TC Forecaster Website: https://rammb-data.cira.colostate.edu/tc_realtime/index.asp) during life cycle of ESCS Tauktae are presented in **Fig. 5**. These imageries indicate continued supply of warm moist around the system centre from the near equatorial belt in association with the westerly wind burst till the late night of 16th May. Comparatively Cooler & drier air prevailed to the north of the system all through its life period. The rapid intensification characteristic exhibited by the system during 00 UTC of 16th to 00 UTC of 17th, could have been aided by this continuous supply of warm & moist air from the south. However no cold & dry air intrusion could be attributed to the weakening of the system after landfall. On the other hand the system maintained the Cyclonic Storm intensity over and for nearly 24 hours under the favourable interaction with a mid-latitude upper level trough.

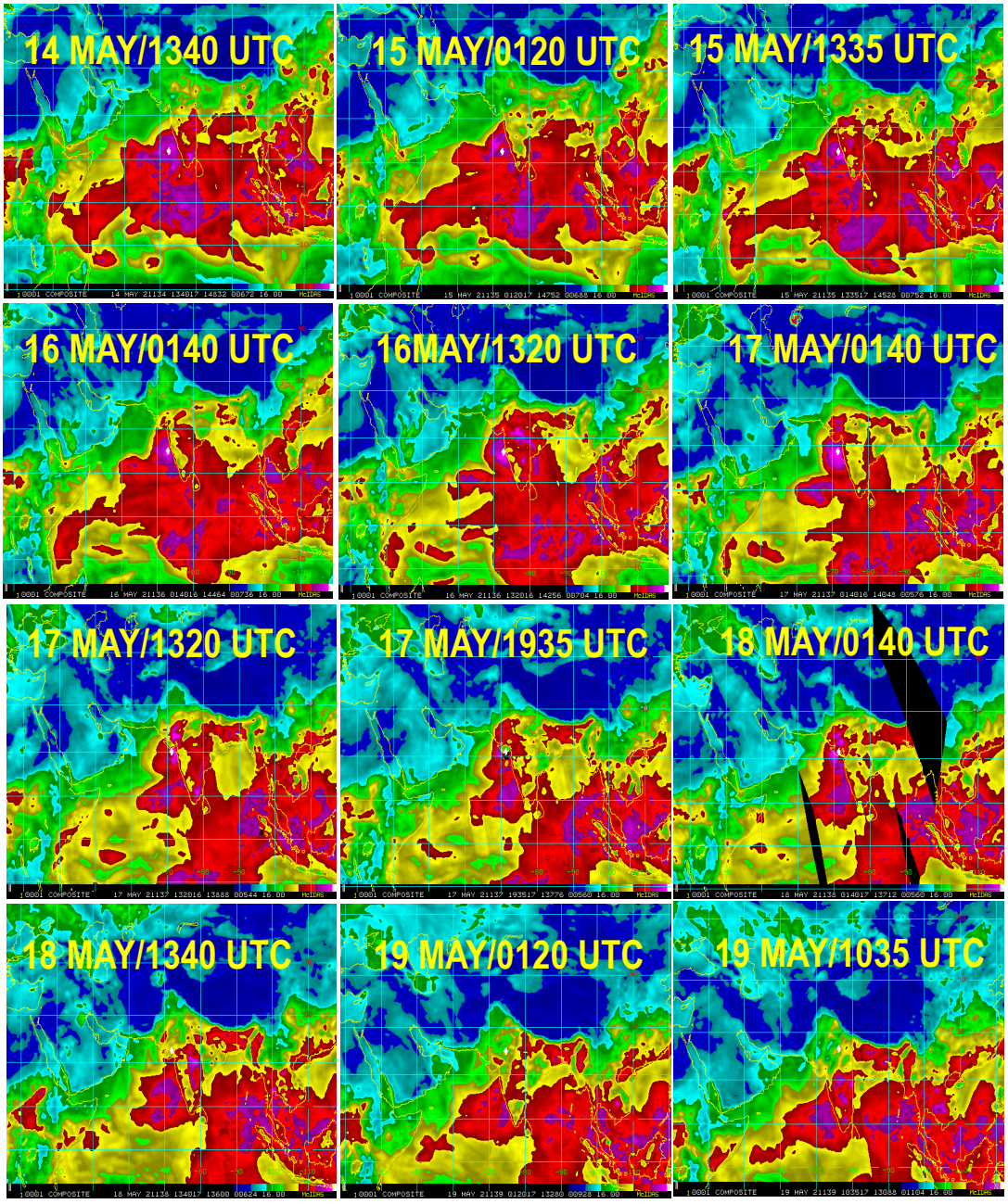


Fig. 5: Typical total precipitable water vapour imageries during life cycle of ESCS Tauktae (14th-19th May, 2021).

The mean wind speed and wind shear in middle and deep layer is presented in **Fig. 6.** The mean wind shear speed in the deep layer significantly reduced (<10 knot) especially during the rapid intensification period from 16th morning to17th morning. The mean wind shear in the middle layer remained 'low' since the genesis until the landfall. This also lowered slightly during the period of rapid intensification.

The mean wind direction in the deep layer represented the near northward movement of the system.

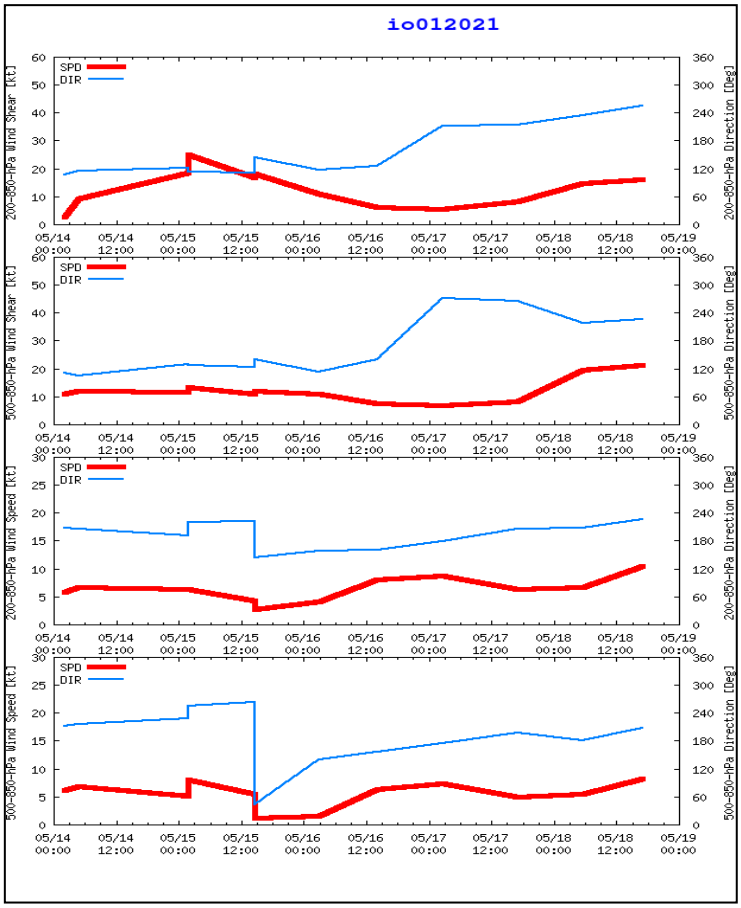


Fig.6: Wind shear and wind speed in the middle and deep layer around the system during ESCS TAUKTAE (14 May -19 May), 2021

4.4 Characteristic movement of the system

It moved with 12 hour average translational speed of 14.4 kmph against LPA (1990-2013) of 11.8 kmph for VSCS category over the Arabian Sea during pre-monsoon season (Fig.7). During initial two days of the maturing Phase (1800 UTC of 14th to 0600 UTC of 16th May), Tauktae moved slower than the average. After maturing into an ESCS also the movement slowed down when it began re-curving close to its landfall time. After landfall, the system moved faster than normal as it was steered by strong upper troposheric westerlies ahead of the trough. Also the system moved nearly northwards till 1800 UTC of 17th and re-curved northeastwards subsequent to landfall.

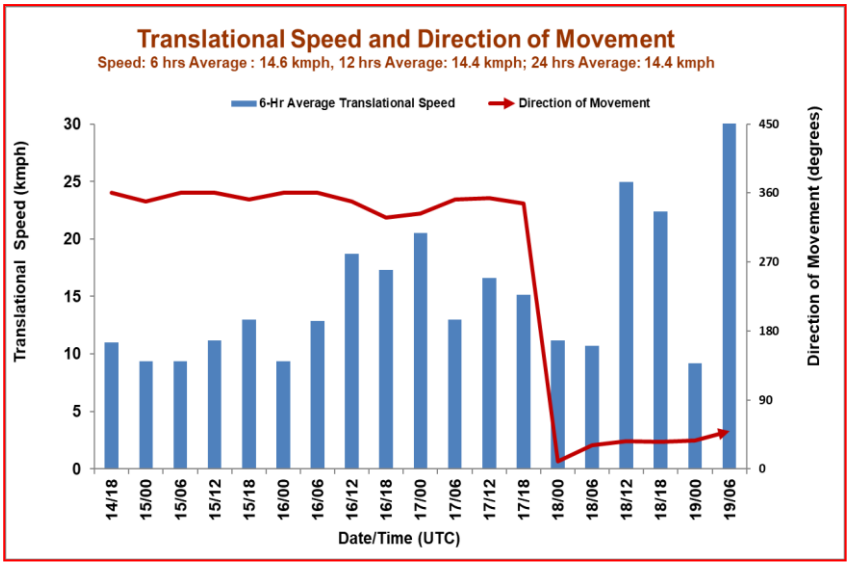


Fig. 7: Translational speed & direction of movement

4.5 Maximum Sustained Surface Wind speed and estimated central pressure

The six hourly maximum sustained wind speed and estimated central pressure is presented in Fig. 8. After landfall, the system exhibited rather slow weakening during 1800 UTC of 17th to 0600 UTC of 19th May. The peak MSW of the cyclone was 180-190 kmph (100 knots) gusting to 210 kmph during 0530 IST (0000 UTC) 0f 17th to 1130 IST (0600 UTC) of 17th over the EC AS. The lowest estimated central pressure (ECP) was 950 hPa during the period with a pressure drop of about 50 hPa at the centre as compared to the surroundings.

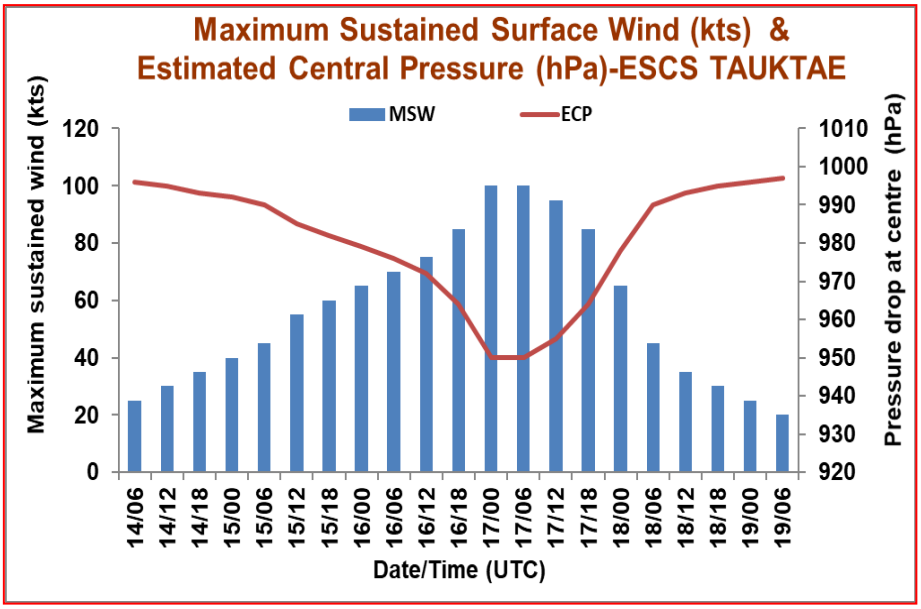


Fig. 8: Maximum sustained surface winds (kts) & Estimated Central Pressure

4.6 Features contributed to the rapid intensification of 'Tauktae'

'Tauktae' underwent a phase of rapid intensification with increase in maximum sustained wind speed (MSW) from 65 knots at 0000 IST of 16th to 100 knots at 0000 IST of 17th May.

Apart from the substantial reduction in mean vertical wind shear as illustrated in **Fig. 6** as well as the consistently high values of TCHP (> 140 KJ / cm^2 as discussed above) over major parts of the Arabian Sea, **Fig.9** shows the anomalies of the skin Sea Surface Temperatures (SSTs) during 14th – 17th May.

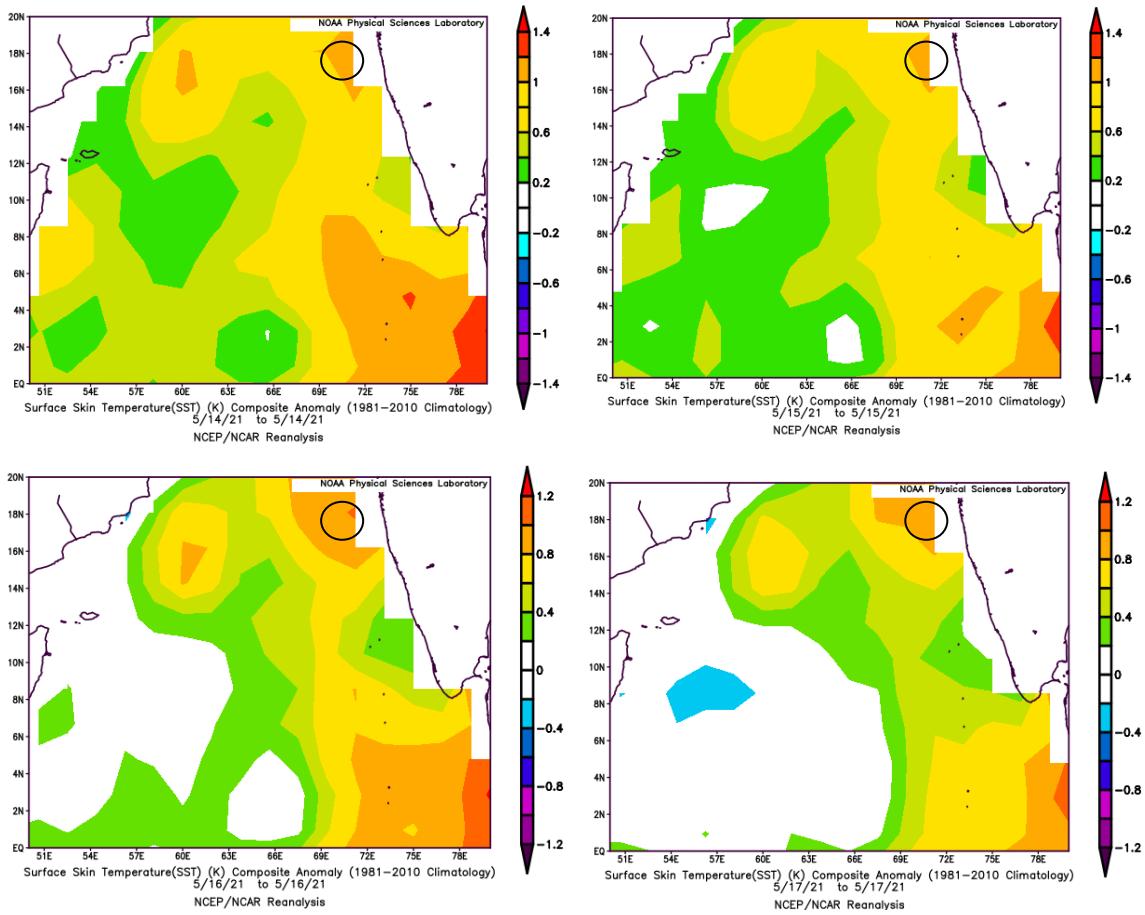


Fig. 9: Daily composite Skin SST anomalies over the Arabian Sea during 14th, 15th, 16th & 17th May 2021

The prevalence of a warm pool (in which temperatures above normal by 0.8- 1.2°C) may be noticed over the east-central Arabian Sea off north Maharashtra coast, over which the rapid intensification occurred on all the 4 days. Analysis of previous days (figures not shown) indicates that this warm pool was building up over this specific region since 4th May. This signifies a major role played by the warmer than normal SSTs with respect to the rapid intensification of the system.

5 Features observed via Satellite

At 0300 UTC of 14th May, convection over Lakshadweep and adjoining southeast Arabian Sea had further organised in a curved band pattern. Associated minimum cloud top temperature (CTT) was -93ºC. Intensity of the system was categorised as T 1.5. broken low and medium clouds with embedded intense to very intense convection lay over Arabian Sea (AS) between latitude 6.0°N & 15.0°N and long 57.0°E & 78.0°E and Lakshadweep area.

At 1200 UTC of 14th May, convection over Lakshadweep and adjoining southeast AS had further organised and the curved band pattern continued. Associated minimum CTT was -93ºC. Intensity of the system was categorized as T 2.0. broken low and medium clouds with embedded intense to very intense convection lay over AS between latitude 6.0°N & 17.0°N and long 58.0°E & 77.5°E and Lakshadweep area.

At 1800UTC of 14th May, convection over Lakshadweep and adjoining southeast AS had further organised and clouds the curved band pattern continued. Associated minimum CTT was -93ºC. Intensity of the system was categorised as T 2.5. broken low and medium clouds with embedded intense to very intense convection lay over AS between latitude 10.0°N & 17.0°N and long 67.0°E & 75.0°E and Lakshadweep area.

At 1200 UTC of 15th May, the intensity of the system was categorised as T 3.5 with Central Dense Overcast (CDO) pattern. Associated minimum CTT was -93ºC. Broken low and medium clouds with embedded intense to very intense convection lay over AS between latitude 11.0°N & 19°N and east of long 65.0ºE.

At 0000UTC of 16th May, the intensity of the system was categorised as T 4.0 with CDO pattern. Associated minimum CTT was -93ºC. Broken low and medium clouds with embedded intense to very intense convection lay over AS between latitude 12.0°N & 20°N and east of long 67.0ºE.

At 2100 UTC of 16th, the intensity of the system was categorised as T 5.0 with eye pattern. However, eye had become ragged. Broken low and medium clouds with embedded intense to very intense convection lay over EC AS between latitude 13.5°N & 20°N and east of long 67.0ºE, over south Konkan, Goa and also over southwest Madhya Maharashtra.

At 1800 UTC of 17th May, a vortex was seen over northeast Arabian Sea (near south Gujarat coast) with large ragged eye. Eye temperature was (minus) 13.0ºC. Broken low and medium clouds with embedded intense to very intense convection lay over EC & adjoining northeast AS between latitude 16.0°N & 22.5°N and east of long 68.0ºE and also over Gulf of Cambay, Gujarat, Konkan, Goa and north Madhya Maharashtra. Minimum CTT was -93°C.

At 0300 UTC of 18th May, the associated vortex was seen over land (over southwest Gujarat). Associated broken low and medium clouds with embedded intense to very intense convection lay over south Rajasthan, Gulf of Kutch, Gulf of Cambay, North Konkan, Madhya Maharashtra and adjoining Madhya Pradesh and also over northeast

Arabian Sea between latitude 18.0°N & 22.5°N and east of long 69.0°E and also over Gulf of Cambay, Gujarat, Konkan, Goa and north Madhya Maharashtra. Minimum CTT was -93°C.

At 1500 UTC of 18th May, associated broken low and medium clouds with embedded intense to very intense convection lay over south Gujarat, north Konkan, Gulf of Cambay and adjoining EC AS and moderate to intense convection over south Rajasthan, Gulf of Kutch, south Konkan, Madhya Maharashtra, northwest Vidarbha, southwest Madhya Pradesh and adjoining EC & northeast AS between latitude 18.0°N & 22.5°N and east of long 65.0°E.

At 1200 UTC of 19th May, the system weakened into a Well-Marked Low Pressure Area over Northeast Rajasthan and the clouds also became disorganized.

Typical INSAT-3D imageries during the life cycle of ESCS TAUKTAE (14^{th}-19^{th} May) are presented in **Fig. 10(a)-Fig 10(f)** and Scatterometer derived winds in **Fig. 11.**

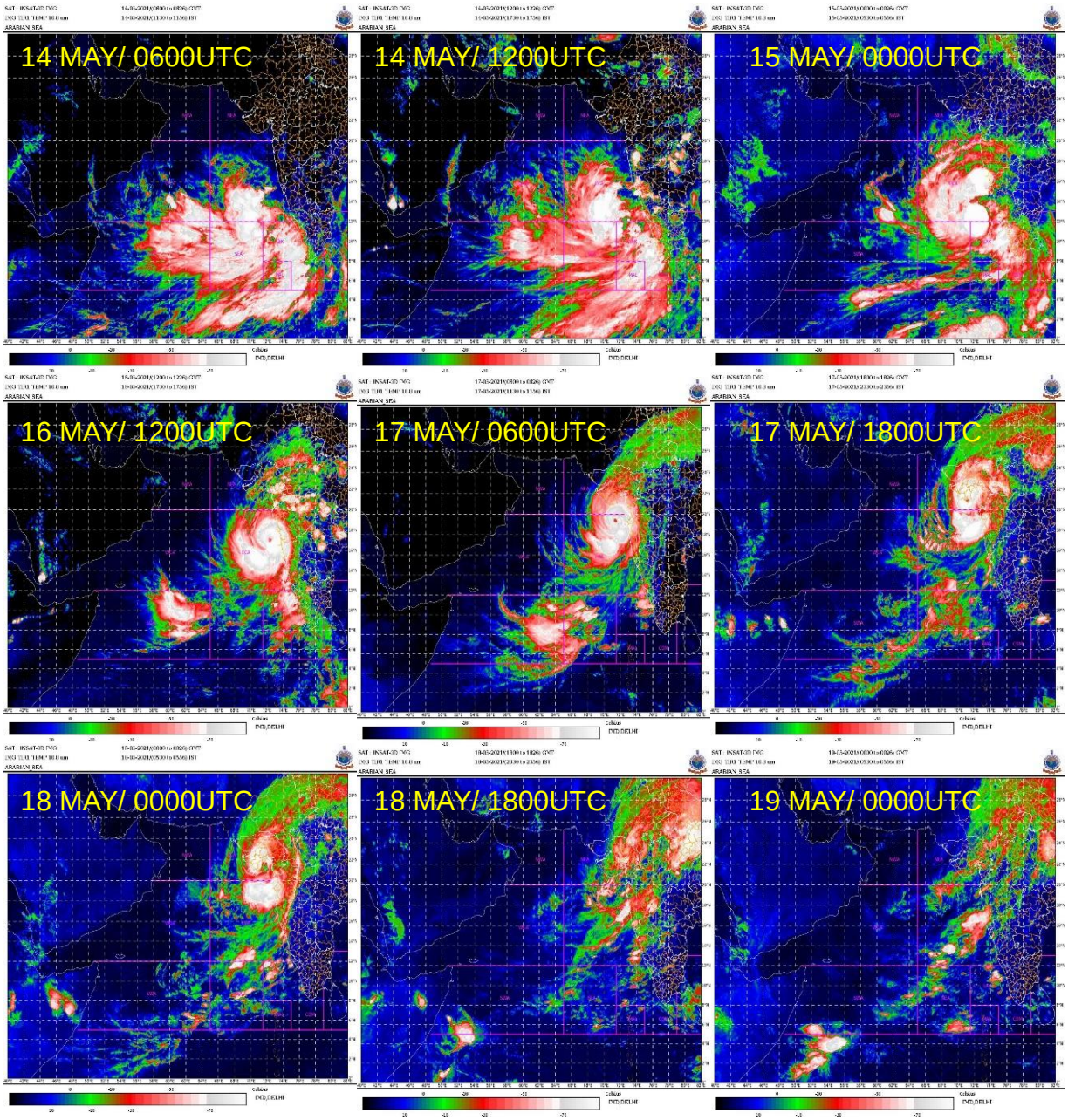


Fig. 10(a): INSAT-3D enhanced colored imageries during life cycle of ESCS TAUKTAE during 14-19 May, 2021

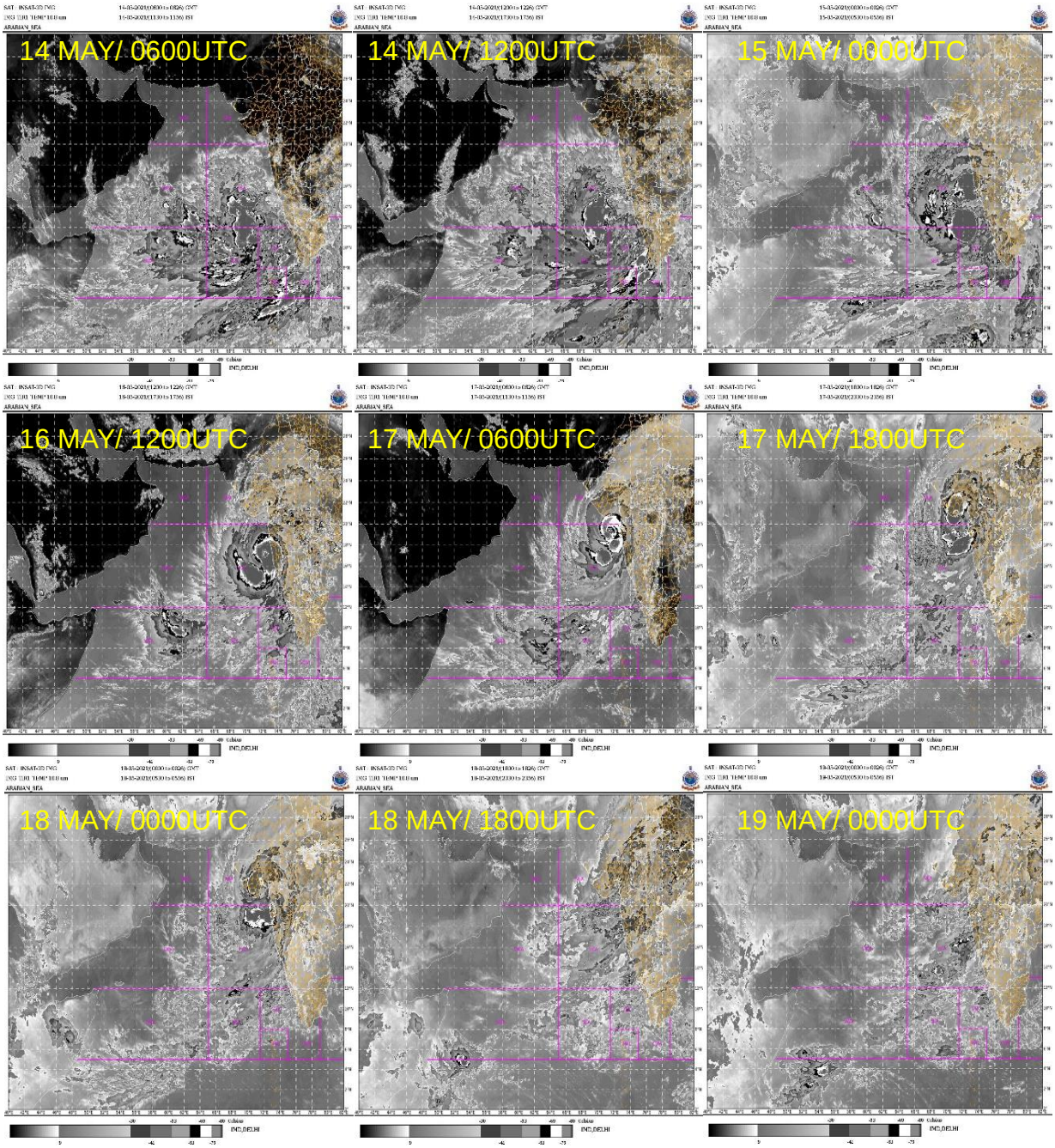


Fig. 10(b): INSAT-3D BD imageries during life cycle of ESCS TAUKTAE during 14-19 May, 2021

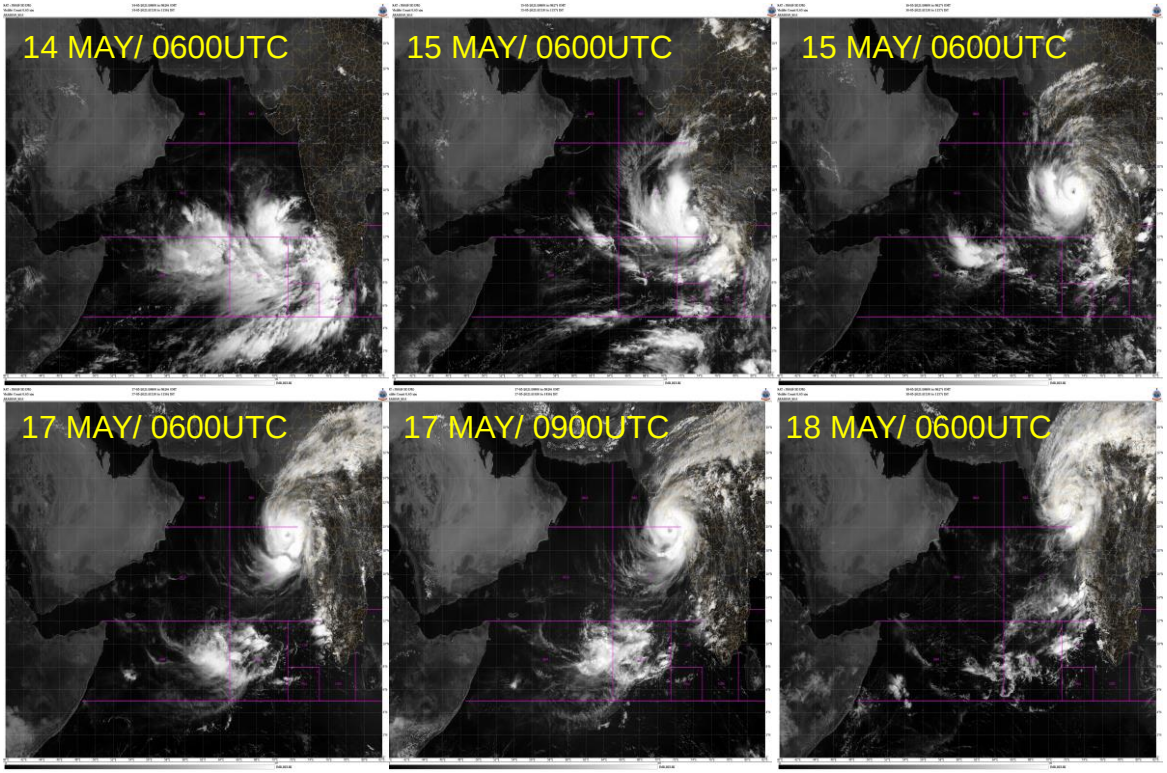


Fig. 10(c): INSAT-3D Visible imageries during life cycle of ESCS TAUKTAE during 14-19 May, 2021

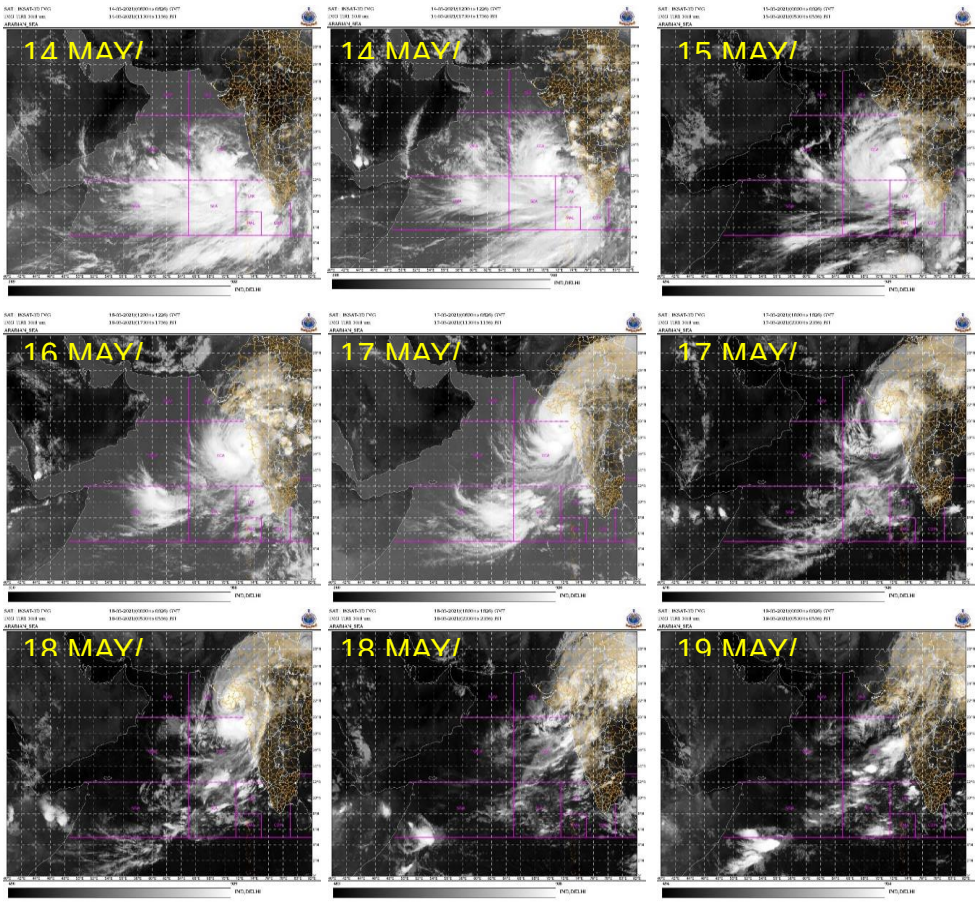


Fig. 10(d) : INSAT-3D IR imageries during life cycle of ESCS TAUKTAE during 14-19 May, 2021

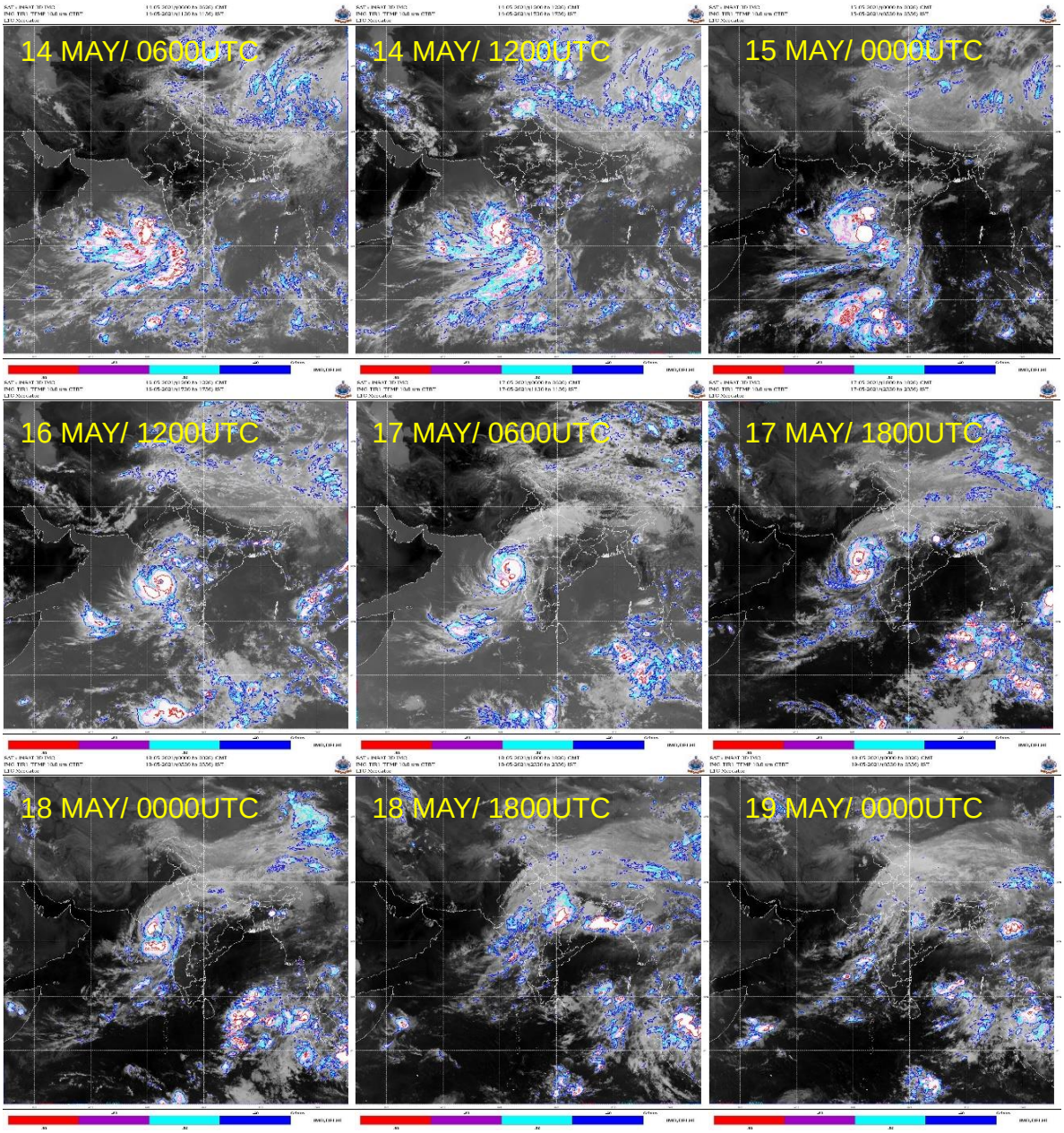


Fig. 10(e): INSAT-3D Cloud Top Brightness Temperature (CTBT) imageries during life cycle of ESCS TAUKTAE during 14-19 May, 2021

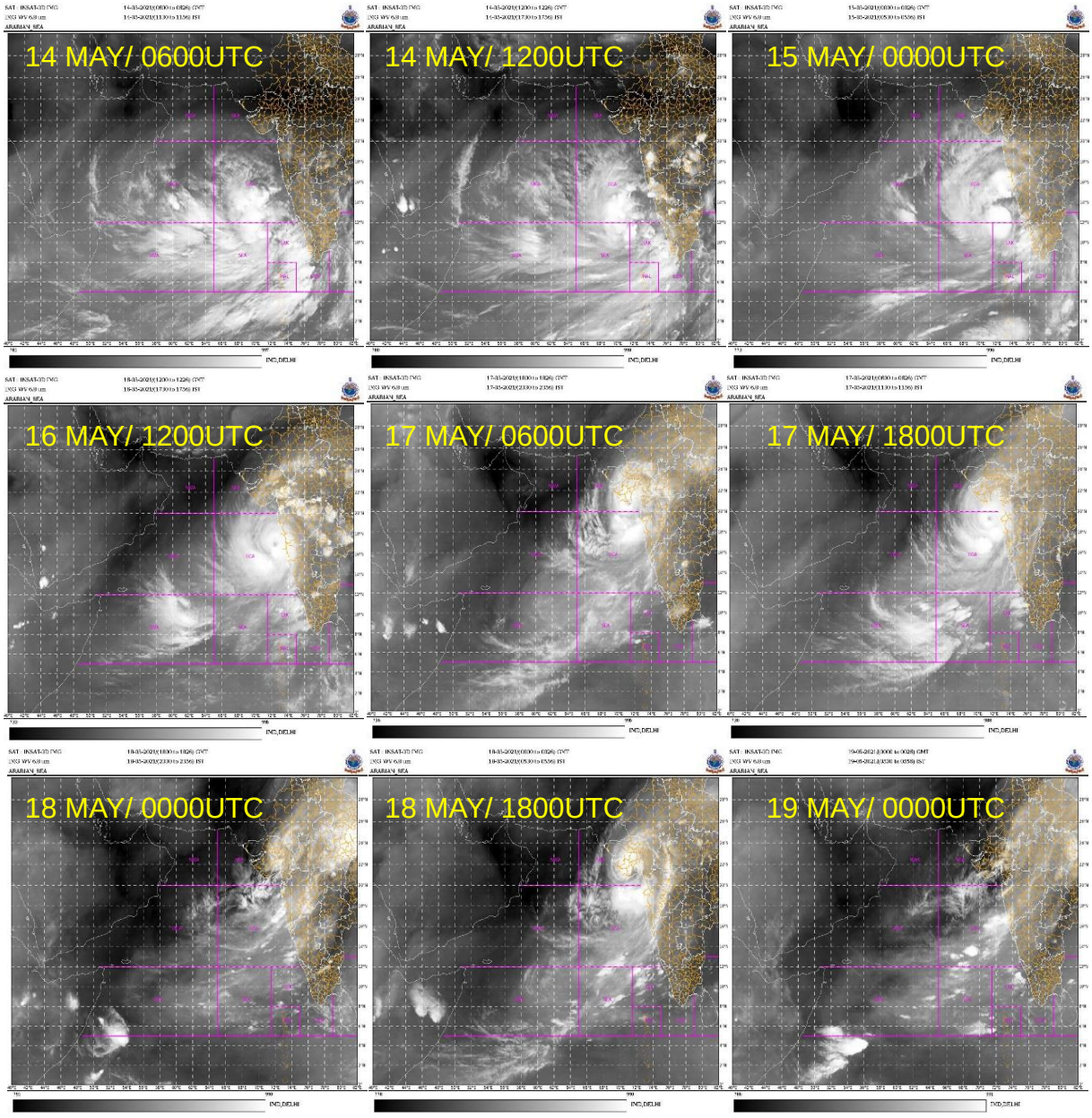


Fig. 10(f): INSAT-3D WATER VAPOUR imageries during life cycle of ESCS TAUKTAE during 14-19 May, 2021

Typical ASCAT imageries during life cycle of ESCS **TAUKTAE during 14-19 May 2021** since inception as a Depression are presented in Fig.10.

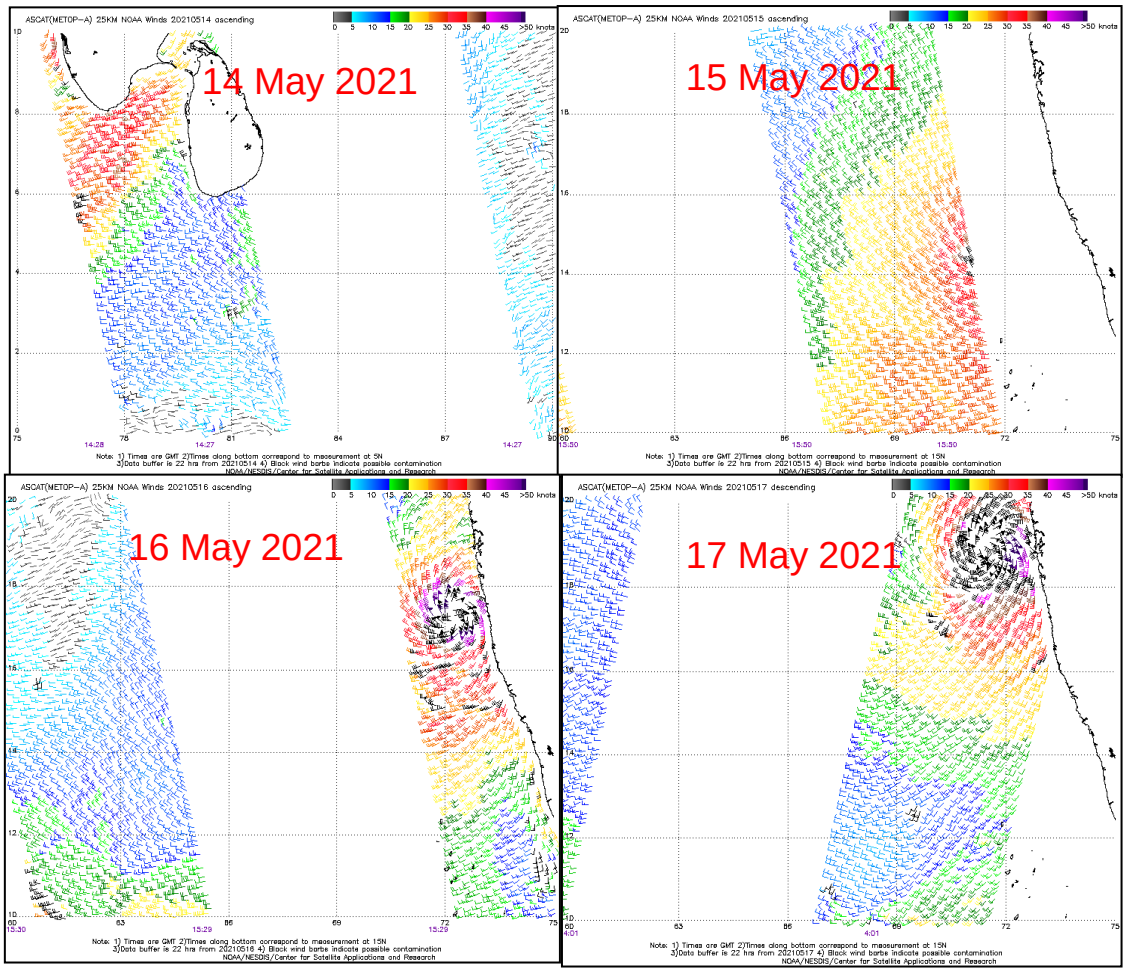


Fig. 11: ASCAT imageries during life cycle of ESCS TAUKTAE during 14-19 May, 2021

6. Doppler Weather RADAR based observations

ESCS TAUKTAE was continuously monitored by the Doppler Weather Radars (DWRs) at Thiruvananthapuram, Kochi and Goa while the system moved along the west coast. Typical radar imageries from Goa and Kochi are presented in **Fig. 12(a)-Fig 12(b).**

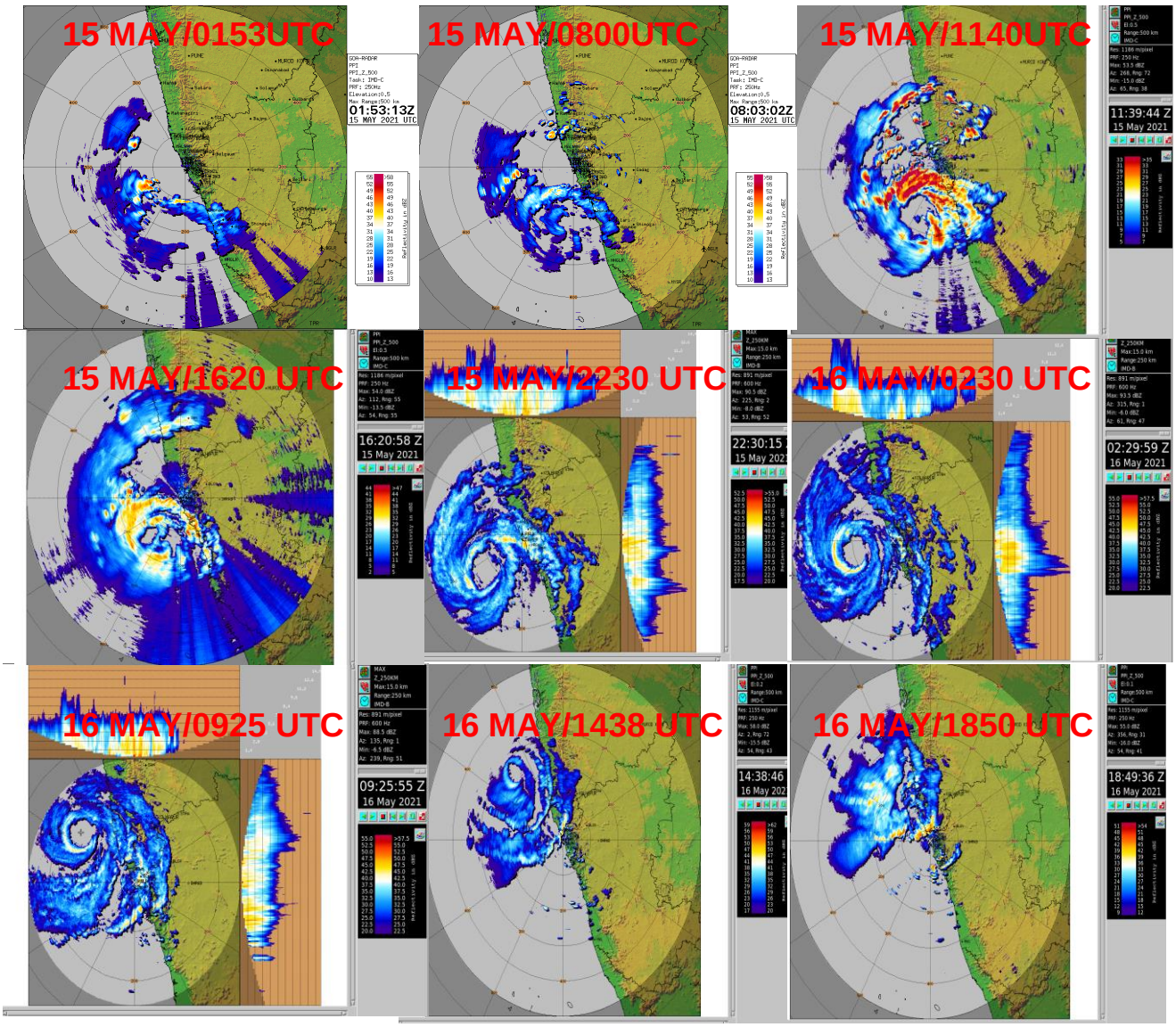


Fig. 12(a): Typical Radar Max dBZ imageries from DWR GOA during 15-16 May**,** 2021

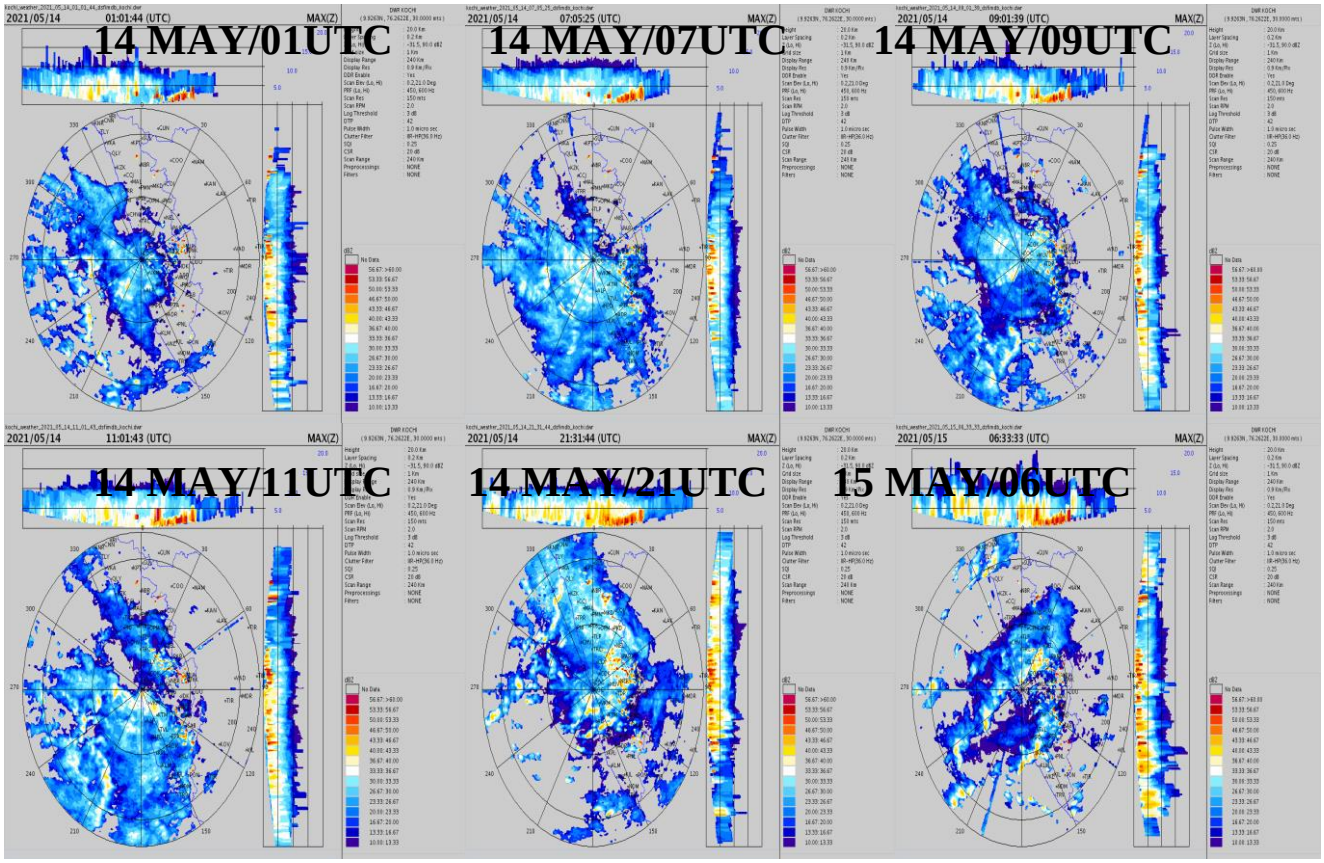


Fig. 12 (b): Typical Radar Max Z imageries from DWR Kochi **during 14-15 May, 2021**

7. Dynamical features

IMD GFS analysis of mean sea level pressure, winds at 10m, 850 hPa, 500 hPa and 200 hPa levels based on 0000 UTC during 12th -19th May, 2021 are presented in **Fig.13(a) – (h).** On 12th May 00 UTC, IMD GFS indicated presence of strong (30 – 40 knots) near equatorial westerlies at 10 m level in association with a near equatorial convergence zone over south Arabian Sea.

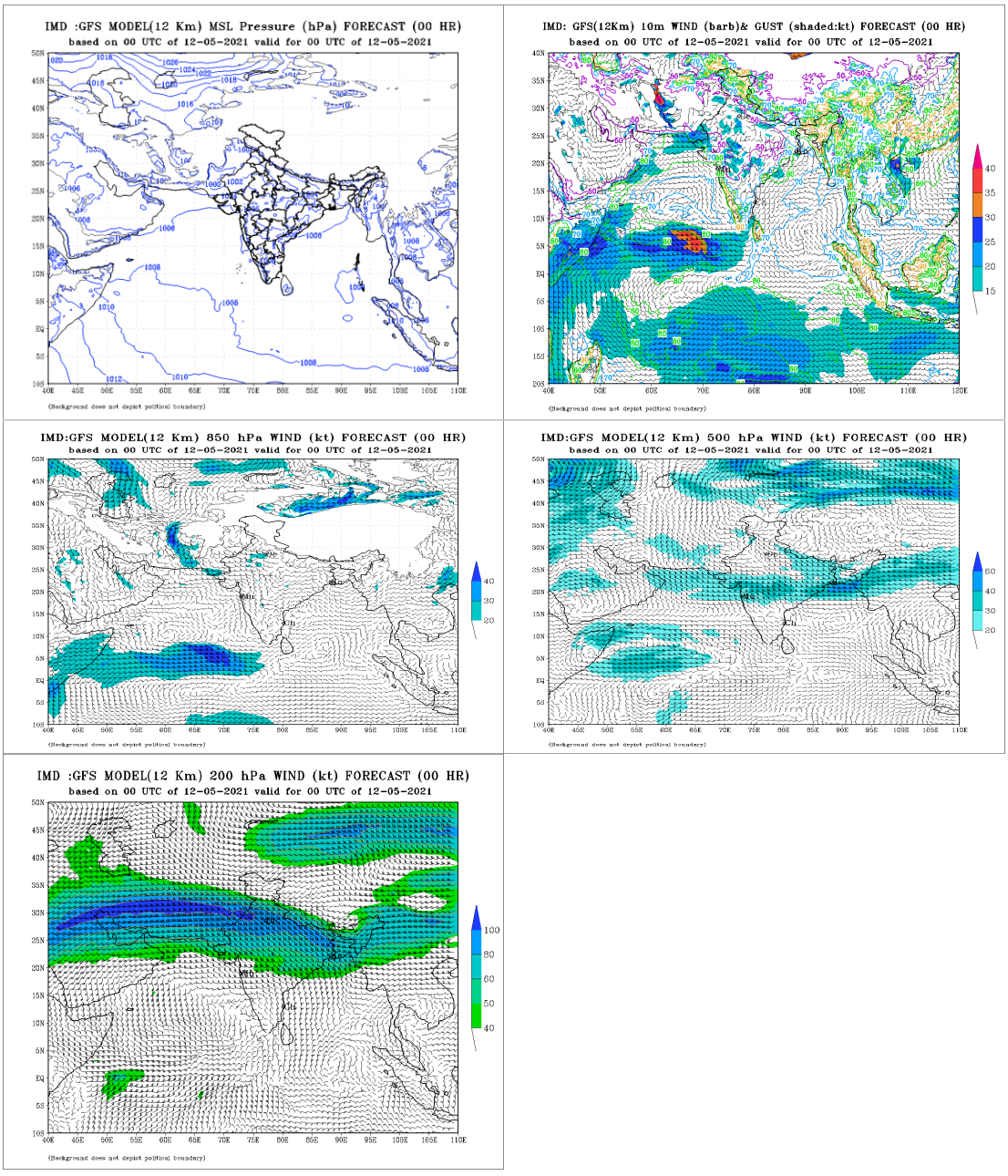


Fig. 13 (a): IMD GFS (T 1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 12th May,2021

On 13th May 00 UTC, IMD GFS indicated the continued presence of strong (30 – 40 knots) near equatorial westerlies at 10 m level in association with a near equatorial convergence zone over south Arabian Sea and also indicated deepening of westerlies upto 500 hPa level.

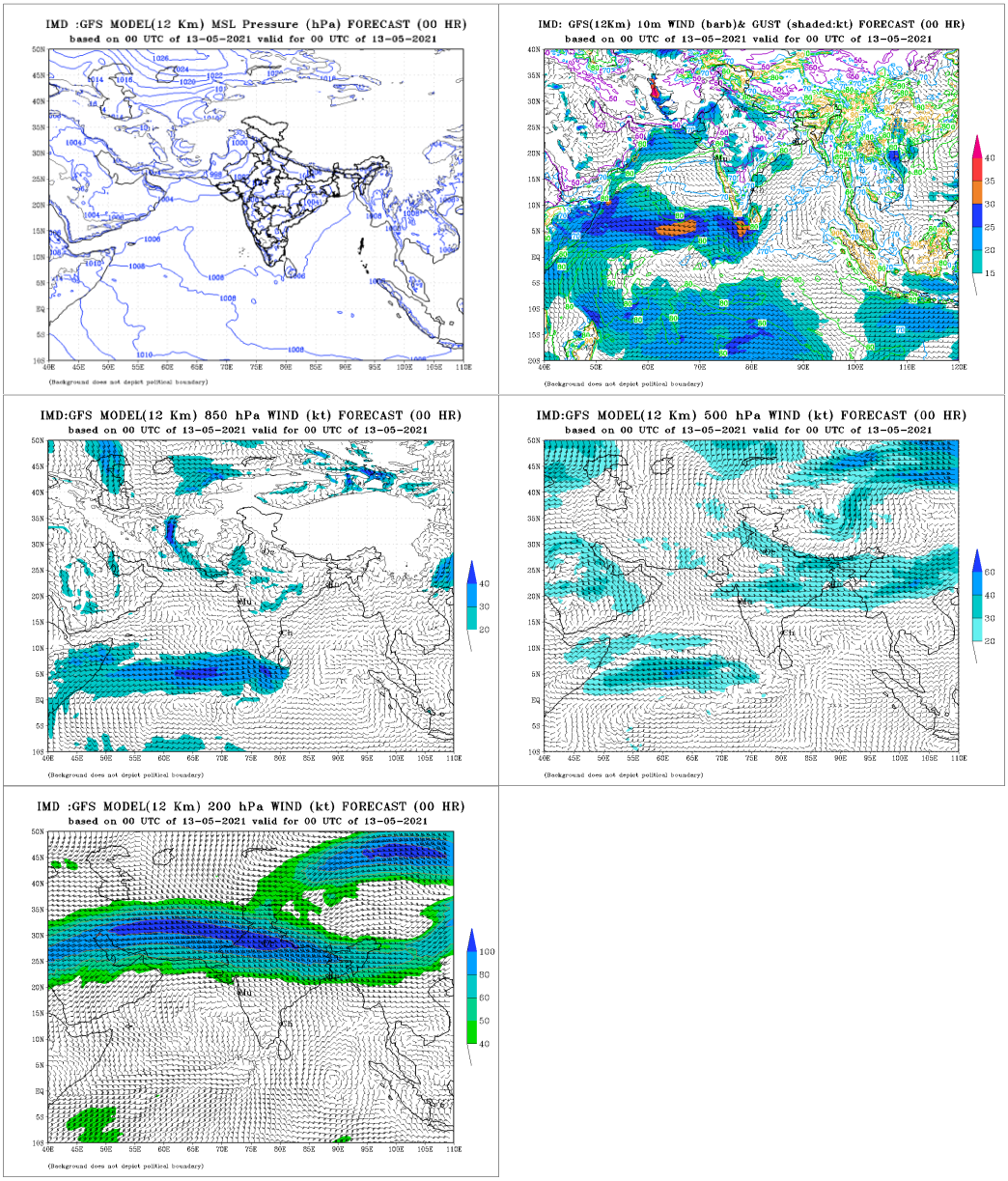


Fig. 13 (b): IMD GFS (T 1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 13th May,2021

On 14th May 00 UTC, IMD GFS indicated a Depression over Lakshadweep area and adjoining southeast Arabian Sea with vertical extension of the cyclonic circulation upto 500 hPa level. The system in reality became a Depression about 3 hours later, ie, around 0300 UTC of 14th.

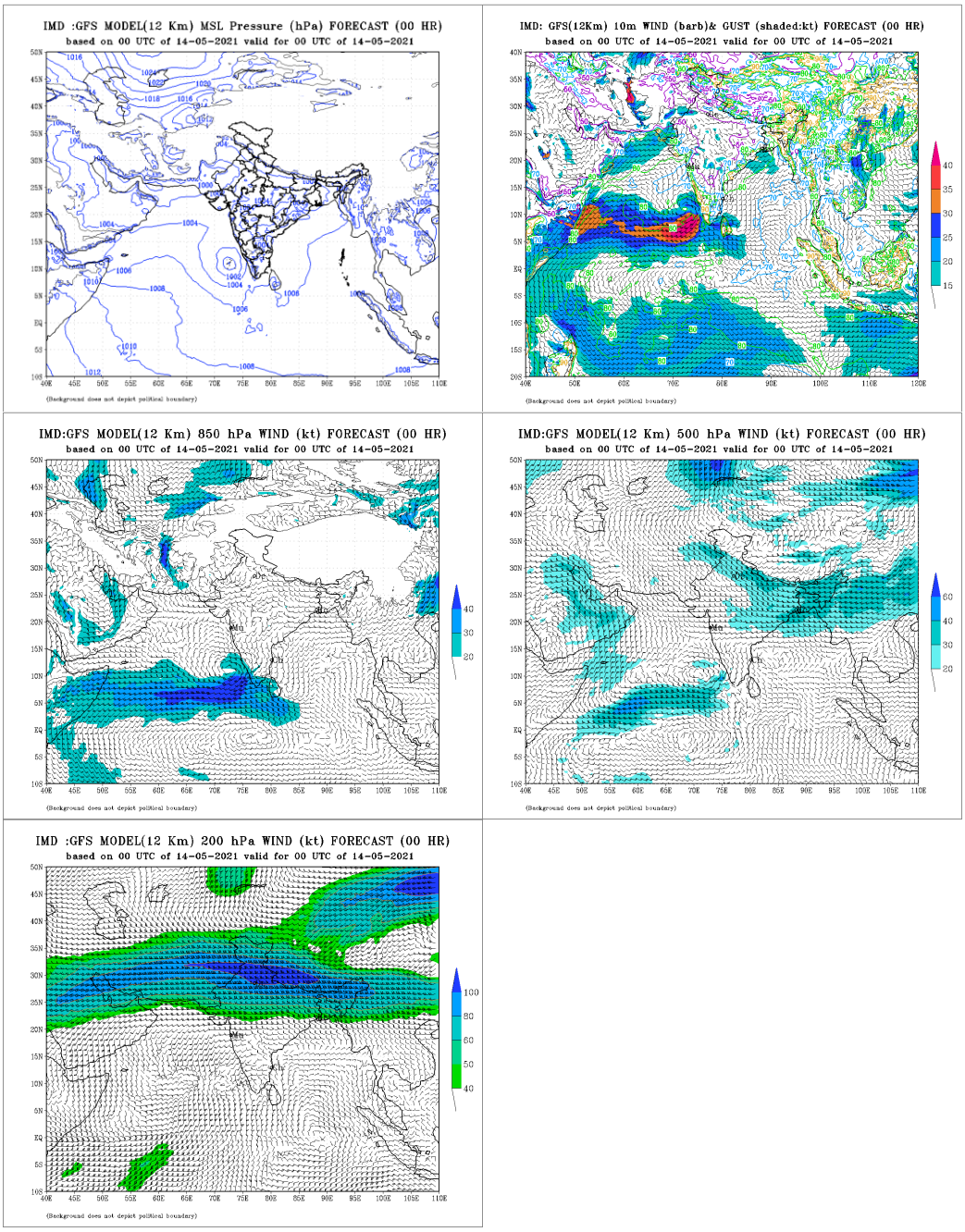


Fig. 13 (c): IMD GFS (T 1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 14th May, 2021

On 15th May 00 UTC, IMD GFS indicated a Cyclonic Storm of severe intensity over southeast & adjoining east central Arabian Sea with vertical extension of the cyclonic circulation upto 500 hPa level. Actually, it was a Cyclonic storm at 00 UTC of 15th May over southeast AS and adjoining Lakshadweep area. IMD GFS had significantly over estimated the intensity of the system.

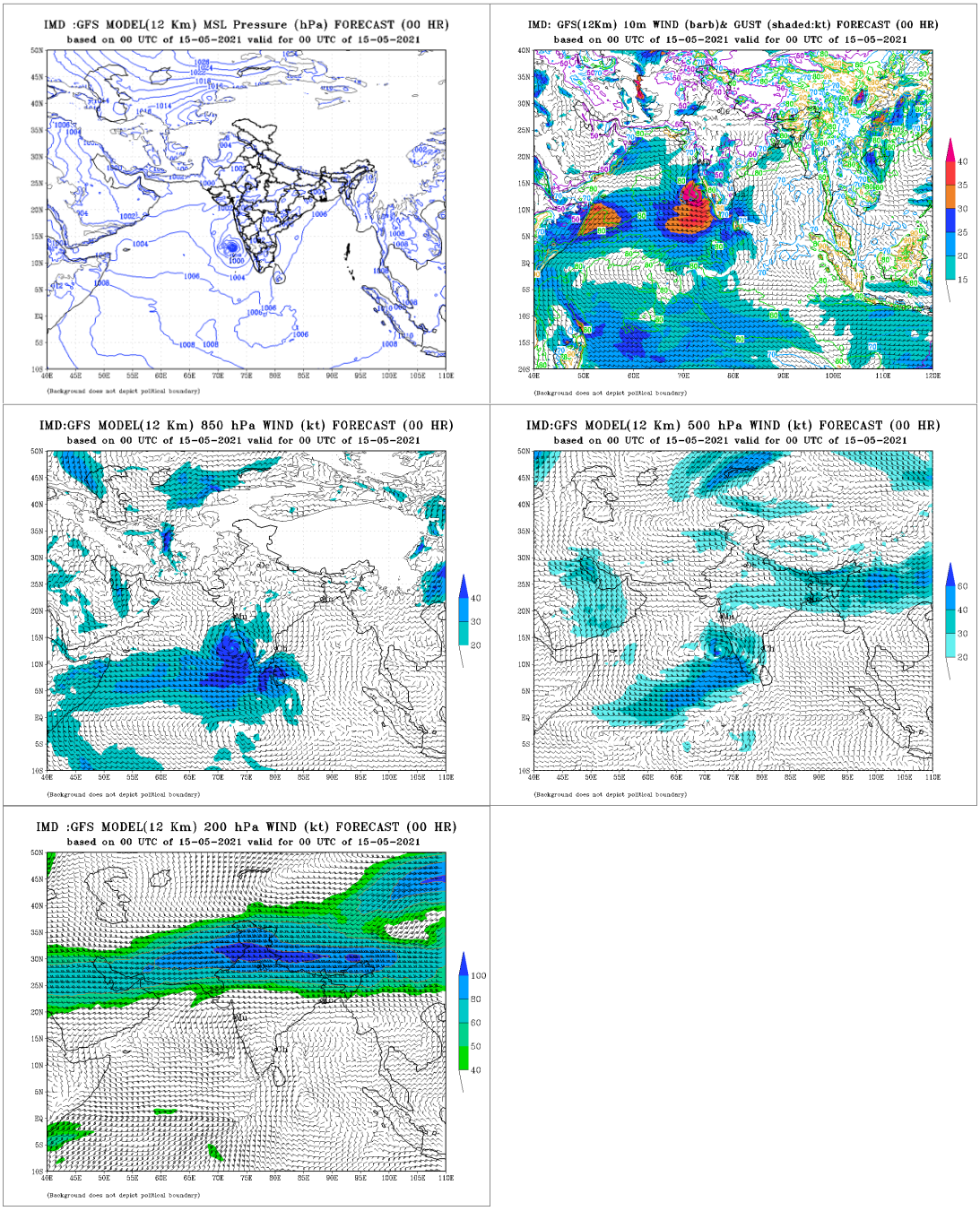


Fig. 13 (d): IMD GFS (T 1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 15th May,2021

On 16th May 00 UTC, IMD GFS indicated rapid intensification of the system. It lay as an Extremely Severe Cyclonic Storm over EC AS very close to Goa coast, with vertical extension of the cyclonic circulation upto 500 hPa level. GFS also indicated near northward movement of the system, very close to west coast. Actually, it was a Very Severe cyclonic storm at 0000 UTC of 16th May over EC AS. IMD GFS over estimated the intensity of the system and also its proximity to the coast.

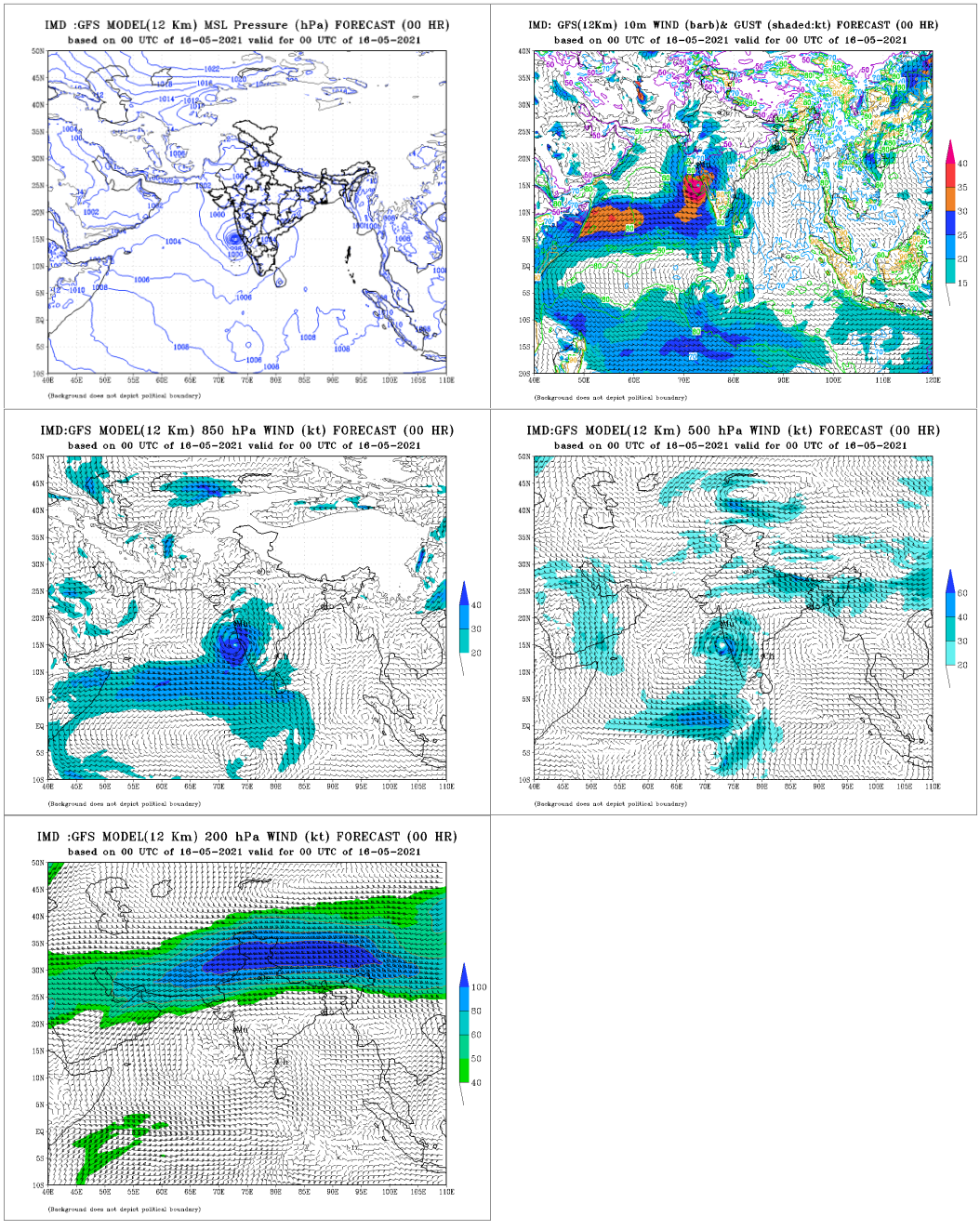


Fig. 13 (e): IMD GFS (T 1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 16 May,2021

On 17th May 00 UTC, IMD GFS indicated further intensification of the system. It lay as a Super cyclonic storm over EC AS, close to north Maharashtra coast with vertical extension of the cyclonic circulation upto 200 hPa level. GFS also indicated near northwards movement of the system, gracing the west coast. Actually, it was an extremely severe cyclonic storm at 0000 UTC of 17th May over EC AS. IMD GFS slightly over estimated the intensity of the system.

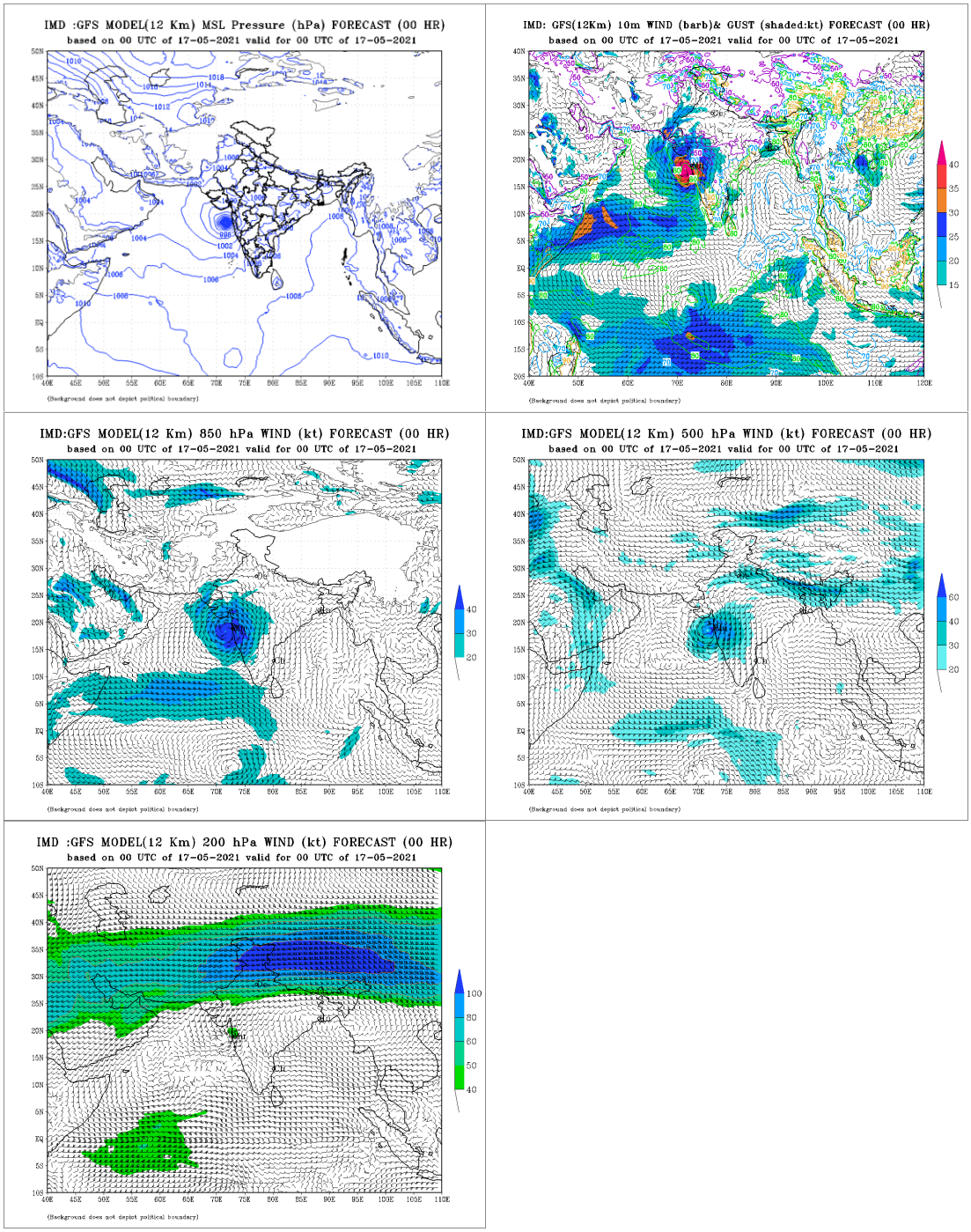


Fig. 13 (f): IMD GFS (T 1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 17th May,2021

On 18th May 00 UTC, IMD GFS indicated the system, soon after making landfall, lying over south coastal Saurashtra. Actually, the system crossed Saurashtra coast and weakened slightly into a VSCS over coastal Saurashtra by this time. This feature was correctly simulated by the model.

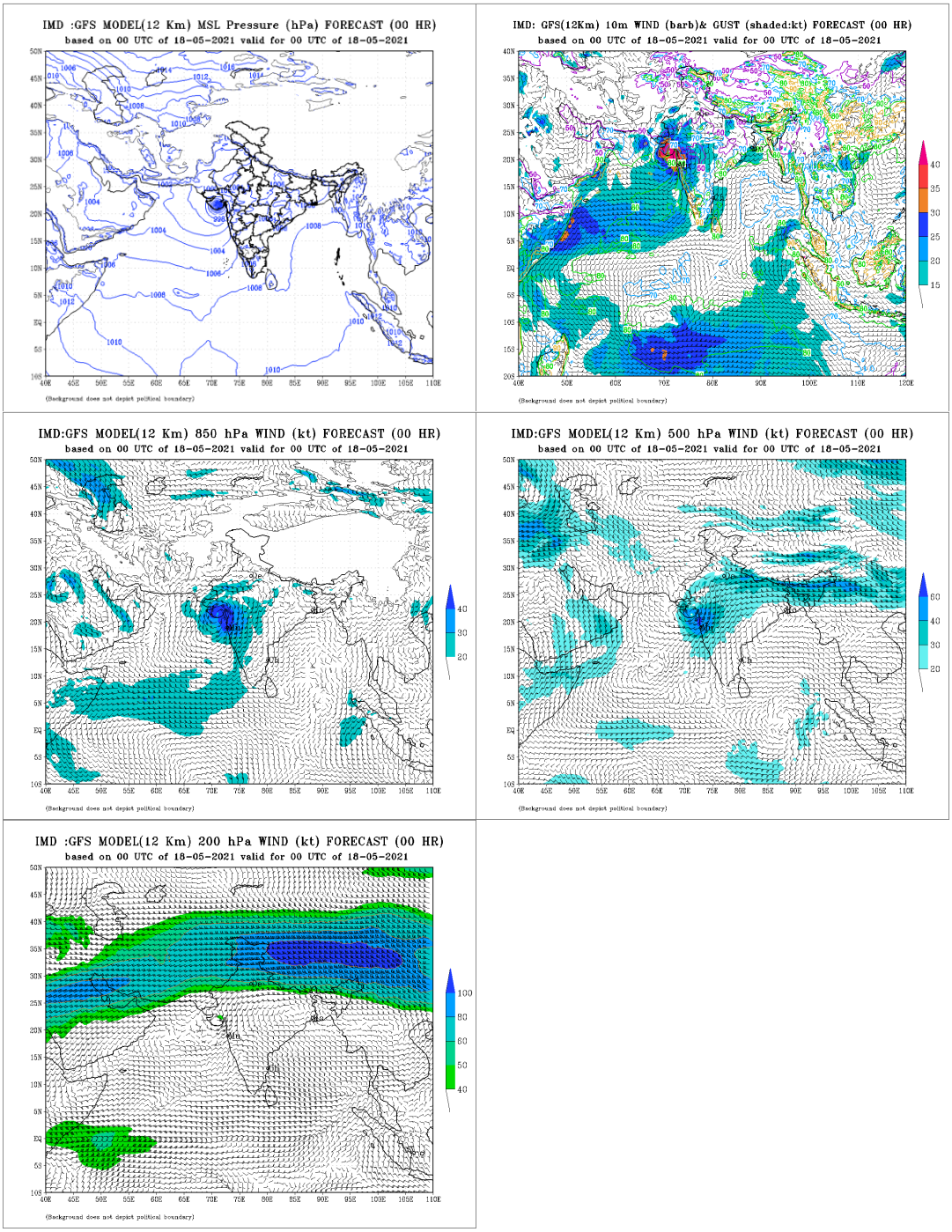


Fig.13 (g): IMD GFS (T 1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 18th May,2021

On 19th May 00 UTC, IMD GFS indicated weakening of the system into a CS category and located over Gujarat – Rajasthan border. The presence of a trough in the mid-latitude westerlies in phase with the system at 500 hPa was also simulated well. By this time the system had weakened into a Depression over north Gujarat & adjoining south Rajasthan. Though the model slightly over estimated the intensity, it picked up intensity the movement of the system.

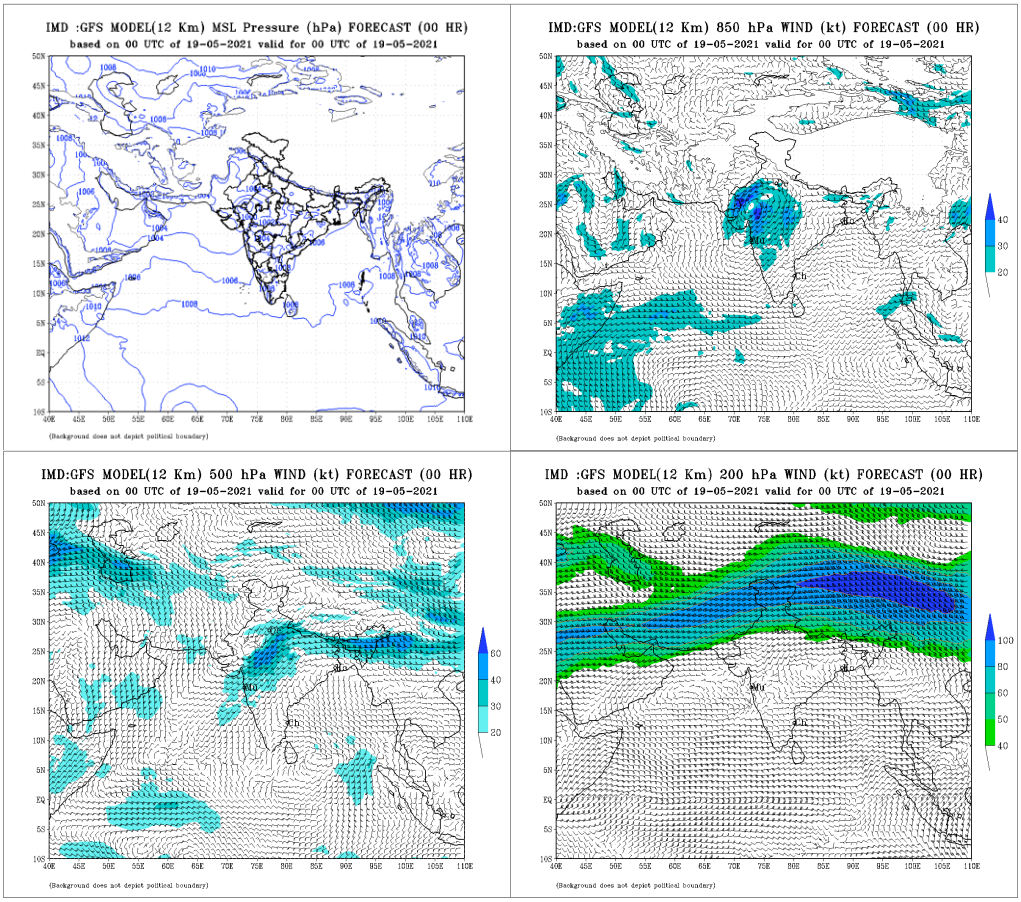


Fig. 13 (h): IMD GFS (T 1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 19th May, 2021

IMD GFS thus simulated more or less realistically, the intensity, movement, landfall and weakening of the system.

8. Realized Weather:

8.1. Realised rainfall

It caused heavy to extremely heavy rainfall activity, strong wind and tidal waves affecting Lakshadweep on 13-14th, Kerala on 14-15th, Karnataka on 15th, Goa and south coastal Maharashtra on 15-16th, north Maharashtra on 16-17th, Gujarat, Daman & Diu, Dadra & Nagar Haveli on 17th and 18th. It's remnant also impacted northwest India with heavy rainfall at isolated places. Rainfall associated with ESCS Tauktae based on IMD-NCMRWF GPM merged gauge 24 hours cumulative rainfall ending at 0830 IST of date is depicted in **Fig 14**.

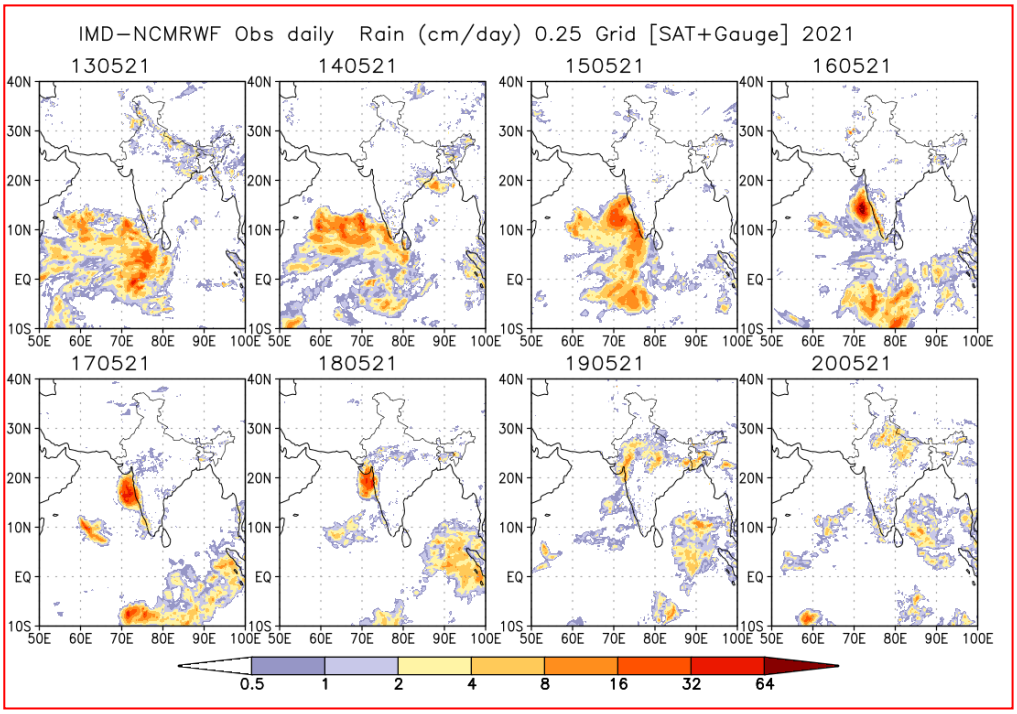


Fig.14: IMD-NCMRWF GPM merged gauge 24 hr cumulative rainfall (cm) ending at 0830 IST of date during 13th May – 18th May and 7 days average rainfall (cm/day)

Rainfall (cm) reported (realised during the past 24 hours ending at 0830 hrs IST of date) along the west coast during 12th-20th May, 2021

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

12 May

LAKSHADWEEP: Agathi-8, Minicoy-1.

13 May

LAKSHADWEEP: Agathi-17, Amini-8, Minicoy-5.

14 May

KERALA & MAHE: Mavelikara-15, Konni-14, Kayamkulam-14, Kayamkulam Agri-13, Neyyattinkara-11, Nedumangad-11, Kottayam-11, Kurudamannil-10, Varkala-10, Mancompu-9, Kozha-9, Vaikom-9, Haripad-9, Kumarakam-9, Chalakudi-8, Aluva-8, Thritala-7, Kochi C.I.A.L.-7, Ernakulam South-7

LAKSHADWEEP: Agathi-12.
SOUTH INTERIOR KARNATAKA: Balehonnur-7

15 May

COASTAL KARNATAKA: Mangaluru AP - 8, Panambur - 7, Mangaluru-7,
KERALA & MAHE: Kochi-21, Peermade-21, Kodungallur-20, Enamakkal-19, Ernakulam South-17, Kumarakam-16, Kannur-16, Kollam-16, Alapuzha-16, Chalakudi-15, Irinjalakuda-15, Ponnani-14, Pattambi-14, Vaikom-14, Cherthala-13, Kozhikode-13, Varkala-13, Mancompu-13, Thritala-13, Mavelikara-12, Aluva-12, Kayamkulam-12, Kurudamannil-11, Konni-11, Quilandi-11, Perumpavur-11, Taliparamba-11, Vellanikkara-11, Kochi C.I.A.L.-11, Kottayam-11, Haripad-11, Vadakkancherry-11, Kozha-11, Kanjirappally-10, Munnar KSEB-10, Manjeri-10, Mahe-9, Perinthalmanna-9, Vadakara-9, Ottapalam-9, Punalur-9, Talassery-9, Hosdurg-9, Piravam-8, Nilambur-8, Angadipuram-8, Vyttiri-8, Karipur -7, Thodupuzha-7, Kudulu-7, Neyyattinkara-7
LAKSHADWEEP: Agathi-10, Amini-8

16 May

KONKAN & GOA: Canacona-7, Pernem-7
COASTAL KARNATAKA: Kollur-24, Manki-19, Kota-19, Puttur -19, Kundapur-17, Bhatkal-16, Udupi-15, Dharmasthala-14, Mani-13, Mulki-12, Karkala-11, Shirali -11, Mangaluru -11, Kadra-11, Panambur -10, Karwar -10, Mudubidre-10, Belthangadi-9, Honavar -9, Gokarna-9, Vitla ARG-9, Sulya-8, Siddapura-8
NORTH INTERIOR KARNATAKA: Vijayapura-8
SOUTH INTERIOR KARNATAKA: Hosanagara-19, Bhagamandala-17, Kalasa-13, Virajpet-13, Linganamakki -9, Thalaguppa-7, Sagar-7
KERALA & MAHE: Mahe-24, Vadakara-23, Vyttiri-21, Taliparamba-17, Talassery-17, Quilandi-16, Ernakulam South-14, Kochi I.A.F.-14, Kochi C.I.A.L.-13, Aluva -13, Manantoddy-13, Irikkur-13, Kannur-12, Piravam-11, Perumpavur-11, Enamakkal-11, Kudulu-10, Thodupuzha-10, Karipur.-10, Munnar KSEB-10, Varkala-10, Kozha-9, Vaikom-9, Nilambur-9, Neyyattinkara-9, Idukki-9, Vadakkancherry-8, Nedumangad-8, Parambikulam-8, Irinjalakuda-8, Perinthalamanna-8, Pattambi-8, Angadipuram-8, Kozhikode-8, Ottapalam-8, Peerumade -8, Chalakudi-7, Ponnani-7, Thiruvananthapuram-7, Ambalavayal-7, Mannarkkad-7, Myladumpara Agri-7, Thritala-7

17 May

KONKAN & GOA: Sawantwadi-37, Ratnagiri -36, Dodamarg-25, Panjim -23, Malvan-21, Kudal-20, Devgad-20, Kankavli-19, Vengurla -18, Mapusa-17, Lanja-16, Dabolim- Navy-15, Vaibhavwadi-15, Sangameshwar Devrukh-14, Guhagarh-12, Margao-12, Dapoli Agri-8, Harnai -8, Sanguem-7
COASTAL KARNATAKA: Kadra-11, Honavar -7, Kollur-7

18 May

GUJARAT REGION: Umergam-18, Daman-15, Daman FMO-13, Surat City-9, Khanvel-8, Valsad-8, Silvassa-7

SAURASHTRA & KUTCH: Bagasra-21, Gir Gadhada-19, Una-17, Savarkundla-17, Palitana-16, Amreli-13, Mahuva-13, Rajula-13, Khambha-13, Babra-13, Gadhda-11, Visavadar-10, Diu-9, Umrala-9, Bhavnagar-8, Dhari-7, Jesar-7

KONKAN & GOA: Palghar Agri-30, Dahanu -28, Santacruz -23, Devgad-23, Sawantwadi-21, Colaba -21, Talasari-17, Canacona-9, Tbia -9, Kankavli-9, Murud-8, Wada-8

19 May

GUJARAT REGION: Nadiad-23, Mahudha-16, Anand-16, Daman FMO-15, Umergam-15, Matar-15, Pardi-14, Daman-14, Khambhat-13, Kheda-13, Tarapur-13, Vaso-13, Olpad-12, Khergam-12, Mahemdavad-12, Dhansura-11, Ahmedabad City-11, Jalalpor-11, Sojitra-11, Kathalal-11, Prantij-10, Wanakbori-10, Borsad-10, Navsari-10, Kapadvanj-10, Virpur-10, Modasa-10, Balasinor-9, Dahegam-9, Bayad-9, Bardoli-9, Talod-9, Madhban-9, Valsad-9, Hansot-9, Vadodara-9, Vagra-9, Meghraj-9, Bhiloda-8, Himatanagar-8, Kamrej-8, Anklav-8, Silvassa-8, Padra-8, Palsana-7, Gandevi-7, Thasra-7, Galteshwar-7, Idar-7, Vapi-7, Poshina-7, Chikhli-7, Sanand-7, Vijapur-7, Khanpur-7, Kaprada-7, Kalol-7, Dascroi-7, Mahuva-7, Lunawada-7, Danta-7, Malpur-7, Petlad-7,

SAURASHTRA & KUTCH: Gir Gadhada-19, Una-18, Bhavnagar-11, Rajula-10, Botad-9, Shihor-9, Visavadar-8, Palitana-8, Vallabhipur-8, Umrala-7,

EAST RAJASTHAN: Veja-23, Kanva-14, Devel-14, Dungarpur Tehsil-14, Dhambola-13, Sarara-13, Girva-11, Aspur-11, Gogunda-10, Ganeshpur-10, Ajmer Tehsil-9, Railmagra-9, Dungla-9, Sagwara-8, Jhadol-8, Udaipur/D-Aero-8, Ajmer-7, Tatgarh-7, Salumber-7, Nithuwa-7, Bari-Sadri-7, Loharia-7, Dhariabad-7, Badesar-7,

20th May:

UTTARAKHAND: Nainital-12; Mussoorie-10; Mukteshwar-9; Haldwani-8

HARYANA, CHANDIGARH & DELHI: Jhajjar-12; Gurgaon-11; Mewat-8; Faridabad-8; Narnaul-8

WEST UTTAR PRADESH: Bareilly-15; Meerut-9; Aligarh-7; Muzzafarnagar-7

EAST UTTAR PRADESH: Gorakhpur-8; Varanasi-8; Sultanpur-7; Mirzapur-7, Jaunpur-7,

WEST RAJASTHAN: Nagaur-7

EAST RAJASTHAN: Dholpur-10; Alwar-9; Jaipur-8, Dausa-7; Sikar-7

8.2 Realised / recorded wind speed

Some of the Peak wind speed (kmph) recorded by the Meteorological Observatories in association with the passage of TAUKTAE are:

Agathi reported maximum sustained wind speed of 45 kts on 14th May, Panaji reported 46 kts on 16th. The maximum wind at the time of landfall over Gujarat and Diu was 90 kts gusting to 100 kts (160-170 kmph gusting to 185 kmph) on 17th May.

8.3 Storm Surge

It was estimated that about 3-4 meters of storm surge above the astronomical tide inundated the low lying areas of coastal districts of Saurashtra around the time of landfall.

9. Damage due to ESCS TAUKTAE

Since the system moved along & off the west coast, it affected all the States & Union Territories along the west coast of India.

As per the situation report #3 published by 'UNICEF' on 20th May, more than 120 people lost their lives as detailed below:
Kerala : 20
Karnataka : 09
Goa : 03
Maharashtra : 19
Gujarat : 67 people including 23 women have been killed across 13 districts of Gujarat .
Number of Livestock lost: 635
TOTAL death toll is estimated to be 118.
Ten districts of Maharashtra & 17 Districts of Gujarat were impacted. The number of Houses damaged was 1532 in Kerala, 1576 in Maharashtra and 16,500 in Gujarat. A total of 1.1 Million people were affected in 421 villages.
Apart from this, 26 people died and more than 50 were reported to be missing after a Barge sank into the Arabian Sea off coast of Mumbai (Maharashtra). Fig. 15 (a) – (h) shows the Photographs of a few damages.

Figure 15:(a) Fishing boat damage due to cyclone at Jaafrabaad fishing harbor **(b)** Indian Navy in the coastal village of Chellanam in Ernakulam district (Kerala) which was heavily hit by tidal waves **(c)** House Collapses into the Sea In Kasargod (Kerala) due to the effect of Cyclone Tauktae. **(d)** Rough Sea waves crash against the Bhagavathi Prem Sinken Dredger, at Surathkal Beach near Mangaluru (PTI) **(e)** uprooted trees in Goa **(f)** & **(g)** flood in Mumbai **(h)** Strong winds uproot electric poles at Bidarahalli near Chikmagalur(PTI)

10. Performance of operational NWP models

IMD operationally runs a regional model, WRF for short-range prediction and one Global model T1534 for medium range prediction (10 days). The WRF-VAR model is run at the horizontal resolution of 9 km and 3 km with 38 Eta levels in the vertical and the integration is carried up to 72 hours over three domains covering the area between lat. 25^0S to 45^0 N long 40^0 E to 120^0 E. Initial and boundary conditions are obtained from the IMD Global Forecast System (IMD-GFS) at the resolution of 12 km. The boundary conditions are updated at every six hours interval.

Global models are also run at NCMRWF. These include GFS and unified model adapted from UK Meteorological Office. In addition to the above NWP models, IMD also run operationally dynamical statistical models. The dynamical statistical models have been developed for (a) Cyclone Genesis Potential Parameter (GPP), (b) Multi-Model Ensemble (MME) technique for cyclone track prediction, (c) Cyclone intensity prediction, (d) Rapid intensification and (e) Predicting decay in intensity after the landfall. Genesis potential parameter (GPP) is used for predicting potential of cyclogenesis (T3.0) and forecast for potential cyclogenesis zone. The multi-model ensemble (MME) for predicting the track (at 12h interval up to 120h) of tropical cyclones for the Indian Seas is developed applying multiple linear regression technique using the member models IMD-GFS, IMD-WRF, GFS (NCEP), ECMWF and JMA. The SCIP model is used for 12 hourly intensity predictions up to 72-h and a rapid intensification index (RII) is developed and implemented for the probability forecast of rapid intensification (RI). Decay model is used for prediction of intensity after landfall. The performance of the individual models, MME forecasts, SCIP, GPP, RII for ESCS 'Tauktae' are presented and discussed in following sections.

10.1 Prediction of cyclogenesis [Genesis Potential Parameter (GPP)] for ESCS Tauktae

Fig. 16 (a-f) indicates that the GPP could predict the potential zone for cyclogenesis on 14^{th} May, over southeast Arabian Sea about 120 hours in advance. However, the location of genesis became accurate only with a lead time of 72 hours.

Since all low pressure systems do not intensify into cyclones, it is important to identify the potential of intensification (into cyclone) of a low pressure system at the early stages (T No. 1.0, 1.5, 2.0) of development. Average GPP ≥ 8.0 is the threshold value for

system likely to develop into a cyclonic storm and average GPP < 8.0 indicates a non-developing system. The area average analysis of GPP on 14th May is presented in **Fig. 17.** The area average analysis was predicting the system to develop into a cyclonic storm from the 00 UTC run of 14th.

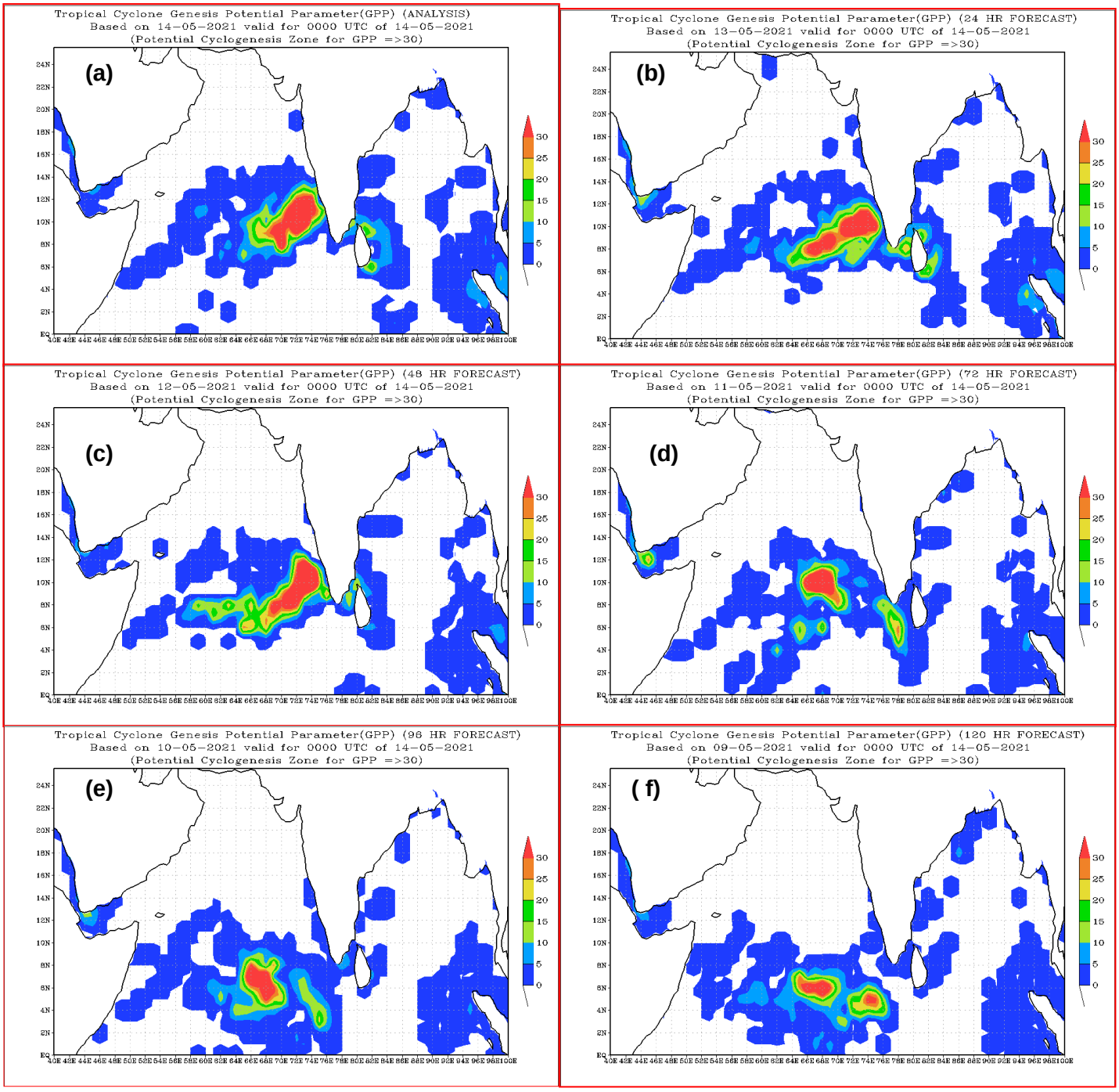


Fig.16 (a-f): Predicted zone of cyclogenesis for 0000 UTC of 14th May based on 0000 UTC of 09th-14th May 2021

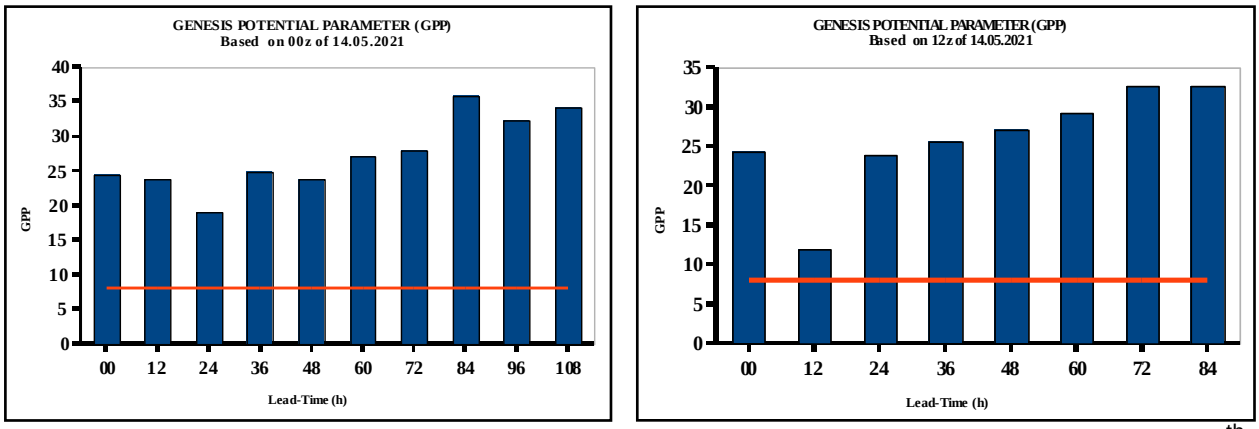


Fig. 17: Area average analysis and forecasts of GPP based on (a) 0000 of 14th & (b) 1200 UTC of 14th May 2021

10.2 Track prediction by NWP models

Tracks predicted by various NWP models including IMD GFS, IMD MME, IMD HWRF, WRF-VAR, NCMRWF Unified Model (NCUM), UM Regional, NCMRWF Ensemble Prediction System (NEPS), NCEP GFS, ECMWF, UKMO and JMA during 14th to 17th May are presented in **Fig.18**. Based on initial conditions of 0000 UTC of 14th May, most of the models, other than JMA & NCEP- GFS indicated likely crossing of the system over Gujarat coast. JMA was far out when it predicted the system to move away from the west coast of India fooled by NCEP GFS, which hinted the possibility of crossing south Pakistan coast to the west of Kutch (India). HWRF (HYCOM) forecast was the most realistic followed by that of ECMWF, though the actual landfall point remained to be nearly 50 to 100 km to the east respectively. Predicted landfall timings also varied and most of the models lagged by nearly 12 hours, at this stage.

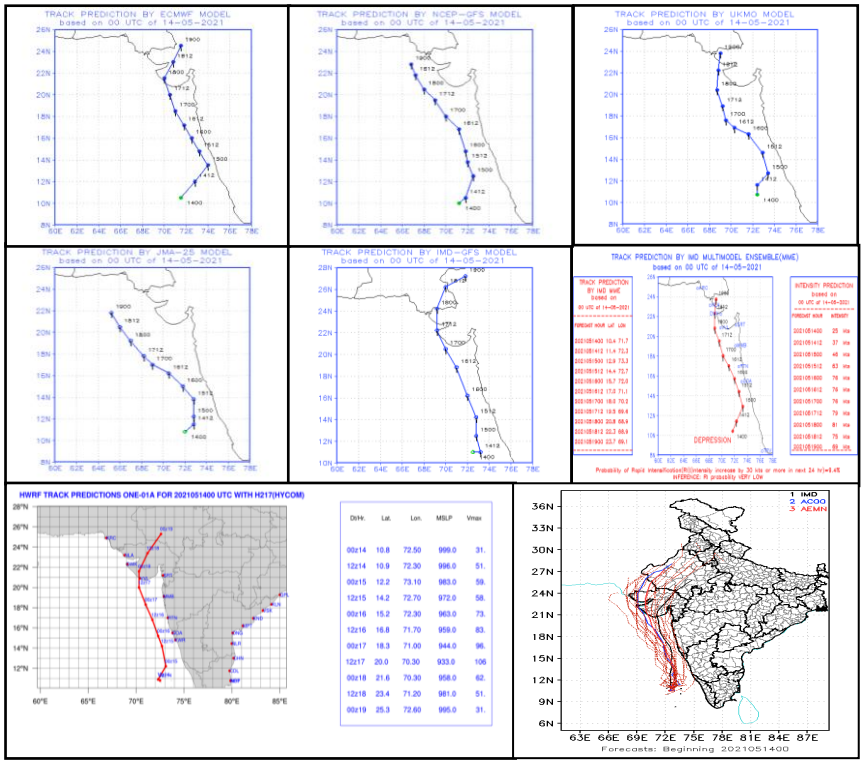


Fig. 18 (a): NWP model for tropical cyclone "TAUKTAE" based on 0000 UTC of 14th May 2021

Based on initial conditions of 0000 UTC of 15th May, a few more models like UKMO shifted the track more eastwards confirming the system to cross Gujarat coast. However, the forecasts by ECMWF, HWRF (HYCOM) and the mean track from the strike probability of GEFS were nearly accurate, whereas IMD GFS indicated the landfall point about 50 km to the west, JMA to the west of Kutch (India) and NCEP GFS far to the west of Indian coast line. The landfall timings continued to vary most of them predicted it to happen during the morning hours of 18th May.

Based on the initial conditions of 1200 UTC of 15th May, MME for the first time indicated chances of rapid intensification on 16th – 17th May, reaching the maximum intensity (98 Knots) at 1200 UTC of 17th May.

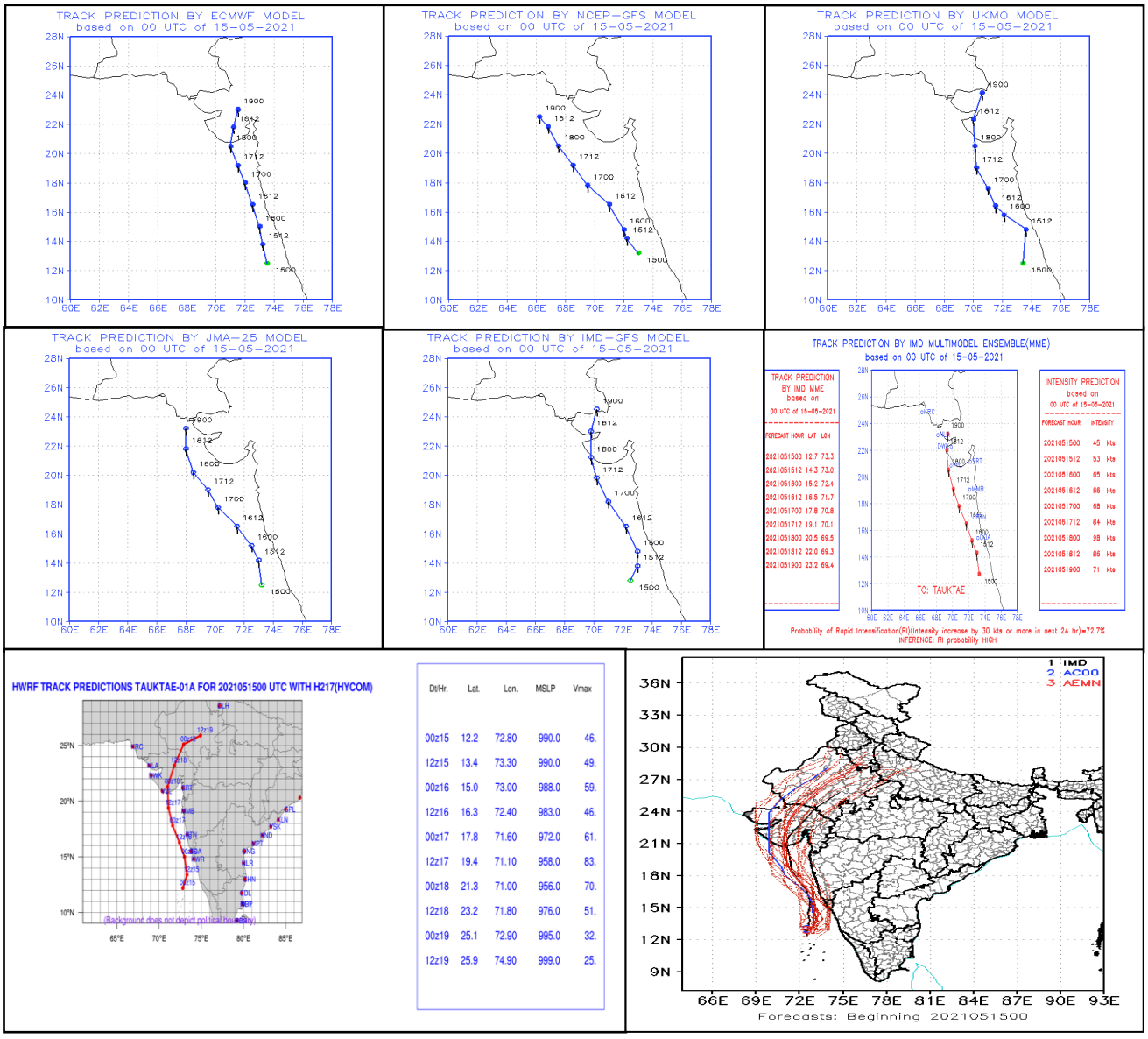


Fig. 18 (b): NWP model for tropical cyclone "TAUKTAE" based on 0000 UTC of 15th May 2021

Based on initial conditions of 0000 UTC of 16th May, all the models, except JMA predicted the landfall point with reasonable accuracy. The landfall timings also started converging in majority of the model forecasts. However, at this stage, MME indicated an intensity of 100 knots at 0000 UTC of 18th, over Saurashtra, after landfall.

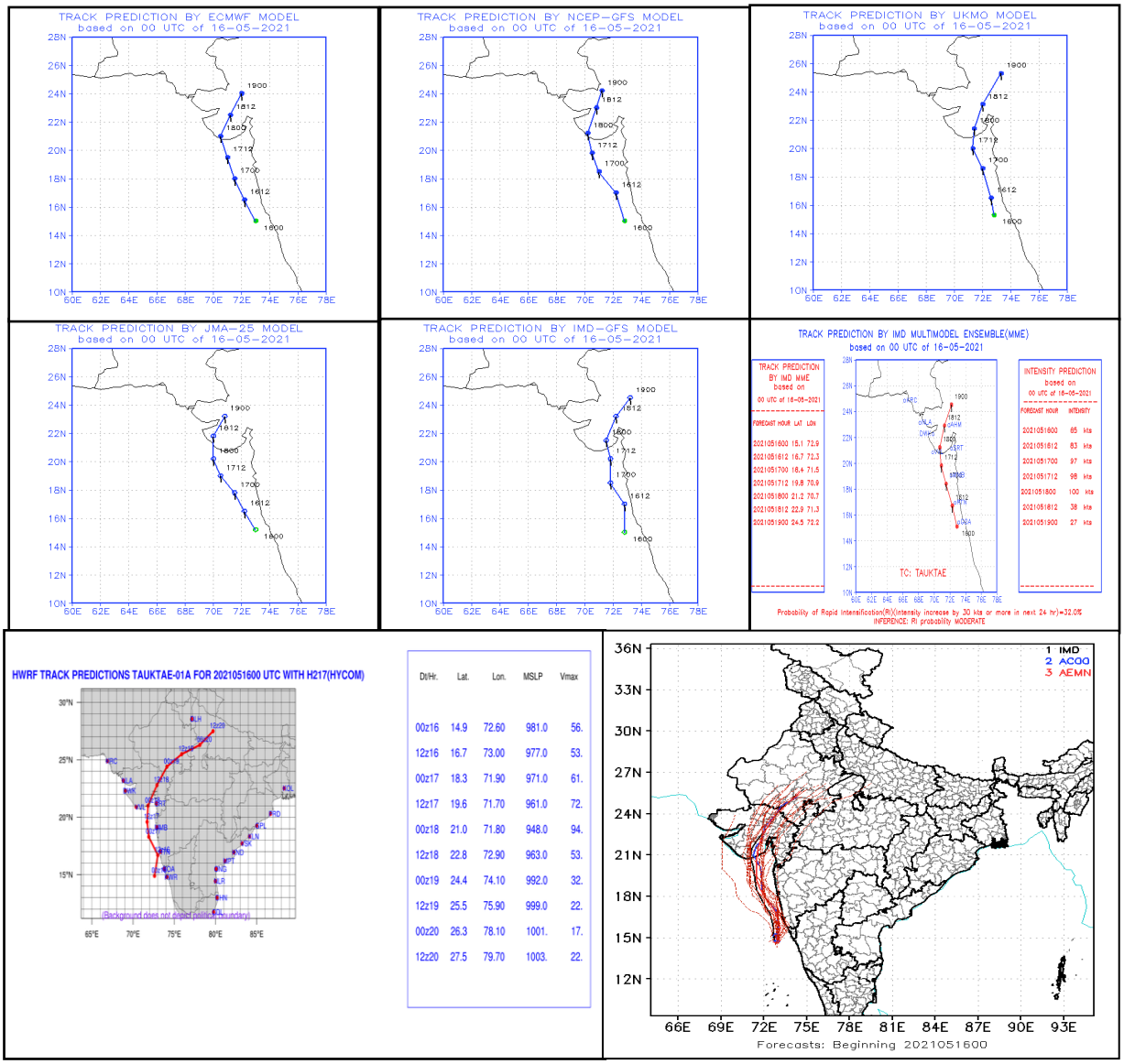


Fig. 18 (c): NWP model for tropical cyclone "TAUKTAE" based on 0000 UTC of 16th May 2021

Based on initial conditions of 0000 UTC of 17th May, all the models converged in the landfall point. However, the time of landfall still varied. All of them also predicted the initial near northward movement followed by north-northeastwards re-curvature after landfall. At this point, MME indicated an intensity of 105 Knots till 1200 UTC of 17th and a rapid weakening after landfall into 55 knots at 0000 UTC of 18th May.

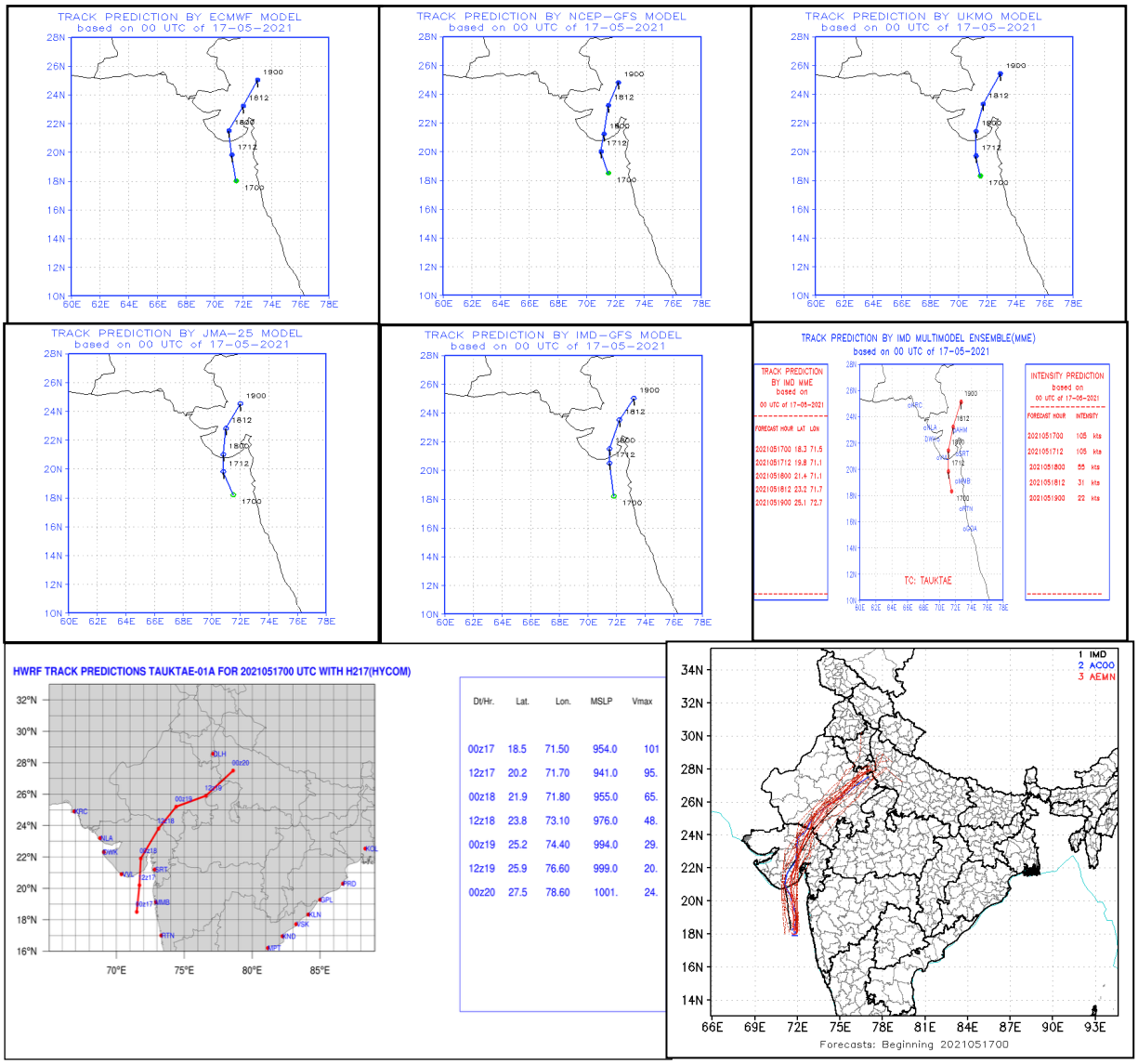


Fig. 18 (d): NWP model for tropical cyclone "TAUKTAE" based on 0000 UTC of 17th May 2021

10.3 Track forecast errors

Average track forecast errors by various NWP models are presented in **Table 3a**. For 24 hrs lead period track forecast error was the least i.r.o. MME followed by IMD-GFS and GEFS. For 48 hrs lead period, the track forecast error was the least i.r.o. ECMWF followed by MME and IMD-GFS. For 72 hours lead period, the error was the least i.r.o. ECMWF followed by HWRF and IMD GFS. For 96 and 120 hrs lead period, error was the least in case of ECMWF and HWRF. The along track and cross track errors by different models are presented in **Tables 3 b & 3c.**

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Table-3a: Average track forecast errors (Direct Position Error (DPE)) in km (Number of forecasts verified is given in the parentheses)

LEAD-TIME	12h	24h	36h	48h	60h	72h	84h	96h	108h	120h
IMD-MME*	36(7)	36(7)	54(7)	83(7)	112(6)	151(5)	202(4)	333(3)	360(1)	435(1)
GEFS(mean)	50(11)	58(9)	79(9)	117(7)	119(6)	113(5)	155(4)	233(3)	275(2)	313(1)
ECMWF	47	66	66	78	95	95	123	184	154	182
NCEP-GFS	77	54	93	138	190	278	388	576	543	688
UKMO	62	61	70	101	151	163	262	367	373	443
JMA	43	62	108	165	239	335	454	601	711	880
HWRF	49 (15)	64 (15)	90 (15)	115 (13)	118 (11)	121 (9)	152 (7)	155 (5)	153 (3)	287 (1)
IMD-GFS	67	42	53	87	124	136	212	317	415	335
NCUM (G)	63(10)	74(10)	117(9)	154(9)	212(9)	255(8)	357(7)	461(7)	585(6)	636(5)
NEPS	54(9)	80(9)	89(10)	136(9)	192(9)	276(8)	373(7)	390(6)	443(5)	462(5)
NCUM (R)	62(10)	63(10)	101(9)	180(10)	251(9)	299(9)	-	-	-	-

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

Table-3b. Average along-track forecast errors (ATE) in km

(Number of forecasts verified is given in the parentheses)

Lead Time	12 Hr	24 Hr	36 Hr	48 Hr	60 Hr	72 Hr	84 Hr	96 Hr	108 Hr	120 Hr
HWRF	42 (15)	44 (15)	49 (15)	64 (13)	74 (11)	82 (09)	93 (7)	128 (5)	122 (3)	78 (1)
NCUM(R)	40	30	70	120	180	195	-	-	-	-
NCUM(G)	30	40	50	80	90	80	140	220	340	370
NEPS	40	45	50	90	110	160	170	150	230	270

Table-3c Average cross-track forecast errors (CTE) in km

(Number of forecasts verified is given in the parentheses)

Lead Time	12 Hr	24 Hr	36 Hr	48 Hr	60 Hr	72 Hr	84 Hr	96 Hr	108 Hr	120 Hr
HWRF	74 (15)	92 (15)	111 (15)	140 (13)	133 (11)	121 (9)	90 (7)	104 (5)	85 (3)	94 (1)
NCUM(R)	25	30	40	100	130	185	-	-	-	-
NCUM(G)	20	25	85	110	155	220	310	390	450	480
NEPS	10	50	40	95	130	200	300	360	370	320

10.4 Landfall forecast errors

Average model errors in landfall point and time are presented in **Tables 4 (a & b)**. The tables indicate that many models like NCEP GFS, JMA and NCUM didn't predict landfall till 0000 UTC of 15th May. Though the mean error of GEFS was high in the initial run based on 00 UTC of 14th May, it reduced significantly from the next run (based on 12 UTC of 14th May onwards, signifying the importance of ensemble prediction system in providing guidance nearly 72 hours in advance. The landfall point errors of ECMWF and IMD GFS were significantly less as compared to other models. The landfall time errors were the least by IMD HWRF upto 72 hours lead period.

Table-4(a): Landfall point forecast errors (km) of NWP Models at different lead time (hour)

('NLF' indicates No Landfall Forecast)

Forecast Lead Time (hour) →	16.5 h (17/00)	28.5 h (16/12)	40.5 h (16/00)	52.5 h (15/12)	64.5 h (15/00)	76.5 h (14/12)	88.5 h (14/00)
IMD-GFS	33	43	47	47	155	197	251
GEFS (mean)	44	50	32	15	68	98	501
ECMWF	00	00	41	15	10	172	96
NCEP GFS	00	15	86	267	NLF	NLF	NLF
UKMO	10	00	33	74	116	NLF	219
JMA	33	62	119	NLF	NLF	NLF	NLF
NCUM(R)	10.4	9.6	80.7	NLF	NLF	NLF	NLF
NCUM(G)	67.8	59.3	51.8	36.4	141.2	NLF	NLF
NEPS	64.9	26.2	24.5	317.7	153.1	NLF	NLF
IMD-MME	00	00	33	33	319	214	327

Table-4(b): Landfall time forecast errors (hour:minute) at different lead time (hr)

('+' indicates delay landfall, '-' indicates early landfall)

Forecast Lead Time (hour) →	16.5 h (17/00)	28.5 h (16/12)	40.5 h (16/00)	52.5 h (15/12)	64.5 h (15/00)	76.5 h (14/12)	88.5 h (14/00)
IMD-GFS	00:00	-01:30	+02:30	+07:30	+08:30	+04:00	-04:30
GEFS	-3	-3	-3	+9	+3	-3	+21
ECMWF	+02:00	-02:00	+07:00	-03:30	+09:30	+01:30	+07:00
NCEP GFS	+03:00	00:00	+07:00	+14:30	NLF	NLF	NLF
UKMO	+03:00	+01:30	+02:00	+05:00	+11:00	NLF	+25:30
JMA	+05:30	+01:30	+14:30	NLF	NLF	NLF	NLF
NCUM(R)	+01:30	+04:00	+22:30	NLF	NLF	NLF	NLF
NCUM(G)	+03:30	+04:30	+09:30	+10:30	+13:30	NLF	NLF
NEPS	+03:30	+08:30	+09:30	+13:30	+15:30	NLF	NLF
IMD-MME	+02:30	-01:00	+03:00	+01:30	+19:30	+19:30	+25:30

10.5 Intensity forecast errors by various NWP Models

The intensity forecasts errors of various models are presented in **Table 5**. It is seen that upto 24hrs lead period and for longer lead period (beyond 96 hrs), SCIP, IMD GFS & GEFS based errors were less than HWRF errors. However, for 36 to 84 hrs lead period, intensity forecast errors by IMD HWRF were more or less similar to that of SCIP.

Table-5 Average absolute errors (AAE) and Root Mean Square (RMSE) errors in knots

Lead Time	12 Hr	24 Hr	36 Hr	48 Hr	60 Hr	72 Hr	84 Hr	96 Hr	108 Hr	120 Hr
HWRF (AAE)	11.8 (15)	13.1 (15)	15.8 (15)	17.8 (13)	10.4 (11)	10.5 (09)	12.0 (7)	9.9 (5)	13.4 (3)	7.7 (1)
IMD-GFS (AAE)	12.2	15	12.2	7.5	14.3	8.7	15.3	24.5	--	--
GEFS (AAE)	13 (11)	16 (9)	18 (9)	16 (7)	14 (6)	14 (5)	13 (4)	13 (3)	18 (2)	12 (1)
IMD-SCIP (AAE)	6.1 (7)	4.7 (7)	9.1 (7)	16.7(7)	11.7(6)	19.0(5)	18.5(4)	--	--	--
HWRF (RMSE)	14.3 (15)	16.7 (15)	20.2 (15)	21.5 (13)	13.5 (11)	13.1 (9)	15.2 (7)	10.8 (5)	19.2 (3)	10.4 (1)
IMD-GFS (RMSE)	14.5	19.4	15.5	8	17.6	10.2	22.7	27.5	--	--
GEFS (RMSE)	20 (11)	23 (9)	27 (9)	24 (7)	17 (6)	16 (5)	14 (4)	16 (3)	18 (2)	12 (1)
IMD-SCIP (RMSE)	7.5	5.5	10.2	20.8	17.1	22.0	26.8	--	--	--

(Number of forecasts verified is given in the parentheses)

Intensity forecast by IMD Statistical Cyclone Intensity Prediction (SCIP) model is presented in Fig. 19. The SCIP model is developed by applying multiple linear integration technique by using the predictors viz., initial storm intensity, intensity changes in past 12 hours, storm motion speed, initial position, vertical wind shear averaged along the storm track, vorticity at 850 hPa, divergence at 200 hPa & SST. The AAE & RMSE thus calculated shows that it was less than or equal to 10 knots upto a lead time of 36 hours and higher with increase in lead time. Based on the initial conditions of 00 UTC of 16th, the intensity predicted by the SCIP model was very close to the observed intensity.

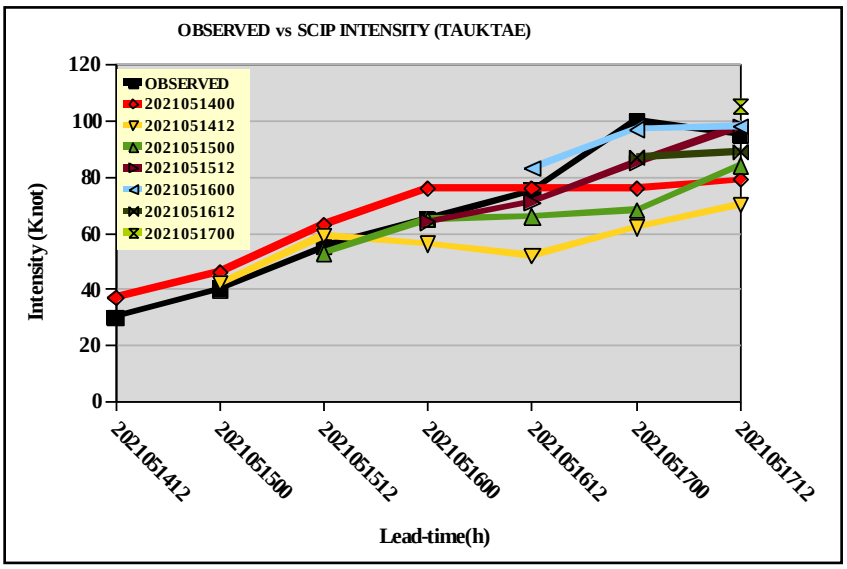
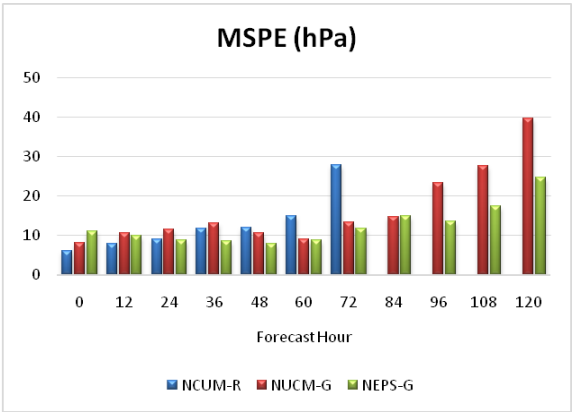


Fig.19: Intensity forecast based on 0000 and 1200 UTC during 14th May to 17th May of IMD SCIP model

The mean absolute error in Minimum SLP (MSPE in hPa) and (MSWE in kt) for NCUM (G), NCUM(R) & NEPS are shown in Figure 20. Minimum average error in Min SLP in model analyses is evident in NCUM-G whereas the least error is seen at higher lead times (>36 h) in NEPS-G. Error in MSW by all the models are relatively higher (<= 72 h) than in Min SLP.



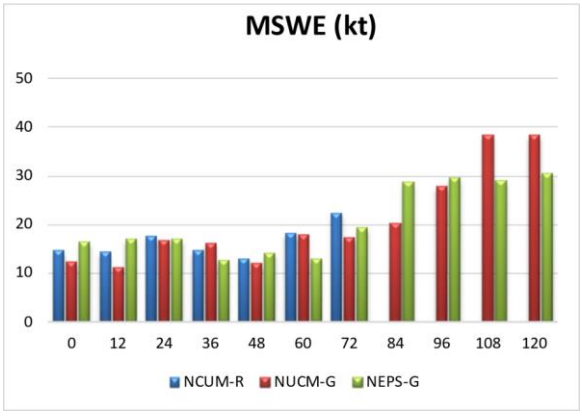


Fig.20: Intensity forecast errors by NCUM (Global & Regional) and NEPS

11. Operational Forecast Performance

i) Genesis Forecast

- First information about development of low pressure area over southeast Arabian Sea and adjoining areas was given in the extended range outlook issued on 6th May (**about 7 days prior to the formation of low pressure area** over southeast Arabian Sea & adjoining Lakshadweep area on 13th May and **8 days prior to formation of depression** over Lakshadweep area on 14th May).
- Subsequently, in the Tropical Weather Outlook issued on 10th May and national weather forecast bulletin issued at 1200 hrs IST, it was indicated that a low pressure would form over southeast Arabian Sea around 14th May and would intensify further into a cyclonic storm. (about **4 days prior to formation of cyclonic storm** on 14th May).
- The extended range outlook issued on 13th May (about **4 days prior to landfall over Gujarat** coast) indicated that the system would move towards Gujarat coast and would impact the areas including southeast, eastcentral & northeast Arabian Sea, Lakshadweep – Maldives area, Lakshadweep Islands, areas along & off Kerala, Karnataka, Goa, Maharashtra, Gujarat & south Pakistan coasts and also the coastal & adjoining districts of all these States. Accordingly, likely impact was also issued in the extended range outlook for fishermen, ships and ports along the west coast of India.

ii) Track, landfall and intensity forecast

- The Press Release updated on 13th May (**5 days prior to landfall**) on development of low pressure area over southeast Arabian Sea. It indicated that the cyclonic storm over southeast Arabian Sea and adjoining Lakshadweep area would reach Gujarat coast on 18th May.
- **In the first bulletin issued at 1245 hrs IST of 14th May,** it was indicated that the system would intensify into a very severe cyclonic storm and reach Gujarat coast by 18th May morning **(about 80 hours prior to landfall of TAUKTAE). (Fig.21)**
- In the bulletin issued at 2030 hrs IST of 14th May (**about 75 hours prior to landfall**), it was indicated that the system would reach near Gujarat coast in the morning of 18th May and that winds as high as 150-160 kmph gusting to 180 kmph would prevail along & off south Gujarat since late night of 17th.

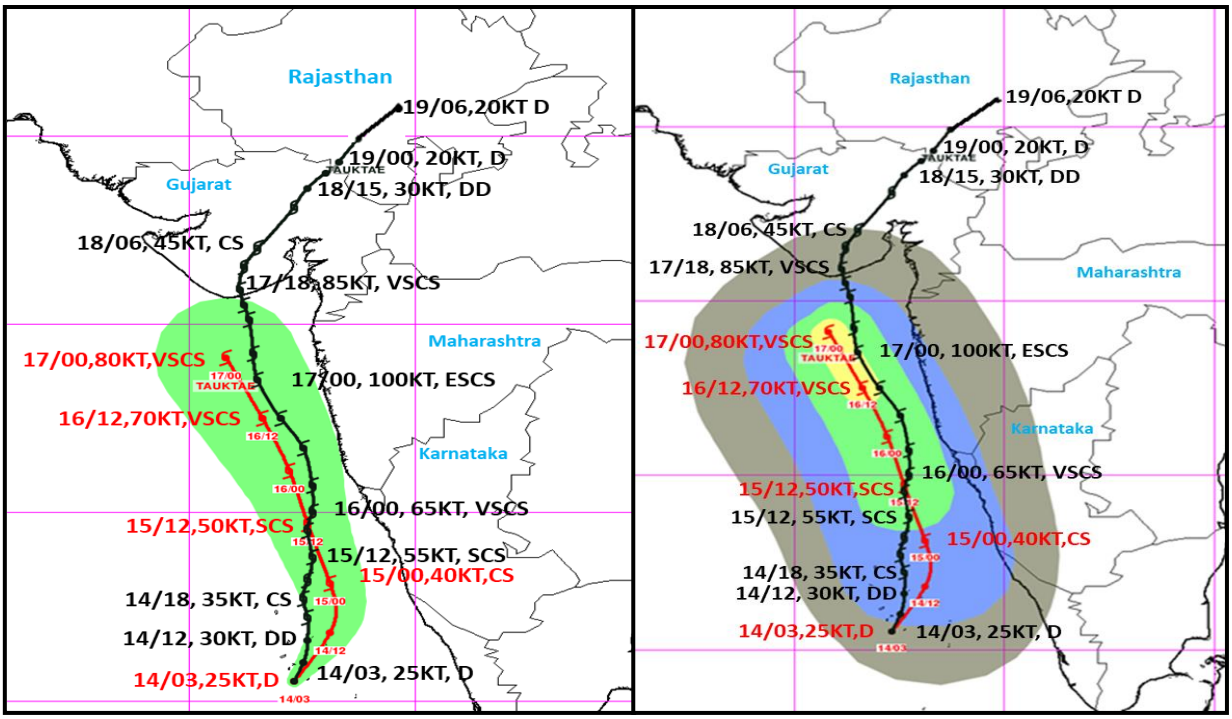


Fig.21 (a-b): Observed track (14-19 May) and forecast track issued at 1245 hours IST of 14th May based on 0830 hrs IST observations of 14th May (80 hours prior to landfall).

- The landfall point & time was further updated in the bulletin issued at 0330 hours IST of 16th May (**about 45 hours prior to landfall**) that the system would reach Gujarat coast in the evening hours of 17th & cross Gujarat coast between Porbandar & Mahuva (Bhavnagar district) around 18th May early morning with wind speed of 150-160 kmph gusting to 180 kmph.
- In the bulletin issued at 0815 hrs IST of 17th May (**about 15 hours prior to landfall**), the warnings were further specified and it was informed that the system would reach Gujarat coast in the evening hours of 17th & cross Gujarat coast between Porbandar & Mahuva (Bhavnagar district) during the night (2000 – 2300 hrs IST) of 17th May as a Very Severe Cyclonic Storm with a maximum sustained wind speed 155-165 kmph gusting to 185 kmph.
- Actually, the extremely severe cyclonic storm TAUKTAE crossed Saurashtra coast close to about 20 km northeast of Diu near latitude 20.8^{0}N and longitude 71.1^{0}E during 2000-2300 hrs IST of 17th May with wind speed of 160-170 kmph gusting to 185 kmph.
- Thus, the track, landfall point & time, intensity and associated adverse weather like heavy rainfall, gale wind and storm surge were well predicted by IMD.
- **Figures 22 & 23** represent the observed and forecast track, intensity & landfall forecast issued at various lead times indicating accuracy in track, landfall and intensity forecast.

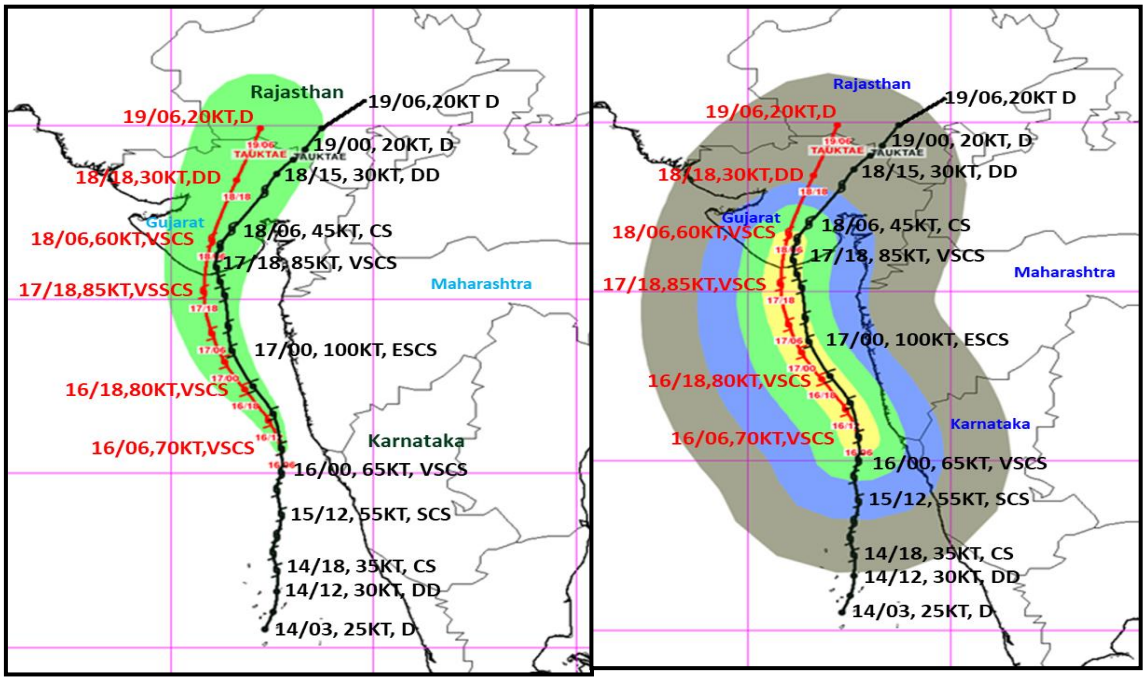


Fig.22 (a-b): Observed track (14-19 May) and forecast track issued at 1430 hours IST of 16th May based on 1130 hrs IST observations of 16th May (**about 36 hours prior to landfall**) demonstrating accuracy in track, intensity and landfall.

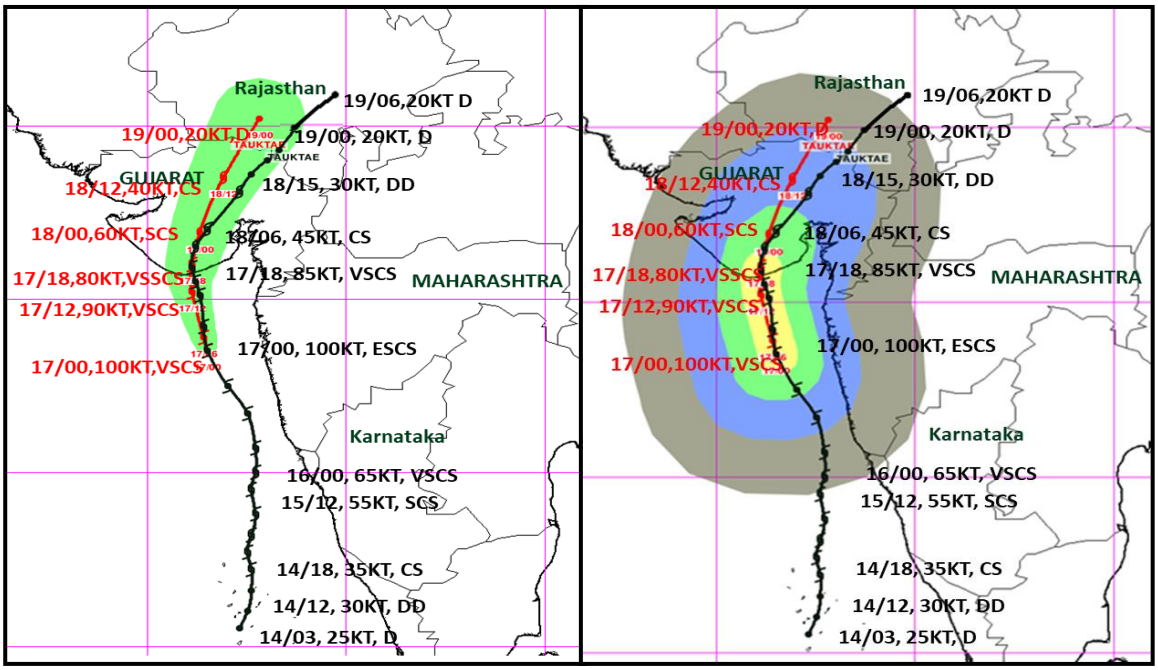


Fig.23 (a-b): Observed track (14-19 May) and forecast track issued at 0830 hours IST of 17th May based on 0530 hrs IST observations of 17th May (**about 15 hours prior to landfall**) demonstrating accuracy in track, intensity and landfall.

DATE/TIME IN UTC, IST = UTC + 0530 HRS, D: DEPRESSION, DD: DEEP DEPRESSION, CS: CYCLONIC STORM, SCS: SEVERE CYCLONIC STORM, VSCS: VERY SEVERE CYCLONIC STORM, ESCS: EXTREMELY SEVERE CYCLONIC STORM

OBSERVED TRACK, FORECAST TRACK, CONE OF UNCERTAINTY

MSW(knot)/kmph)	Impact	Action
28-33 /(52–61)	Very rough seas.	Total suspension of fishing operations
34-40/(62-74)	High to very high seas	Total suspension of fishing operations
41-63/(75-117)	Very High seas	Total suspension of fishing operations
≥ 64 (≥118)	Phenomenal	Total suspension of fishing operations

iii) Operational Track, Intensity and Landfall Point & Time Forecast Errors:

The operational track, intensity and landfall errors as compared to long period average errors during 2016-20 are presented in **Fig. 24**.

- The track forecast errors for 24, 48 and 72 hrs lead period were 73, 118, and 224 km respectively against the LPA errors of 77, 117, and 159 km respectively.
- The absolute error (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 4.4, 8.9 and 15.5 knots against the LPA errors of 7.9, 11.4, and 14.1 knots during 2015-19 respectively**.**
- The landfall point forecast errors for 24 and 48 hrs lead period were 27 and 71km respectively against the LPA errors of 32 and 62 km during 2016-20 respectively.
- The landfall time forecast errors for 24 and 48 hrs lead period were 3.5 and 6.5 hours respectively against the LPA errors of 2.5 and 6.5 hours during 2016-20 respectively.

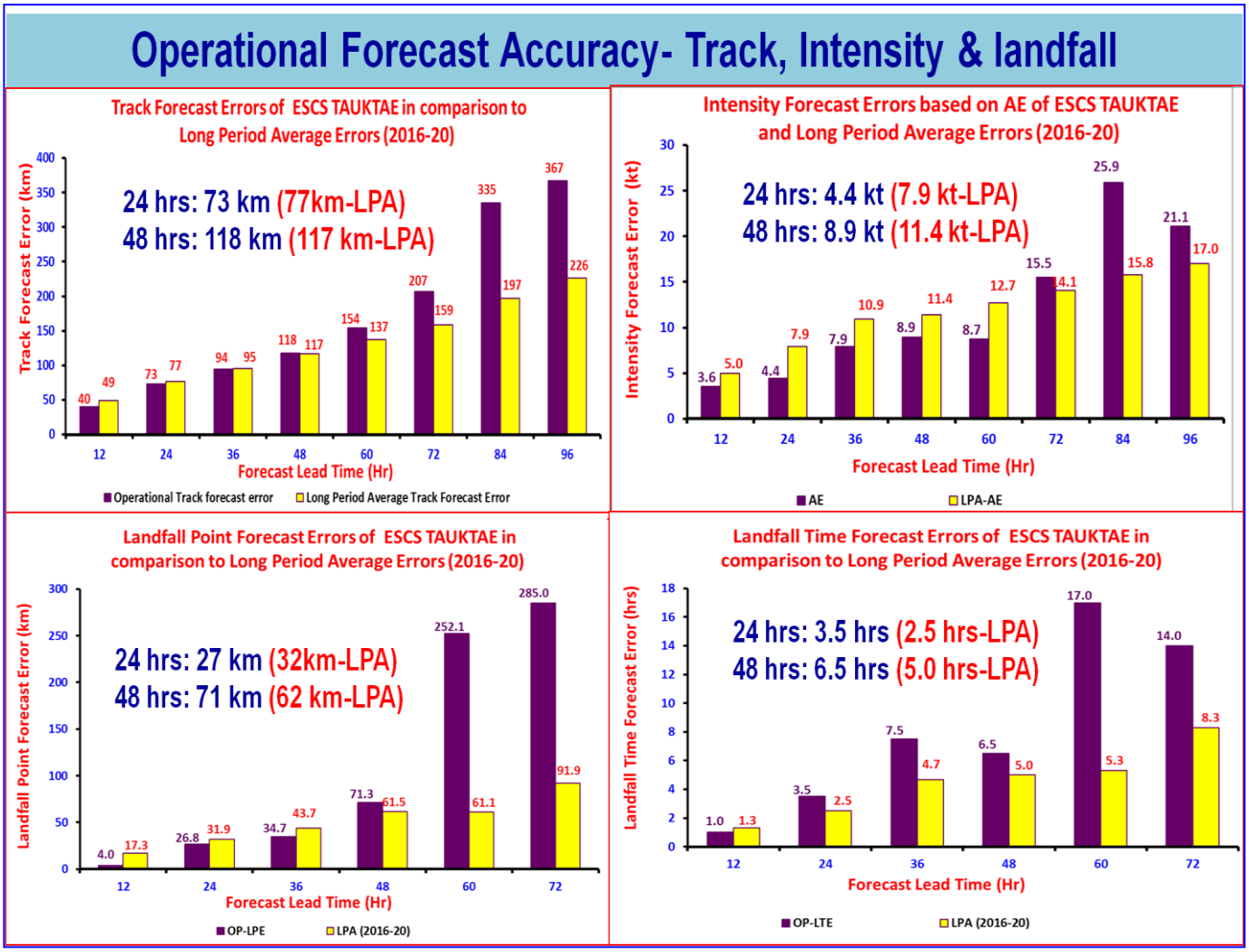


Fig. 24: Operational track, intensity and landfall errors of extremely severe cyclonic storm Tauktae as compared to long period average errors during 2016-2020

12. Adverse weather forecast verification

The verifications of adverse weather like heavy rainfall, gale wind and storm surge forecast issued by IMD are presented in **Tables 6-8**. It is found that all the three types of adverse weather were predicted accurately and well in advance.

Table 6: Verification of Heavy Rainfall Forecast

Date/Base Time of observation	24 hr Heavy rainfall warning ending at 0300 UTC of next day	Realised 24-hour heavy rainfall ending at 0300 UTC of date
14.05.2021/0300	**Lakshadweep Islands:** Heavy to very heavy falls at a few places with extremely heavy falls (≥ 20 cm) at isolated places very likely on 14th May, heavy to very heavy falls at isolated places on 15th May and heavy falls at isolated places on 16th May. **Kerala:**Heavy to very heavy falls at a few places and extremely heavy falls (≥ 20 cm) at isolated places on 14th, heavy to very heavy falls at a few places 15th and heavy to very heavy falls at isolated places on 16th& 17th May. **Tamil Nadu (Ghat districts):** Heavy to very heavy falls & extremely heavy falls at isolated places very likely on 14th and heavy to very heavy falls at isolated places on 15th May. **Karnataka (coastal & adjoining Ghat districts):** Heavy to very heavy falls at a few paces with extremely heavy falls at isolated places on 14th & 15th and heavy falls at isolated places on 16th. **Konkan & Goa:** Heavy falls at isolated places very likely over Goa on 14th, at most places with heavy to very heavy falls at a few places over south Konkan & Goa and heavy to very heavy falls at isolated places over north Konkan on 15th and heavy falls at isolated places on 16th. **Gujarat:** Heavy to very heavy falls at a few places on 17th and with heavy to very heavy falls at a few places extremely heavy falls (≥ 20 cm) at isolated places over Saurashtra & Kutch on 18th.	Heavy to extremely heavy rainfall activity, over Lakshadweep on 13-14th, Kerala on 14-15th, Karnataka on 15th, Goa and south coastal Maharashtra on 15-16th north Maharashtra on 16-17th, Gujarat, Daman & Diu, Dadra Nagar and Haveli on 17th and 18th and West Rajasthan on 18th & 19th
15.05.2021/0300	**Lakshadweep Islands:** Heavy to very heavy falls at isolated places over northern Islands on 15th May and heavy falls at isolated places on 16th May.	

	Kerala: Heavy to very heavy falls at a few places and extremely heavy falls at isolated places on 15th, heavy to very heavy falls at isolated places on 16th and heavy falls at isolated places on 17th May. **Tamil Nadu (Ghat districts):** Heavy to very heavy falls at isolated places on 15th May. **Karnataka (coastal & adjoining Ghat districts):** Heavy to very heavy falls at a few paces and extremely heavy falls at isolated places on 15th and heavy to very heavy falls at isolated places on 16th. **Konkan & Goa:** Heavy to very heavy falls at a few places over south Konkan & Goa and heavy to very heavy falls at isolated places over north Konkan on 15th and heavy to very heavy falls at a few places over Konkan & Goa & adjoining Ghat areas on 16th and heavy falls at isolated places on 17th May over north Konkan. **Gujarat:** Heavy to very heavy falls at isolated places over Saurashtra & Kutch and extremely heavy falls at isolated places (in Junagarh & Gir Somnath Districts) on 17th and with heavy to very heavy falls at a few places over Saurashtra & Kutch with extremely heavy falls (≥ 20 cm) at isolated places (Porbandar, Devbhoomi Dwarka, Jamnagar & Kutch districts) on 18th. **West Rajasthan:** Heavy to very heavy falls at isolated places very likely on 18th & 19th May.	
16.05.2021/0300	**Kerala:** Heavy to very to very heavy falls at isolated places on 16th and heavy falls at isolated places on 17th May. **Karnataka (coastal & adjoining Ghat districts):** Heavy to very heavy falls at isolated places on 16th. **South Konkan & Goa:** Heavy to very heavy falls at a few places and extremely heavy falls at isolated places over south Konkan & Goa and adjoining Ghat areas on 16th and heavy to very heavy falls at isolated places on 17th May. **North Konkan:** Heavy to very heavy falls at isolated places on 16th and 17th	

	May. **Gujarat:** Heavy to very heavy falls at isolated places over Saurashtra & Kutch, Diu and southern most Gujarat region with extremely heavy falls at isolated places on 17th and with heavy to very heavy falls at a few places over Saurashtra & Kutch and Diu & south Gujarat region with extremely heavy falls (≥ 20 cm) at isolated places on 18th. **Rajasthan:** Heavy to very heavy falls & extremely heavy falls at isolated places very likely over south Rajasthan on 18th & heavy to very heavy falls at isolated places over Rajasthan on 19th May.	
17.05.2021/0300	**Konkan & adjoining Madhya Maharashtra:** Heavy to very heavy falls and extremely heavy falls at isolated places on 17th May and isolated heavy rainfall over north Konkan on 18th May. **Gujarat:** Heavy to very heavy falls at a few places and extremely heavy falls at isolated places very likely over Saurashtra, Diu and adjoining Gujarat region on 17th & heavy to very heavy falls at a few places over Gujarat region and heavy to very heavy falls at isolated places over Saurashtra on 18th May. Isolated heavy to very heavy rainfall also likely over Kutch during the same period. **Rajasthan:** Heavy to very heavy falls & extremely heavy falls at isolated places very likely over south Rajasthan on 18th & heavy to very heavy falls at isolated places over Rajasthan on 19th May.	
18.05.2021/0300	**Gujarat:** Heavy to very heavy falls isolated places very likely over Gujarat region and Saurashtra on 18th May. **Rajasthan**: Heavy to very heavy falls at isolated places very likely over south Rajasthan on 18th & heavy falls at isolated places over north Rajasthan on 19th May	
19.05.2021/0300	Heavy to very heavy falls at isolated places very likely over East Rajasthan on 19th May. Heavy to very heavy falls and extremely heavy falls at isolated places over Uttarakhand , heavy to very heavy rainfall at isolated places over Himachal Pradesh, Haryana, West Uttar Pradesh and Heavy rainfall at isolated places over Punjab, East Uttar Pradesh, north Madhya Pradesh and West Rajasthan during next 24 hours.	

Table 7: Verification of Squally/Gale wind forecast (14-19 May)

Date/Base Time of observation	Gale/ Squally wind Forecast at 0300 UTC of date	Realised wind
14.05.2021/0300	Squally weather with wind speed reaching 45-55 kmph gusting to 65 kmph is very likely over southeast Arabian Sea and adjoining Lakshadweep – Maldives area and equatorial Indian Ocean on 14th May. It is very likely to increase gradually becoming 50- 60 kmph gusting to 70 kmph over the same region from 14th morning. It is likely to increase gradually becoming Gale wind speed reaching 70 – 80 kmph gusting to 90 kmph over east-central Arabian Sea and adjoining southeast Arabian Sea and Lakshadweep area from 15th May morning. Squally wind speed reaching 45-55 kmph gusting to 65 kmph likely along & off Kerala coast on 14th May and 50-60 kmph gusting to 70 kmph along & off Kerala - Karnataka coasts on 15th May. Squally wind speed reaching 40-50 kmph gusting to 60 kmph likely along & off south Maharashtra & Goa coasts on 15th and Gale winds speed reaching 60-70 kmph gusting to 80 kmph along & off south Maharashtra – Goa coasts on16th May. Squally wind speed reaching 40-50 kmph gusting to 60 kmph likely over northeast Arabian Sea and along & off south Gujarat & Daman and Diu coasts on 17th morning and gradually increase becoming Gale winds speed reaching 90-100 kmph gusting to 115 kmph over northeast Arabian Sea along & off Gujarat coast from the early hours of 18th May and increase gradually thereafter till 18th morning.	Agathi reported maximum sustained wind speed of 85 kmph, Minicoy-50 kmph, Amini Divi-38 kmph kts on 14th May. Coastal Karnata reported 55 kmph on 15th May. Mumbai City reported 114 kmph on 18th May. Gujarat coast reported 160-170 gusting to 185 kmph at the time of landfall on 18th
15.05.2021/0300	Squally weather with wind speed reaching 45-55 kmph gusting to 65 kmph is very likely over Maldives area and equatorial Indian Ocean during next 06 hours. Gale wind speed reaching 75 – 85 kmph gusting to 95 kmph is prevailing over east-central Arabian Sea and adjoining southeast Arabian Sea and Lakshadweep area. It is likely to increase over eastcentral Arabian	

	Sea becoming 120-130 kmph gusting to 145 kmph from 16th May morning. Squally wind speed reaching 50-60 kmph gusting to 70 kmph along & off Kerala coast on 15th May. Squally wind speed reaching 50-60 kmph gusting to 70 kmph likely along & off Karnataka south Maharashtra & Goa coasts on 15th and Gale winds speed reaching 60-70 kmph gusting to 80 kmph along & off Maharashtra –Goa coasts on16th May. Squally wind speed reaching 40-50 kmph gusting to 60 kmph likely over northeast Arabian Sea and along & off south Gujarat & Daman and Diu coasts on 17th morning and gradually increase becoming Gale winds speed reaching 150-160 kmph gusting to 175 kmph over northeast Arabian Sea from 18th morning and along & off Saurashtra & Kutch coasts (Devbhoomi Dwarka & Porbandar) and 120 -150 kmph gusting to 165 kmph over Kutch, Porbandar, Junagarh, Jamnagar districts of Gujarat from 18th May afternoon / evening for subsequent 06 hours.	
16.05.2021/0300	Gale wind speed reaching 130–140 kmph gusting to 155 kmph is prevailing over eastcentral Arabian Sea. It is likely to increase over eastcentral Arabian Sea becoming 145-155 kmph gusting to 170 kmph from 16th May mid-night. Gale winds speed reaching 80-90 kmph gusting to 100 kmph along & off south Maharashtra –Goa and adjoining Karnataka coasts on 16th, 50-60 kmph gusting to 70 kmph along & off north Maharashtra coast on 16th. It is likely to become 65- 75 kmph gusting to 85 kmph along & off north Maharashtra coast from 17th till 18th morning. Squally wind speed reaching 40-50 kmph gusting to 60 kmph likely over northeast Arabian Sea and along & off south Gujarat & Daman and Diu coasts from 16th morning and gradually increase becoming Gale winds speed reaching 150-160 kmph gusting to 175 kmph over northeast Arabian Sea and along & off Gujarat coast (Porbandar, Junagarh, Gir Somnath, Amreli, Bhavnagar)	

	and 100 -120 kmph gusting to 135 kmph over Bharuch, Anand, south Ahemedabad, Botad, Surendranagar, 90 -100 kmph gusting to 120 kmph over Devbhoomi Dwarka, Jamnagar, Rajkot, Morbi districts of Gujarat from early hours of 18th. Gale winds speed reaching 70-90 kmph gusting to 100 kmph likely to prevail along & off Dadra, Nagar Haveli, Daman, Valsad, Navsari, Surat, Kheda districts from 17th mid-night till 18th morning.	
17.05.2021/0300	Gale wind speed reaching 180–190 kmph gusting to 210 kmph is likely to prevailing over eastcentral Arabian Sea during next six hours Gale winds speed reaching 80-90 kmph gusting to 100 kmph is likely to prevail along & off Maharashtra coast on 17th and gradually decrease thereafter. Gale wind speed reaching 90-100 kmph gusting to 110 kmph is prevailing over adjoining northeast Arabian Sea. It would gradually increase becoming 170–180 kmph gusting to 200 kmph from evening of 17th for subsequent 06 hrs and decrease thereafter Gale wind speed reaching 70-80 kmph gusting to 90 kmph is prevailing along and off south Gujarat & Daman and Diu coasts. It is likely to increase becoming Gale winds speed reaching 155-165 kmph gusting to 185 kmph along & off Gujarat coast (Amreli, Bhavnagar) Junagarh, Gir Somnath and 120 -140 kmph gusting to 165 kmph over Bharuch, Anand, south Ahmedabad, Botad, 90 -100 kmph gusting to 120 kmph over Devbhoomi Dwarka, Jamnagar, Porbandar, Rajkot, Morbi, Kheda districts of Gujarat from tonight till 18th early morning. Gale winds speed reaching 80-90 kmph gusting to 100 kmph likely to prevail along & off Dadra, Nagar Haveli, Daman, Valsad, Navsari, Surat, Surendranagar, districts from 17th evening till 18th morning.	
18.05.2021/0300	Gale wind speed reaching 90-100 kmph gusting to 110 kmph is likely to prevail over Gulf of Khambat and adjoining northeast Arabian Sea during next 06 hours. It is likely to reduce gradually thereafter.	

	Gale wind speed reaching 40-50 gusting to 60 kmph along & off extreme north Maharashtra coast during next 06 hours. Gale winds speed reaching 100-110 kmph gusting to 120 kmph likely to prevail over Amreli, Bhavnagar, Botad, 90-100 kmph gusting to 110 kmph over Surendranagar, Rajkot, Anand, South Ahmedabad : 60-70 kmph gusting to 80 kmph over Diu, Gir Somnath, Junagarh, Kheda, Bharuch, Jamnagar, Porbandar & Morbi during next 06 hours and gradually decrease thereafter. Squally wind speed reaching 45-55 kmph gusting to 65 kmph likely to prevail along and off Dadra, Nagar Haveli, Daman, Valsad, Navsari, Surat, districts and 35-45 kmph gusting to 55 kmph over Devbhoomi Dwarka & Kutch during next 06 hours and gradually decrease thereafter. Squally wind speed reaching 45-55 kmph gusting to 65 kmph is likely to prevail over south Rajasthan from the evening of 18th till 19th early morning.	
19.05.2021/0300	Squally wind speed reaching 45-55 kmph gusting to 65 kmph is likely to prevail over East Rajasthan and adjoining west Madhya Pradesh during next 12 hours.	

Table 8: Verification of Storm Surge Forecast

Date/Base Time of observation	Storm Surge Forecast at 0300 UTC of date	Realized surge
14.05.2021/0300	Tidal wave of about 1 meter height above the astronomical tide is very likely to inundate low lying areas of Lakshadweep Islands on 15th& 16th May.	About 3-4 m above astronomical tide over Diu and of coastal districts of Saurashtra.
15.05.2021/0300	Tidal wave of about 2- 3 m above astronomical tide is likely to inundate coastal areas of Morbi, Kutch, Devbhoomi Dwarka & Jamnagar districts and 1-2 meters along Porbandar, Junagarh, Gir Somnath, Amreli, Bhavnagar and 0.5 to 1m over the remaining coastal districts of Gujarat during the time of landfall..	
16.05.2021/0300	Tidal wave above astronomical tide is likely to inundate coastal areas as per details	

	below: about 3 m over Junagarh,1-2.5 m over Diu, Gir Somnath, Amreli, Bharuch, Bhavnagar, Ahmedabad, Anand, Surat and about 0.5 - 1m over Devbhoomi Dwarka , Jamnagar, Porbandar, Kutch the remaining coastal districts of Gujarat during the time of landfall.(Details given in Annexure-I).	
17.05.2021/0300	Tidal wave above astronomical tide is likely to inundate coastal areas as per details below: about 3 -4 meter (m) over Anand & Amreli, Gir Somnath, Diu, Bhavnagar, 2-3 m over Bharuch, southern parts of Ahmedabad, 1-2 m over Surat, Navsari, Valsad, and 0.5 – 1m over the remaining coastal districts of Gujarat during the time of landfall.(Details given in Annexure-I).	
18.05.2021/0300	Tidal wave above astronomical tide is likely to inundate coastal areas during next 06 hours, as per details below: About 1-2 meter (m) over Anand & Amreli, Gir Somnath, Diu, Bhavnagar, 1 m over Bharuch, southern parts of Ahmedabad, Surat, Navsari, Valsad, during next 06 hours.	

13.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 commencing from 14th May morning 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 12 hours prior to landfall till the system maintained the intensity of cyclonic storm over Gujarat.
- **Cyclone structure forecast for shipping and coastal hazard management:** The radius of maximum wind and radii of MSW ≥28, ≥34, ≥50 and ≥64 knots wind in four quadrants of cyclone was issued every six hourly, commencing from 16th May morning giving forecast for +06, +12, +18, +24, +36 and +120 hrs lead period.

Four stage Warning:

- **Considering the development of cyclonic** storm over southeast Arabian Sea and Lakshadweep area, IMD issued first Press Release at 1400 hours IST of 11th May (**2 days in advance of formation of low pressure area on 13th May**). Heavy rainfall, strong wind and tidal waves warnings were issued alongwith advisories for fishermen.
- The Press Release was further updated on 13th May (**5 days prior to landfall**) on development of low pressure area over southeast Arabian Sea. It indicated that

the cyclonic storm over southeast Arabian Sea and adjoining Lakshadweep area would reach Gujarat coast on 18th May.

- **Considering the expected development of a cyclonic storm the Pre cyclone watch** was issued for south Gujarat and Diu coasts in the first bulletin issued at 1245 hrs IST of 14st May, when the system was a depression over Lakshadweep **(about 80 hours prior to landfall of extremely severe cyclonic storm TAUKTAE)**.
- **Warnings were further upgraded and Cyclone alert** for Gujarat & Diu coasts was given in the bulletin issued at 0920 hrs IST of 15th May, on intensification of the system into a cyclonic storm **(about 62 hours prior to landfall of extremely severe cyclonic storm TAUKTAE)**
- **Warnings were further upgraded and Cyclone Warning** for Gujarat and Diu coasts was issued at 1730 hrs IST of 16th May, when the system was a very severe over eastcentral Arabian Sea **(about 30 hours prior to landfall of TAUKTAE)**
- **Post landfall outlook for interior districts of Gujarat and southern districts of Rajasthan** indicating expected severe weather over interior districts of Gujarat and southern parts of Rajasthan was issued at 0815 hrs IST of 17th May, when the system was an extremely severe cyclonic storm over eastcentral Arabian Sea **(about 15 hours prior to landfall of TAUKTAE)**

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 west coast of India including Lakshadweep Islands, Kerala, Karnataka, Goa, Maharashtra, Gujarat, Daman & Diu, Dadra and Nagar Haveli and Rajasthan. The bulletins also contained the suggested action for disaster managers and general public in particular for fishermen. These bulletins were also issued to Defense including Indian Navy & Indian Air Force, NDRF, Indian Cost Guard, ports, Shipping, fishery, Railways, surface transport and aviation authorities.

- **Warning graphics:** The graphical display of the observed and forecast track with cone of uncertainty and the wind forecast for different quadrants were disseminated by email and uploaded in the RSMC, New Delhi website (http://rsmcnewdelhi.imd.gov.in/) regularly. The adverse weather warnings related to heavy rain, gale/squally wind & storm surge were also presented in graphics alongwith colour codes in the website.
- **Warning and advisory through social media:** Daily updates (every three hourly or whenever there was any significant change in intensity/track/landfall) were uploaded on Facebook and Twitter during the life period of the system since the development of low pressure area over the Arabian Sea. However, from 17th afternoon (0700 UTC) onwards, hourly updates were issued and sent to disaster managers by email, uploaded on websites, posted on Facebook and Twitter till the system maintained the intensity of cyclonic storm.

- **Press Conference, Press release and Media briefing:** Press and electronic media were given daily updates since inception of system through press release, e-mail, website, video capsule by DGM and SMS.
- **Warning and advisory for marine community:** The three/six hourly Global Maritime Distress Safety System (GMDSS) bulletins were issued by the Marine Weather Services division at New Delhi and bulletins for maritime interest were issued by Area cyclone warning centres of IMD at Mumbai, Chennai and Cyclone warning centres at Thiruvananthapuram, Ahmedabad to ports, fishermen, coastal and high Sea shipping community.
- **Fishermen Warning:** Regular warnings for fishermen for deep Sea of Arabian Sea and the states of Tamil Nadu, Kerala, Karnataka, Goa, Maharashtra & Gujarat, the Union Territories along the west coast & Lakshadweep Islands were issued since 11th May.
- **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 17th afternoon (0700 UTC) onwards till the system maintained the intensity of cyclonic storm.

High level briefing meetings attended by the Director General of Meteorology, India Meteorological Department:

- ❖ Meeting on impending Cyclone Scenario in Arabian Sea under the Chairmanship of Member Secretary, NDMA on 13th May and Hon'ble Cabinet secretary on 14th May.
- ❖ National Crisis Management Committee Meeting chaired by Hon'ble Prime Minister and Cabinet Secretary on 16th.
- ❖ Review Meeting under the joint Chairmanship of Hon'ble Minister of State for Ports, Shipping & Waterways (I/C), Hon'ble Minister of Commerce & Industry on 16th May.
- ❖ National Crisis Management Committee (NCMC) Meeting on 20th May.
- ❖ Frequent Press Briefings

Statistics of bulletins issued by RSMC New Delhi, Area Cyclone Warning Centre Mumbai, CWCs Thiruvananthapuram, Ahmedabad, Meteorological Centres Bengaluru & Goa in association with the ESCS Tauktae are given in **Tables 9-10.**

Table9: Bulletins issued by Cyclone Warning Division, New Delhi

S. N	Bulletin	No. of Bulletins	Issued to
1	Bulletins from DGM IMD	7	To senior level Govt. Officials including Cabinet Secretary, Principal Secretary to Prime Minister, Secretary Ministry of Home Affairs, Ministry of Agriculture, Defence, Information & Broadcasting, Ministry of Earth Sciences, Deptt. of Science & Technology, Shipping & Surface Transport, Ministry of Home Affairs, Director Punctuality, Indian Railways, Director All India Radio, Doordarshan, Secretary NDMA, Director General NDRF, Chief Secretaries of Tamilnadu, Kerala, Karnataka, Goa, Maharashtra, Gujarat, Administrator Lakshadweep Islands, Dadra & Nagar Haveli, Daman & Diu.
2	National Bulletins	41 + 1 Special message on 13th May	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, PIB MoES, Headquarter Integrated Defense Staff, Director General Doordarshan, All India Radio, National Disaster Response Force, UNI, Chief Secretary- Kerala, Karnataka, Goa, Dadra & Nagar Haveli, Gujarat and Maharashtra and Administrator Lakshadweep Islands, Dadra & Nagar Haveli, Daman & Diu.
3	RSMC Bulletins	30	1. IMD's website 2. WMO/ESCAP member countries including Somalia and WMO through GTS and E-mail.
4	GMDSS Bulletins	27	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)
5	Tropical Cyclone Advisory Centre Bulletin (Text & Graphics)	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
6	Tropical Cyclone Vital Statistics	18	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	82,80,446	SMS to disaster managers at national level and concerned states (every time when there was change in intensity)--1780 To general public to users registered with RSMC website from the states of Kerala, Karnataka, Goa, Gujarat and Maharashtra and National level disaster managers—1,39,378 Through INCOIS on Ocean State Forecast-12,53,449 To farmers of Tamilnadu, Kerala, Karnataka, Goa, Maharashtra, Gujarat, Rajasthan, Haryana, Uttar Pradesh, Uttrakhand through Kisaan Portal-68,85,839
7.	Warnings through Social Media	Daily four times and when intensity changed	Cyclone Warnings were uploaded on Social networking sites (Face book, Twitter and Whatsapp) since inception to weakening of system (every time when there was change in track, intensity and landfall characteristics)
8.	Hourly Bulletin	15	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, PIB MoES, Headquarter Integrated Defence Staff, Director General Doordarshan, All India Radio, National Disaster Response Force, UNI, Chief Secretary- Kerala, Karnataka, Goa, Dadra & Nagar Haveli, Gujarat and Maharashtra and Administrator Lakshadweep Islands.
9.	Press Release	9	Disaster Managers, Media persons by email and uploaded on website
10.	Press Briefings	Frequently	Regular briefing daily

Table3: Statistics of bulletins issued by Area Cyclone Warning Centre Mumbai, CWCs Thiruvananthapuram & Ahmedabad, Meteorological Centre Bengaluru & Goa

S.N.	Type of Bulletin	ACWC Mumbai	CWC TRV	MC BNG	MC Goa	CWC AHM
1.	Sea Area Bulletins	23	Nil	Nil	0	Nil
2.	Coastal Weather Bulletins	12	8	Nil	0	19
3.	Fishermen Warnings issued	25	16	4	22	21
4.	Port Warnings	24	8	Nil	13	21

5.	Heavy Rainfall Warning	4	12	6	9	10
6.	Gale Wind Warning	8	7	01	9	16
7.	Storm Surge Warning	8	-	Nil	5	12
8.	Information & Warning issued to State Government & other Agencies	8	25	7	22	18
9.	SMS	11552	-	469	77	-
10.	No. of Press releases	3	5	4	4	5
11.	No. of impact based warnings for District and City	5	94	1	14	11
12.	No. of whatsapp messages	All bulletins and warning communicated to concerned group	108	469	360	800
13.	No. of updates on facebook	17	57	150	32	39
14.	No. of updates on tweeter	20	38	125	48	05
15.	No. of Forecast / Warning video released	3	2	8	6	2

11. Summary

A low pressure area formed over southeast Arabian Sea & adjoining Lakshadweep area in the morning (0830 hrs IST/ 0300 UTC) of 13th May 2021. It lay as a well marked low pressure area over Lakshadweep area and adjoining southeast Arabian Sea in the same evening (1730 hours IST/1200 UTC of 13th May). Under favourable environmental conditions, it concentrated into a depression over Lakshadweep area in the morning (0830 hrs IST) of 14th May, 2021. It intensified into a deep depression over Lakshadweep area and adjoining southeast & eastcentral Arabian Sea in the same afternoon (1430 hrs IST/ 0900 UTC of 14th May) and into cyclonic storm **"TAUKTAE"** in the same midnight (2330 hrs IST/1800 UTC) over the same region.

It moved nearly northwards and intensified into a severe cyclonic storm in the evening (1730 hrs IST) of 15th May over eastcentral Arabian Sea. Continuing to move nearly northwards, it intensified into a very severe cyclonic storm over eastcentral Arabian Sea in the early hours (0230 hrs IST/2100 UTC) of 16th May over eastcentral Arabian Sea. It gradually started moving north-northwestwards from noon (1130 hours IST/0600 UTC) of 16th May and intensified rapidly into an extremely severe cyclonic storm in the early hours (0530 hrs IST/0000 UTC) of 17th May. Thereafter, it entered marginally unfavourable environment, weakened gradually and crossed Saurashtra coast near latitude 20.8°N

and longitude 71.1°E, close to northeast of Diu (about 20 km northeast of Diu) during 2000-2300 hours IST of 17th May, 2021 with maximum sustained wind speed of 160-170 kmph gusting to 185 kmph. During the landfall, the system moved slowly nearly northward, as it started recurvature in the track. After landfall, it weakened into a very severe cyclonic storm over Saurashtra in the midnight (2330 hrs IST) of 17th May.

Thereafter, it started moving north-northeastwards and weakened into a severe cyclonic storm in the forenoon (0830 hours IST) over Saurashtra and further into a cyclonic storm during noon (1130 hours IST) of 18th May, 2021 over Saurashtra and adjoining Gujarat region. Continuing to move north-northeastwards, it weakened into a deep depression over Gujarat region in the evening (1730 hrs IST) and into a depression over Gujarat region and adjoining South Rajasthan in the midnight (2330 hrs IST) of 18th May.

12. Acknowledgement:

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