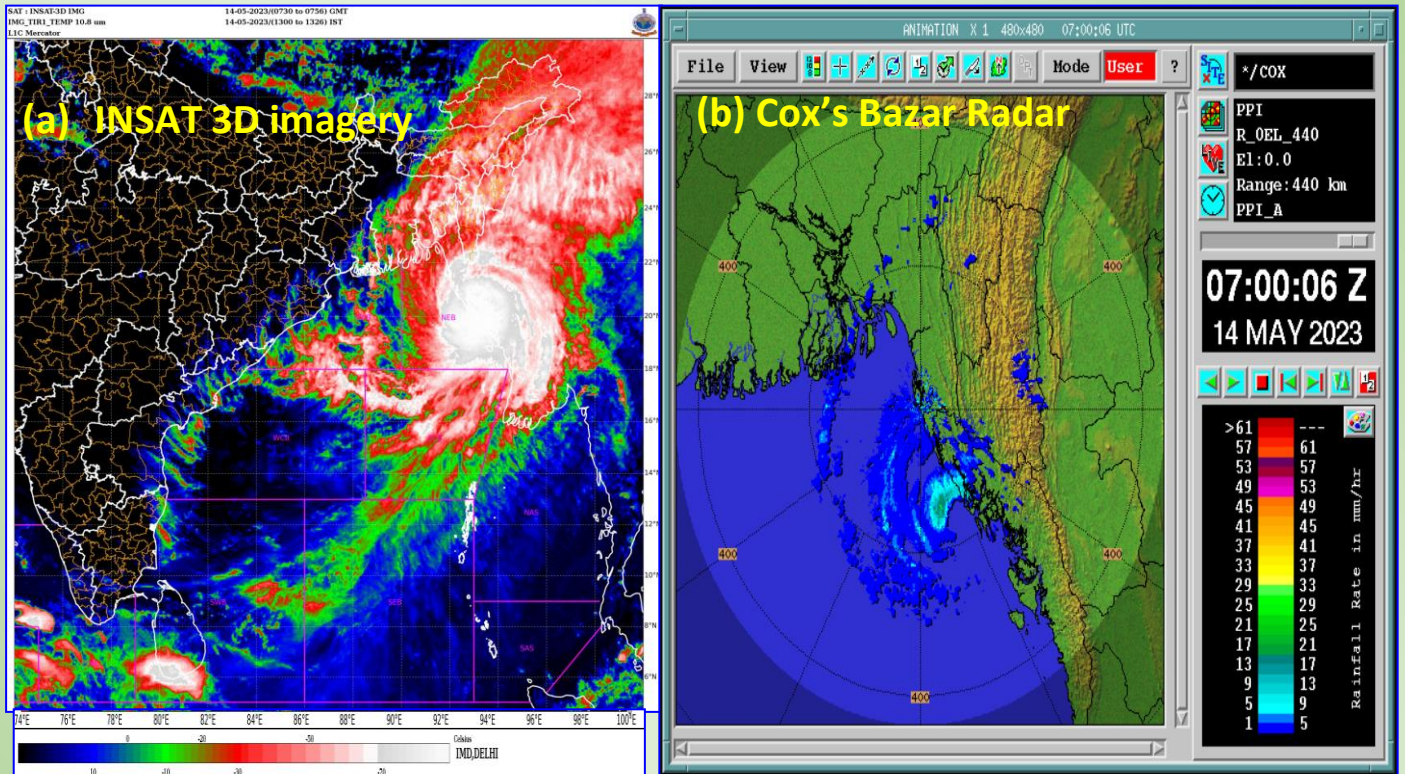




Extremely Severe Cyclonic Storm “MOCHA” over the BoB (9th-15th May, 2023): A Report



Typical (a) satellite and (b) radar imagery during landfall of extremely severe cyclonic storm “MOCHA”

Cyclone Warning Division
India Meteorological Department
New Delhi

Extremely Severe Cyclonic Storm “MOCHA” over the BoB (9th-15th May, 2023): A Report

1. Life History of “MOCHA”:

- A **Cyclonic Circulation** formed over the Southeast Bay of Bengal (BoB) and neighbourhood in the morning (0830 hrs IST/0300 UTC) of 6th May, 2023.
- Under it's influence a **Low Pressure Area** formed over southeast BoB and adjoining south Andaman Sea in the morning (0830 hrs IST/0300 UTC) of 8th May 2023.
- It lay as a **Well Marked Low pressure Area (WML)** over the same region in the early morning (0530 hrs IST/0000 UTC) of 9th May 2023.
- It concentrated into a **Depression** in the same evening (1730 hrs IST/1200 UTC) over Southeast BoB and lay centred at about 510 km southwest of Port Blair.
- It initially moved west-northwestwards and intensified into a **Deep Depression (DD)** in the early morning (0530 hrs IST/0000 UTC) of 10th May 2023 over southeast BoB and lay centred at about 540 km west-southwest of Port Blair.
- Thereafter, it moved north-northwestwards and intensified into a **Cyclonic Storm (CS)** “Mocha” pronounced as “Mokha” in the early morning (0530 hrs IST/0000 UTC) of 11th May 2023 over southeast BoB.
- From 11th morning (0830 hrs IST/0300 UTC), it started moving northwards and intensified into a **Severe Cyclonic Storm (SCS)** in the evening (1730 hrs IST/ 1200 UTC) of 11th May over the same region.
- Thereafter, it gradually started recurving north-northeastwards and intensified into a **Very Severe Cyclonic Storm (VSCS)** in the early morning (0530 hrs IST/0000 UTC) of 12th May over central BoB.
- Moving further north-northeastwards, it intensified into an **Extremely Severe Cyclonic Storm (ESCS)** in the midnight (2330 hrs IST/ 1800 UTC of 12th May) over eastcentral BoB.
- Continuing to move north-northeastwards, it intensified further till early morning of 14th May. The peak intensity was 210-220 kmph gusting to 240 kmph over the eastcentral BoB from 13th midnight to 14th early morning.
- It then slightly weakened and **crossed north Myanmar-southeast Bangladesh coasts between** Kyaukpyu (Myanmar) and Cox's Bazar (Bangladesh) close to north of Sittwe (Myanmar) near latitude 20.3°N and longitude 92.8°E as an ESCS with maximum sustained wind speed (MSW) of 180-190 kmph gusting to 210 kmph during 1230 to 1430 hours IST of (0700 UTC to 0900 UTC) of 14th May.
- Thereafter, continuing to move north-northeastwards with a very fast speed, it weakened into a VSCS over westcentral Myanmar in the evening (1730 hrs IST/ 1200 UTC), SCS over the same region in the night (2030 hrs IST/ 1500 UTC) of 14th and further into a CS over westcentral & adjoining northwest Myanmar in the early morning of 15th May (0230 hrs IST of 15th/ 2100 UTC of 14th).
- Thereafter, it moved west-northwestwards and rapidly weakened into a depression over northwest Myanmar in the morning (0530 hrs IST/ 0000 UTC) of 15th May.
- The observed track of the system is presented in Fig. 1. The best track parameters associated with the system are presented in Table 1.

Table1: Best track positions and other parameters of the Extremely Severe Cyclonic Storm MOCHA over BoB during 09th – 15th May, 2023

Date	Time (UTC)	Lat.	Long.	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimated Pressure drop at the Centre (hPa)	Grade	
09.05.23	1200	8.3	89.5	1.5	1002	25	3	D	
	1800	8.5	89.3	1.5	1002	25	3	D	
10.05.23	0000	8.5	89.0	2.0	1000	30	4	DD	
	0300	8.8	88.9	2.0	1000	30	4	DD	
	0600	9.1	88.7	2.0	999	30	4	DD	
	1200	10.0	88.4	2.0	998	30	5	DD	
	1800	10.8	88.2	2.0	998	30	5	DD	
11.05.23	0000	11.2	88.1	2.5	997	35	6	CS	
	0300	11.4	88.0	2.5	996	35	7	CS	
	0600	11.6	88.0	3.0	996	45	10	CS	
	0900	11.8	88.0	3.0	996	45	10	CS	
	1200	12.2	88.0	3.0	994	50	12	SCS	
	1500	12.5	88.1	3.5	992	50	12	SCS	
	1800	12.7	88.1	3.5	992	50	12	SCS	
12.05.23	2100	12.9	88.1	3.5	986	60	18	SCS	
	0000	13.2	88.1	4.0	982	65	22	VSCS	
	0300	13.6	88.2	4.0	982	65	22	VSCS	
	0600	14.0	88.3	4.5	974	75	30	VSCS	
	0900	14.3	88.4	4.5	974	75	30	VSCS	
	1200	14.6	88.6	4.5	972	80	32	VSCS	
	1500	14.8	88.7	5.0	970	85	34	VSCS	
	1800	15.1	88.8	5.5	964	90	40	ESCS	
13.05.23	2100	15.2	88.9	5.5	964	90	40	ESCS	
	0000	15.4	89.1	5.5	952	100	52	ESCS	
	0300	15.7	89.5	5.5	952	100	52	ESCS	
	0600	16.0	90.0	5.5	950	105	54	ESCS	
	0900	16.4	90.3	5.5	950	105	54	ESCS	
	1200	16.9	90.8	6.0	944	110	60	ESCS	
	1500	17.4	90.9	6.0	944	110	60	ESCS	
	1800	17.9	91.0	6.0	938	115	66	ESCS	
14.05.23	2100	18.3	91.3	6.0	938	115	66	ESCS	
	0000	18.7	91.5	6.0	938	115	66	ESCS	
	0300	19.3	91.9	6.0	944	110	60	ESCS	
	0600	19.9	92.5	5.5	952	100	52	ESCS	
		Crossed North Myanmar – Southeast Bangladesh coasts between KYAUKPYU (Myanmar) and Cox's Bazar (Bangladesh) close to North of Sittwe (Myanmar) near latitude 20.3 and longitude 92.8 with maximum sustained wind speed 180-190 kmph gusting to 210 kmph during 0700-0900 UTC (1230-1430 hrs IST).							
	0900	20.5	92.9	-	964	90	40	ESCS	
	1200	21.1	93.3	-	974	75	30	VSCS	
	1500	21.8	93.8	-	984	60	18	SCS	
	1800	22.7	94.6	-	992	50	12	SCS	
	2100	23.5	95.3	-	996	35	6	CS	
15.05.23	0000	23.9	97.8	-	1000	25	3	D	
	0300	Weakened into a well-marked low pressure area over Northeast Myanmar and Neighborhood							

2. Salient Features

- (i) It was the first cyclonic storm of the year 2023.
- (ii) It crossed Myanmar coast with MSW of 100 knots (180-190 kmph gusting to 210 kmph) on 14th May.
- (iii) Climatologically, about 200 cyclonic storms (MSW \geq 62 kmph) developed over the BoB (**Fig. 2a**) during 1965-2022. Out of these 61 crossed Bangladesh and Myanmar coasts during the period (**Fig. 2b**).
- (iv) During recent years, last ESCS that crossed Myanmar coast was “ESCS GIRI” with MSW of 105 knots on 22nd October, 2010 and “ESCS Nargis”, with MSW of 90 knots on 2nd May, 2008.
- (v) The most intense storm over the BoB was the 1999 Odisha Super Cyclone with peak MSW of 140 knots as per recorded history of IMD, since 1891. It is followed by Super Cyclonic Storms in Nov.1989, May 1990, April 1991 & Amphan May 2020 with peak MSW of 130 knots and Nov.1977 Super Cyclone with peak MSW of 125 knots. ESCS FANI (May, 2019) had peak MSW of 115 knots. Thus, neither “MOCHA” nor “FANI” were the most intense cyclonic storm over the BoB.

(vi) Recurving track:

“MOCHA” exhibited multiple recurvatures in its track. Initially, it moved westwards till 9th midnight (2330 hrs IST/1800 UTC) followed by west-northwestwards movement till 10th evening (1730 hours IST/ 1200 UTC) along the periphery of anticyclone located over the eastcentral BoB and the ridge ran near latitude 15°N. It then followed north-northwestwards track till 11th morning (0830 hrs IST/0300 UTC), under the influence of anticyclonic circulation over South Andaman Sea. Thereafter, it moved nearly northwards till 11th midnight (2330 hrs IST/1800 UTC) under the influence of deep trough in westerlies and anticyclone over central Andaman Sea. It then moved north-northeastwards till 14th midnight (2330 hrs IST/1800 UTC) and east-northeastwards over Myanmar thereafter under the influence of the trough in westerlies lying to the left of the system in middle and upper tropospheric levels. (**Fig.1**).

(vii) Rapid intensification and rapid weakening:

This system exhibited unique feature in terms of its intensification. It encountered Rapid Intensification (RI) process on 11th and 12 May 2023. The maximum sustained wind speed (MSW) increased from 35 kts at 0530 hrs IST/0000 UTC of 11th to 65 kts at 0530 hrs IST of 12th and further to 100 kts at 0530 hrs IST of 13th May. Thus, MSW increased by 65 knots in 48 hours ending at 0530 hrs IST of 13th May. It was mainly because of low vertical wind shear, higher sea surface temperature, higher ocean heat content and increased warm moist air incursion in the core of system over the central BoB. Also a westerly trough in the upper levels provided strong divergence in the upper tropospheric levels accompanied with divergence due to anticyclone lying to the east or southeast of system centre. From 14th morning, “MOCHA” weakened slightly as it entered into an area with relatively low SST and dry air incursion from Indian landmass into the southern sector. After landfall, it weakened rapidly from the evening of 14th due to very high friction from land terrain of Myanmar, significant moisture cut off, and higher vertical wind shear of 40-50 knots.

(viii) Maximum sustained wind speed and estimated central pressure:

The system reached its peak intensity of 115 knots at 1800 UTC of 13th May and maintained its peak intensity till 0000 UTC of 14th May. The estimated central pressure during this period was 938 hPa with pressure drop of about 66 hPa.

3. Monitoring of Cyclonic Storm, “MOCHA”

India Meteorological Department (IMD) maintained round the clock watch over the north Indian Ocean and the cyclone was monitored since 27th April, about 12 days prior to formation of depression on 9th and 17 days prior to the landfall of system over Myanmar-Bangladesh coasts. The information about the system was first released in the weekly extended range outlook issued by IMD on 27th April (**Fig. 3a**), indicating formation of depression over southeast BoB during the week 2 (5-11 May, around 9th May with low probability (1-33%). Further, the extended range outlook issued on 4th May (**Fig. 3b**), indicated formation of depression around 9th May with high probability (68-100%) about 5 days in advance of formation of depression and forecast path was also indicated with landfall towards Myanmar-Bangladesh coasts about 12 days ahead of landfall over Myanmar-Bangladesh coasts.

The cyclone was monitored with the help of available satellite observations from INSAT 3D and 3DR, SCAT SAT, ASCAT, microwave imageries, available ships & buoy observations in the region, Doppler Weather Radar (DWR) at Cox's Bazar and Kyaukpyu. Various global models and dynamical-statistical models run by Ministry of Earth Sciences (MoES) institutions including IMD, NCMRWF, IITM & INCOIS and guidance from models from various international agencies under bilateral arrangement and cyclone specific Hurricane Weather Research Forecast (HWRF) model were utilized to predict the genesis, track, landfall and intensity of the cyclone as well as associated severe weather. The forecasts were mainly based on multi-model ensemble technique developed by IMD. A digitized forecasting system of IMD was utilized for analysis and comparison of various observations and numerical weather prediction models guidance, decision making process and warning products generation. Typical satellite based imageries from INSAT 3D (R) and radar imagery from Cox's Bazar are presented in **Fig.4**. The INSAT 3D imageries during entire life cycle of the system and Cox's Bazar imageries on the day of landfall are placed in Annexure to this report.

4. Operational Forecast Performance:

i) Pre-Genesis Forecast performance

- ❖ First information about likely cyclogenesis over southeast BoB and adjoining Andaman Sea during the week (5th-11th May), around 9th May was issued in the extended range outlook issued on 27th April with low probability (1-33%) of occurrence.
- ❖ Subsequent information about likely cyclogenesis over southeast BoB and adjoining Andaman Sea was issued in the extended range outlook issued on 4th May. It indicated that during later half of week 5th -11th May (around 9th May) there would be formation of depression over southeast BoB and adjoining Andaman Sea with high probability (67-100%)
- ❖ First information about formation of cyclonic circulation over southeast BoB around 6th May and low pressure area around 8th May was issued in the daily weather bulletins issued on 2nd May.
- ❖ On 3rd May, the update issued indicated that the low pressure area would concentrate into a depression during 8th-9th. The regular update also indicated further intensification of the system and nearly northwards movement towards central BoB.

- ❖ **On 4th May, it was indicated that the system would intensify into a cyclonic storm (about 7 days prior to formation of cyclonic storm “MOCHA” at 0530 hrs IST/0000 UTC of 11th May), at a stage when even cyclonic circulation had not formed.**
- ❖ On 5th May, the daily update indicated that the low pressure area would form around 8th May and depression around 9th May. Further intensification into a cyclonic storm and movement of the system towards central BoB was also indicated.
- ❖ **On 8th May, on formation of low pressure area, IMD issued first pre-genesis track forecast indicating that the system would move initially north-northwestwards till 11th and thereafter recurve north-northeastwards towards Bangladesh-Myanmar coasts.**
- ❖ The pre-genesis track forecast issued on 9th May indicated the movement of the system towards Myanmar (**Fig. 5**).
- ❖ Actually, low pressure area formed over southeast BoB & adjoining South Andaman Sea on 8th May, depression over southeast BoB on 9th May, CS over southeast BoB on 11th May and landfall occurred over Myanmar and adjoining Bangladesh coast on 14th May.

ii) Operational track, intensity and landfall forecast performance

- ❖ The first advisory issued on formation of depression indicated landfall over North Myanmar – Southeast Bangladesh coast around 14th May noon (**about 90 hours prior to landfall**).
- ❖ Typical track and intensity forecast issued on 11th May demonstrating the accuracy in track and landfall prediction is presented in **Fig. 6**.
- ❖ The track forecast errors for 24, 48 and 72 hrs lead period were 53, 68 and 78 km respectively against the long period average (LPA) errors (2018-22) of 74, 112, and 153 km respectively (**Fig. 7a**). For all lead periods upto 120 hours, the operational track forecast errors were exceptionally less as compared to LPA errors.
- ❖ The absolute error (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 9.8, 15.0 and 20.9 knots against the LPA errors of 7.4, 10.5 and 14.0 knots during 2018-22 respectively (**Fig.7b**). The intensity forecast errors were higher than LPA as the impact of approaching trough in westerly that provided favourable environment for rapid intensification of the system could not be captured by the models.
- ❖ The landfall point forecast errors for 24, 48 and 72 hrs lead period were zero, 11.0, 11.0 km respectively against the LPA errors (2018-22) of 26.2, 39.9 and 75.7 km during 2018-22 respectively (**Fig.8a**). **There was almost zero error in landfall point forecast for all lead periods upto 96 hrs.**
- ❖ The landfall time forecast errors for 24, 48 and 72 hrs lead period were 1.5, 1.5 and 2.0 hours respectively against the LPA errors (2018-22) of 2.8, 4.5 and 8.0 hours during 2018-22 respectively (**Fig.8b**). **For all lead periods upto 96 hrs, the landfall time errors were appreciably less than LPA errors.**

7. Warnings and advisories issued

Bulletins issued by Cyclone Warning Division, New Delhi

- **Track, intensity and landfall forecast:** IMD continuously monitored, predicted and issued bulletins containing track, intensity, and landfall forecast for +06, +12, +18, +24, +36 and

+48... +120 hrs lead period commencing from 8th May till the system weakened into an LPA. The above forecasts were issued from the stage of low pressure area along with the cone of uncertainty in the track forecast once daily, five times a day during depression and every three hours during the cyclone period.

- **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 alongwith cone graphics, commencing from 8th May.
- **Adverse weather warning bulletins:** The tropical cyclone forecasts alongwith expected adverse weather like gale wind, state of sea and heavy rainfall for northeastern states of India were issued with every six/three hourly update to central, state and district level disaster management agencies including Ministry of Home Affairs (MHA), National Disaster Response Force (NDRF), National Disaster Management Agency (NDMA) for all concerned states along the east coast of India including Andaman & Nicobar Islands, Tamil Nadu, Puducherry, Andhra Pradesh, West Bengal, Odisha, Mizoram, Manipur, Tripura and Assam. The bulletins also contained the suggested action for disaster managers and general public in particular for fishermen, ports and off & along shore activities. These bulletins were also issued to Defence including Indian Navy & Indian Air Force, NDRF, Indian Coast 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 wind & fishermen warnings were also presented in graphics alongwith colour codes in the website.
- **Warnings and advisories 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.
- **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 Kolkata and Area Cyclone Warning Centre at Chennai, Cyclone warning centres at Visakhapatnam and Bhubaneswar to ports, fishermen, coastal and high sea shipping community.
- **Fishermen Warning:** Regular warnings for fishermen for deep Sea of Bay of Bengal were issued since 3rd 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.

- **Director General of Meteorology** addressed media through press conference thrice in connection with this cyclone on 28th April, 3rd May and 8th May. The press briefings were conducted in hybrid mode and WMO/ESCAP Panel member countries including Bangladesh and Myanmar participated in the press conference.

Statistics of bulletins issued by Cyclone Warning Division, RSMC New Delhi and Meteorological Office Port Blair in association with the ESCS MOCHA are given in **Table 4-5**.

Table 4: Bulletins issued by Cyclone Warning Division, New Delhi

S.No	Bulletin type	No. of Bulletins	Issued to
1	National Bulletin	41	1. IMD's website, RSMC New Delhi website 2. FAX and e-mail to Control Room Ministry of Home Affairs & National Disaster Management Authority, Cabinet Secretariat, Minister of Science & Technology, Secretary MOES, Headquarter Integrated Defence Staff, Director General Doordarshan, All India Radio, PIB MOES, DG National Disaster Response Force, Director, Punctuality, Indian Railways, Chief Secretary: Government of Andaman & Nicobar Islands, Tamil Nadu, Puducherry, Andhra Pradesh, West Bengal, Odisha, Mizoram, Manipur, Tripura and Assam.
2.	Special Message	2	1. IMD's website, RSMC New Delhi website 2. FAX and e-mail to Control Room Ministry of Home Affairs & National Disaster Management Authority, Cabinet Secretariat, Minister of Science & Technology, Secretary MOES, Headquarter Integrated Defence Staff, Director General Doordarshan, All India Radio, PIB MOES, DG National Disaster Response Force, Director, Punctuality, Indian Railways, Chief Secretary: Government of Andaman & Nicobar Islands, Tamil Nadu, Puducherry, Andhra Pradesh, West Bengal, Odisha, Mizoram, Manipur, Tripura and Assam.
3.	Hourly bulletins on the day of landfall	3	1. IMD's website, RSMC New Delhi website 2. FAX and e-mail to Control Room Ministry of Home Affairs & National Disaster Management Authority, Cabinet Secretariat, Minister of Science & Technology, Secretary MOES, Headquarter Integrated Defence Staff, Director General Doordarshan, All India Radio, PIB MOES, DG National Disaster Response Force, Director, Punctuality, Indian Railways, Chief Secretary: Government of Andaman & Nicobar Islands, Tamil Nadu & Puducherry, Andhra Pradesh, West Bengal, Odisha, Mizoram, Manipur, Tripura and Assam. 3. WMO/ESCAP Panel member countries including Myanmar and Bangladesh
4	RSMC Bulletin	41 + 5 tropical weather outlooks	1. IMD's website 2. WMO/ESCAP member countries through GTS and E-mail.
5	GMDSS Bulletins	28	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)
6	Tropical Cyclone Advisory Centre Bulletin	22	1. Met Watch offices in Asia Pacific regions and middle east through GTS to issue Significant Meteorological information for International Civil Aviation 2. WMO's Aviation Disaster Risk Reduction (ADRR), Hong Kong through ftp

			3. RSMC website
7	Tropical Cyclone Vital Statistics	24	Modelling group of IMD, National Centre for Medium Range Weather Forecasting Centre (NCMRWF), Indian National Centre for Ocean Information Services (INCOIS), Indian Institute of Tropical Meteorology (IITM), Indian Institute of Technology (IIT) Delhi & Bhubaneswar etc.
8	Warnings through Social Media	6 hourly (depression stage)/3 hourly (cyclonic storm stage) /hourly (landfall day)	Cyclone Warnings were uploaded on Social networking sites (Facebook and Tweeter) since inception to weakening of system (every time when there was change in track, intensity and landfall characteristics).
9	Press Release	9 (4 th to 15 th May)	Disaster Managers, Media persons by email and uploaded on website
10	Press Briefings	Frequently	Regular briefing daily
11	Bulletins for offshore industries	41	6 hourly during depression and 3 hourly during cyclonic storm by email to offshore industries, Directorate General of Hydrocarbons, Coast Guard
12	SMS	Frequently	General public and disaster managers registered through RSMC website
13	Whatsapp Messages	6 hourly (depression stage)/3 hourly (cyclonic storm stage) /hourly (landfall day)	To Disaster management group, Media Group, WMO and WMO/ESCAP Panel member countries group and Offshore industries group.

Bulletins issued by Area Cyclone Warning Centres (ACWCs) Kolkata (KOL) & Chennai (CHN), Cyclone Warning Centres (CWCs) Bhubaneswar (BBN) & Visakhapatnam (VSK) and Meteorological Office (MO) Port Blair:

S.N.	Type of bulletin	ACWC CHN	ACWC KOL	CWC BBN	CWC VSK	MO Port Blair
1.	Sea Area Bulletin	-	8	-	-	
2.	Coastal Weather Bulletin	6	8	6	6	-
3.	Port warnings	10	10	10	10	-
4.	Special Message to disaster management agencies	-	-	-	-	18
5.	Meetings	-	-	-	-	Once on 10 th May with Chief Secretary Andaman & Nicobar Islands
6.	CAP SACHET Message	-	-	-	-	17

8. Realized Weather

As per report from Department of Meteorology and Hydrology (DMH), Myanmar, Sittwe reported MSW of 120 mph (105 knots, 195 kmph) and Pauktaw & Myebon stations reported MSW of 100-120 mph (85-105 knots, 160-190 kmph) during 0700-0900 UTC. IMD predicted "MOCHA" to cross

Myanmar close to Sittwe with MSW of 180-190 gusting 210 kmph during 0600-0900 UTC on 14th May. The estimated MSW during the life cycle of ESCS MOCHA is presented in **Fig. 9**.

The realised storm surge as reported by DMH, Myanmar was 5-10 feet (1.5-3.0m) along Myanmar coast near landfall. IMD predicted storm surge of height about 3.0-3.5m above astronomical tide. **Thus, the forecast genesis, track, landfall time, landfall point and associated surge were predicted very accurately with sufficient lead time.**

9. Damage report

As per media reports from Myanmar (Associated Press Television News, 19th May), the ESCS MOCHA caused 145 deaths in Myanmar. It caused widespread flash floods and power outages, extensive damage to buildings, cell phone towers, trees etc. in Myanmar. Some damage photographs are placed at **Fig. 10**. The adjoining areas of southeast Bangladesh also received the impact of "MOCHA". Many houses were damaged and trees fell because of strong winds and heavy rainfall. However no death was reported from Bangladesh. Some associated damage photographs from Bangladesh are presented in **Fig. 11**. In India, No damage has been reported from Andaman & Nicobar Islands. However, Mizoram state received the burnt from "ESCS MOCHA". Three deaths were reported from Mizoram due to landslides caused by heavy rain and strong winds over Mizoram. Associated damage reports are presented in **Fig. 12**.

10. Acknowledgements:

India Meteorological Department (IMD) and RSMC New Delhi duly acknowledge contribution from WMO and WMO/ESCAP member countries including Myanmar and Bangladesh for sharing hourly observations, imageries from Cox's bazaar Radar and Kyaukpyu. IMD and RSMC New Delhi also acknowledge the contribution from all the stake holders and disaster management agencies who contributed to the successful monitoring, prediction and early warning service of ESCS MOCHA. We acknowledge the contribution of all sister organisations of Ministry of Earth Sciences including National Centre for Medium Range Weather Forecasting Centre (NCMRWF), Indian National Centre for Ocean Information Services (INCOIS), National Institute of Ocean Technology (NIOT), Indian Institute of Tropical Meteorology (IITM) Pune. The support from various Divisions/Sections of IMD including Area Cyclone Warning Centre (ACWC) Kolkata & Chennai, Cyclone Warning Centre Bhubaneswar & Visakhapatnam, Meteorological Office Port Blair. The contribution from Numerical Weather Prediction Division, Satellite and Radar Division, Surface & Upper air instruments Divisions, New Delhi and Information System and Services Division at IMD is also duly acknowledged.

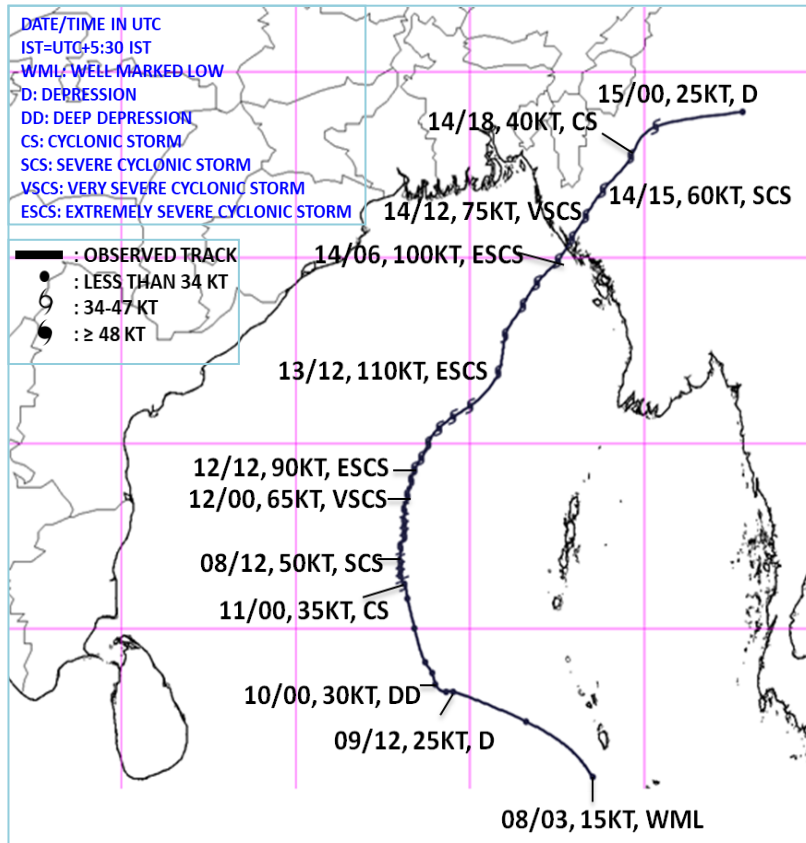


Fig. 1: Observed track of extremely severe cyclonic storm ‘MOCHA’ over the BoB during 9th-14th May, 2023

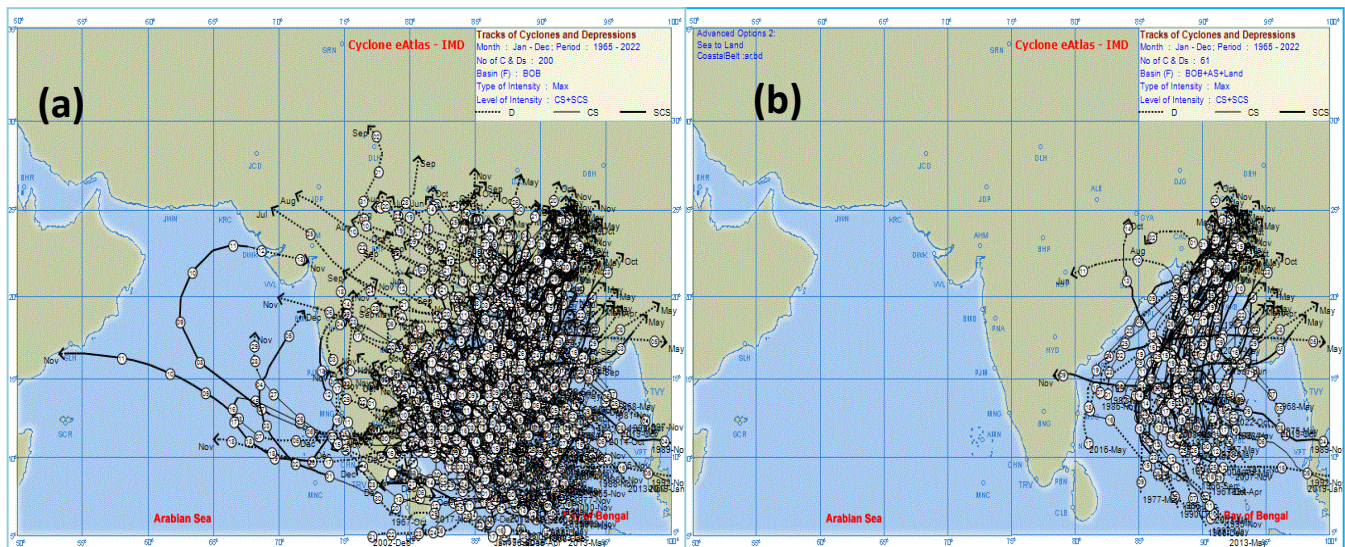


Fig.2: Climatological tracks of (a) all cyclones (MSW \geq 62 kmph) developing over Bay of Bengal and (b) cyclonic storms (MSW \geq 62 kmph) crossing Bangladesh & Myanmar coasts during satellite era (1965-2022)

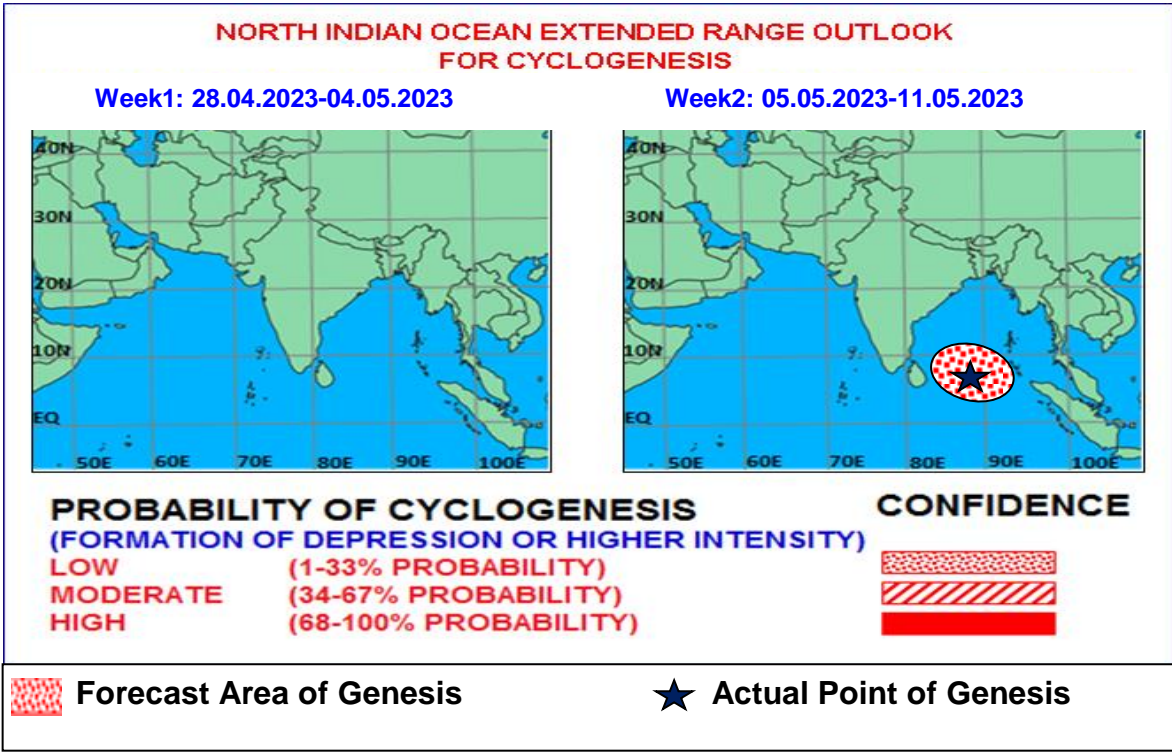


Fig.3a: Extended range outlook issued on 27th April, 12 days prior to formation of depression on 9th May

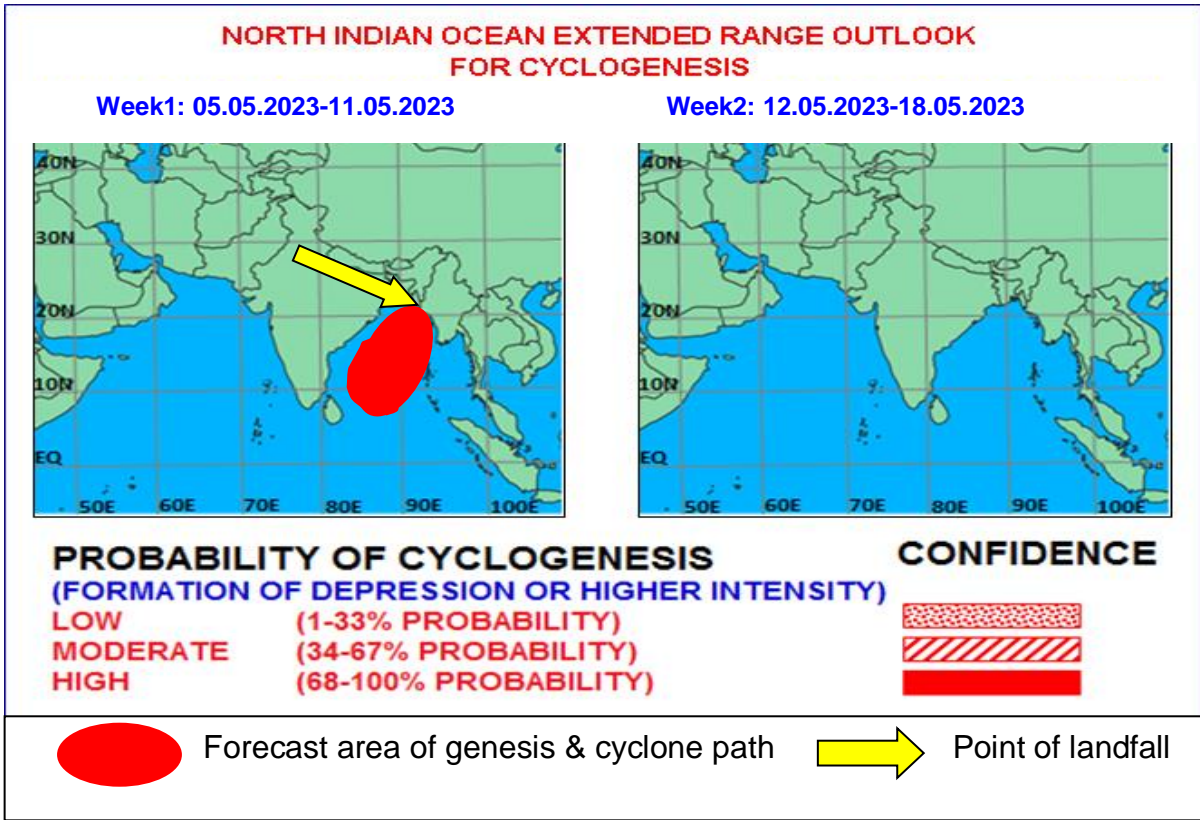


Fig.3b: Extended range outlook issued on 4th May, 5 days prior to formation of depression on 9th May and about 10 days prior to landfall over Myanmar-Bangladesh coasts

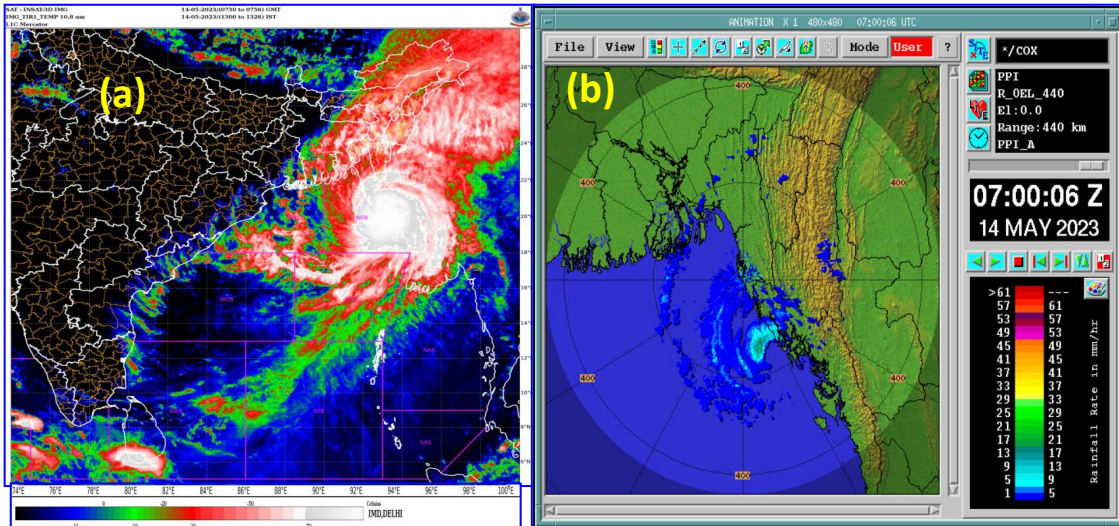
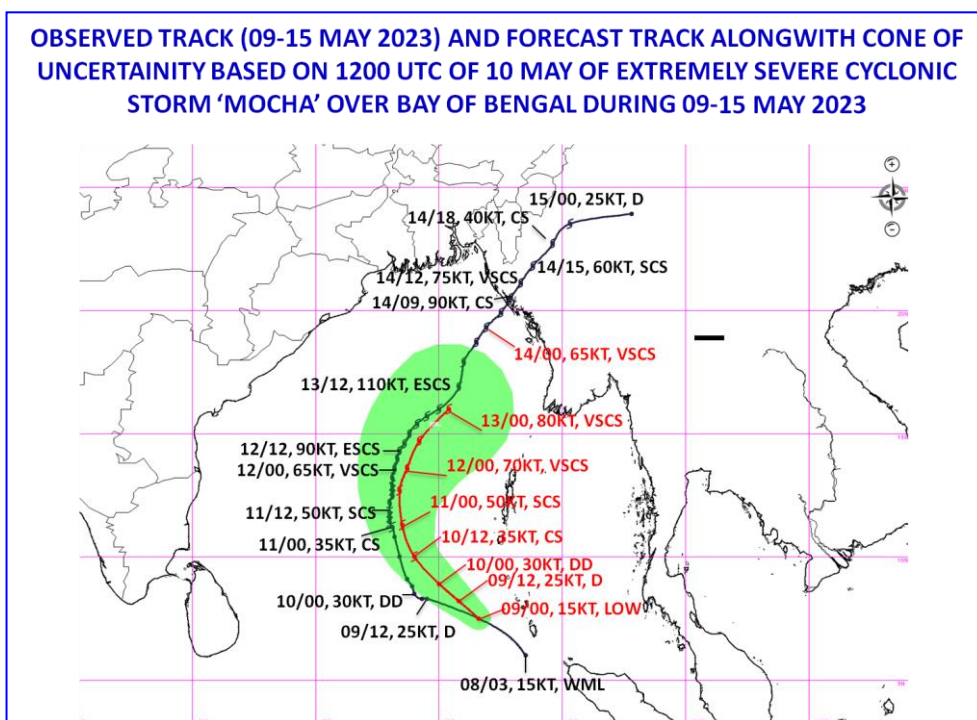


Fig.4: (a) Typical INSAT 3D (R) and (b) Cox's Bazar Radar imagery



D: DEPRESSION, DD: DEEP DEPRESSION, CS: CYCLONIC STORM, SCS: SEVERE CS, VSCS: VERY SEVERE CS, ESCS: EXTREMELY SEVERE CS, SUCS: SUPER CS

- OBSERVED TRACK
- FORECAST TRACK
- CONE OF UNCERTAINTY
- : LESS THAN 34 KT
- : 34-47 KT
- : \geq 48 KT

Fig.5: Pre-genesis track and intensity forecast issued on 9th May morning at the stage of well marked low pressure area

OBSERVED TRACK & FORECAST TRACK BASED ON 0300 UTC OF 11TH MAY (77 HRS PRIOR TO LANDFALL) INDICATING ACCURACY IN TRACK AND LANDFALL FORECAST

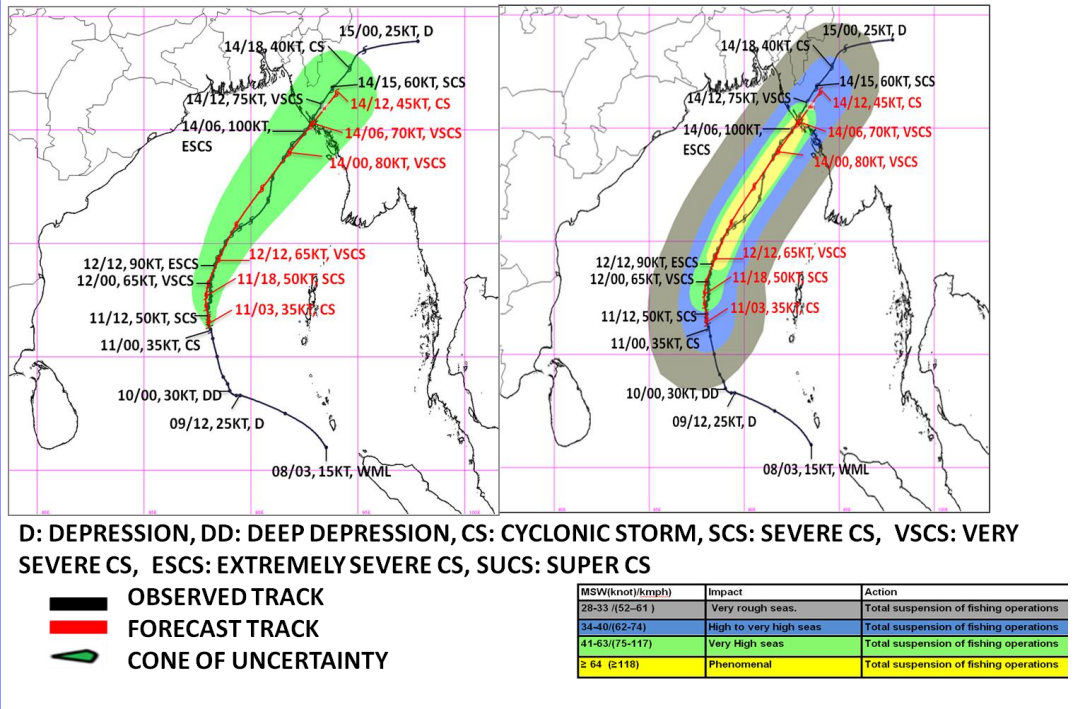


Fig.6: Typical track and intensity forecast issued on 11th May morning demonstrating accuracy in track and landfall prediction (about 77 hours prior to landfall)

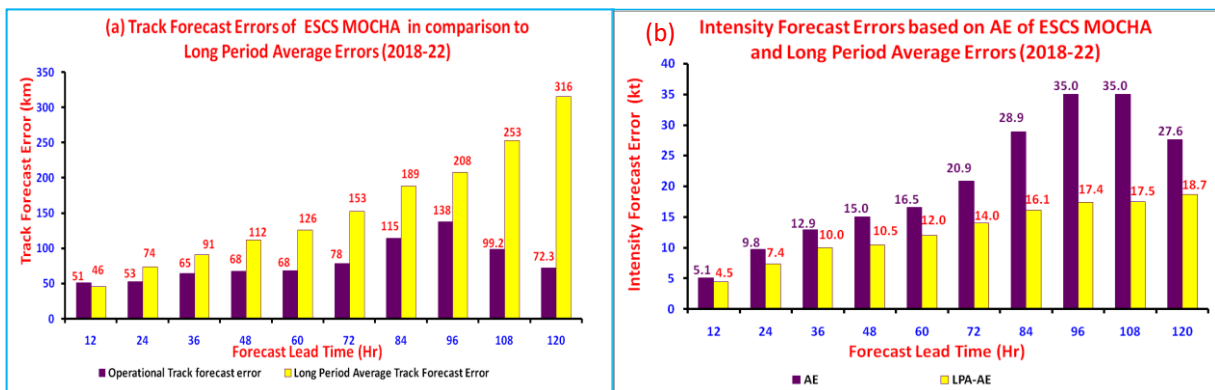


Fig.7: Operational (a) track and (b) intensity forecast errors compared to long period average (LPA) during 2018-22

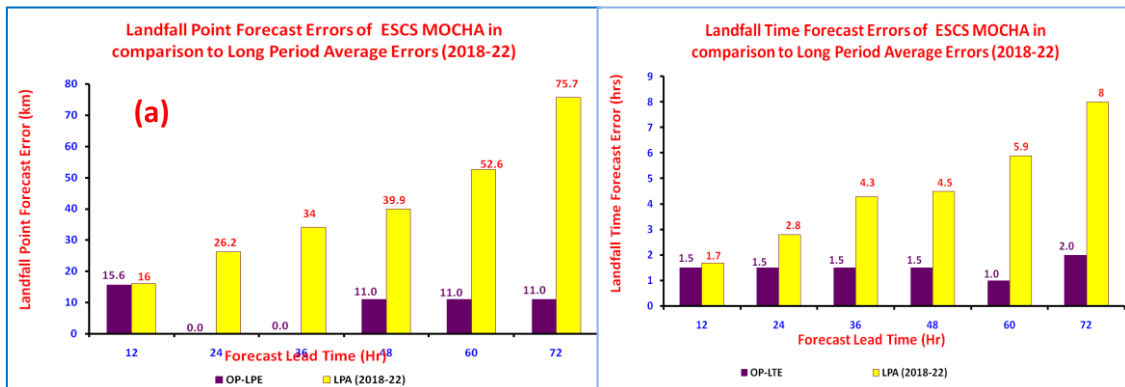


Fig.8: Operational landfall (a) point and (b) time forecast errors compared to long period average (LPA) during 2018-22

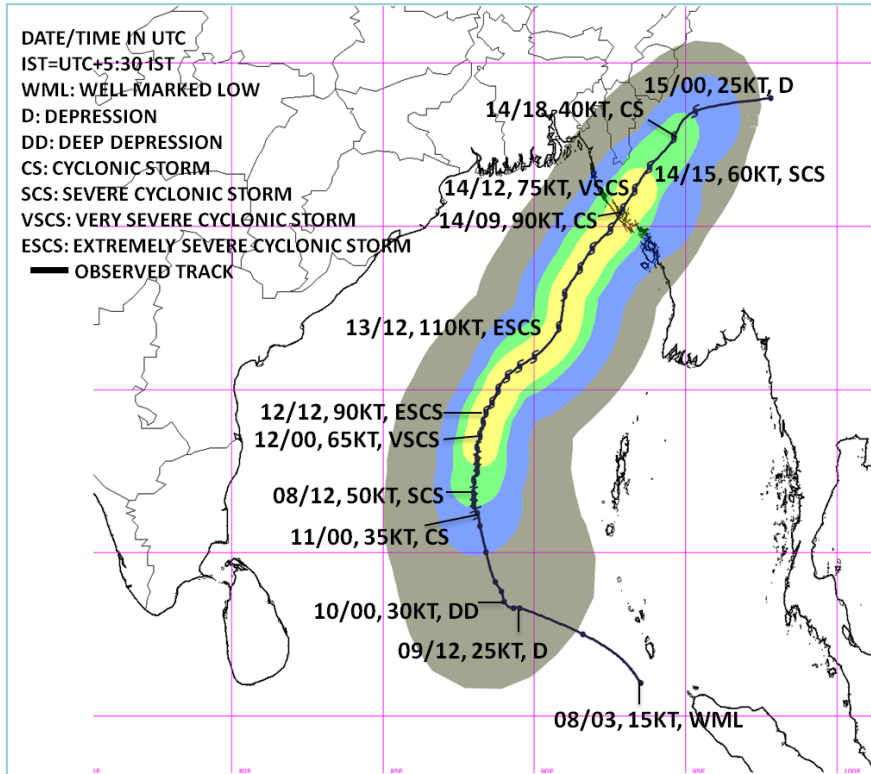


Fig.9: The estimated maximum sustained wind speed in association with ESCS MOCHA during 9th-14th May.



Fig. 10: (a) Extensive damage to huts in Rakhine state of Myanmar (PBS News Hour, 18 May), (b) Collapsed roof tops, Rakhine (AP Television News, 19 May), (c) damaged houses at Basra camp, Sittwe, Myanmar (Radio Free Asia, 16 May) and (d)damaged buildings & trees in Rakhine, Myanmar (Radio Free Asia, 15 May)



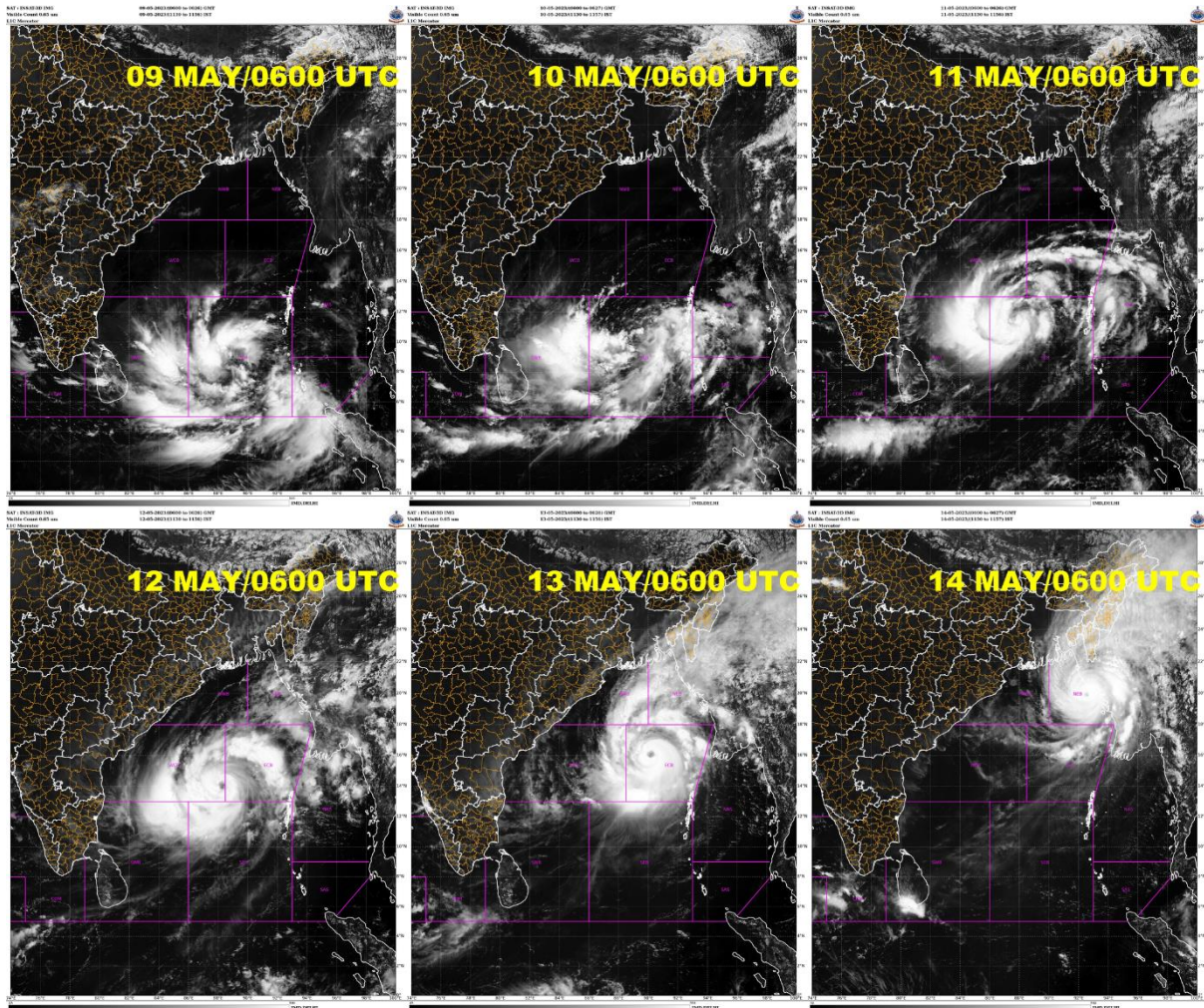
Fig. 11: (a) Damaged home at Saint Martin Island in Cox's Bazar, Bangladesh (Euro News Green, 16 May), (b) Rescue workers clearing roads in Teknaf (Nagaland Post, 24 May)



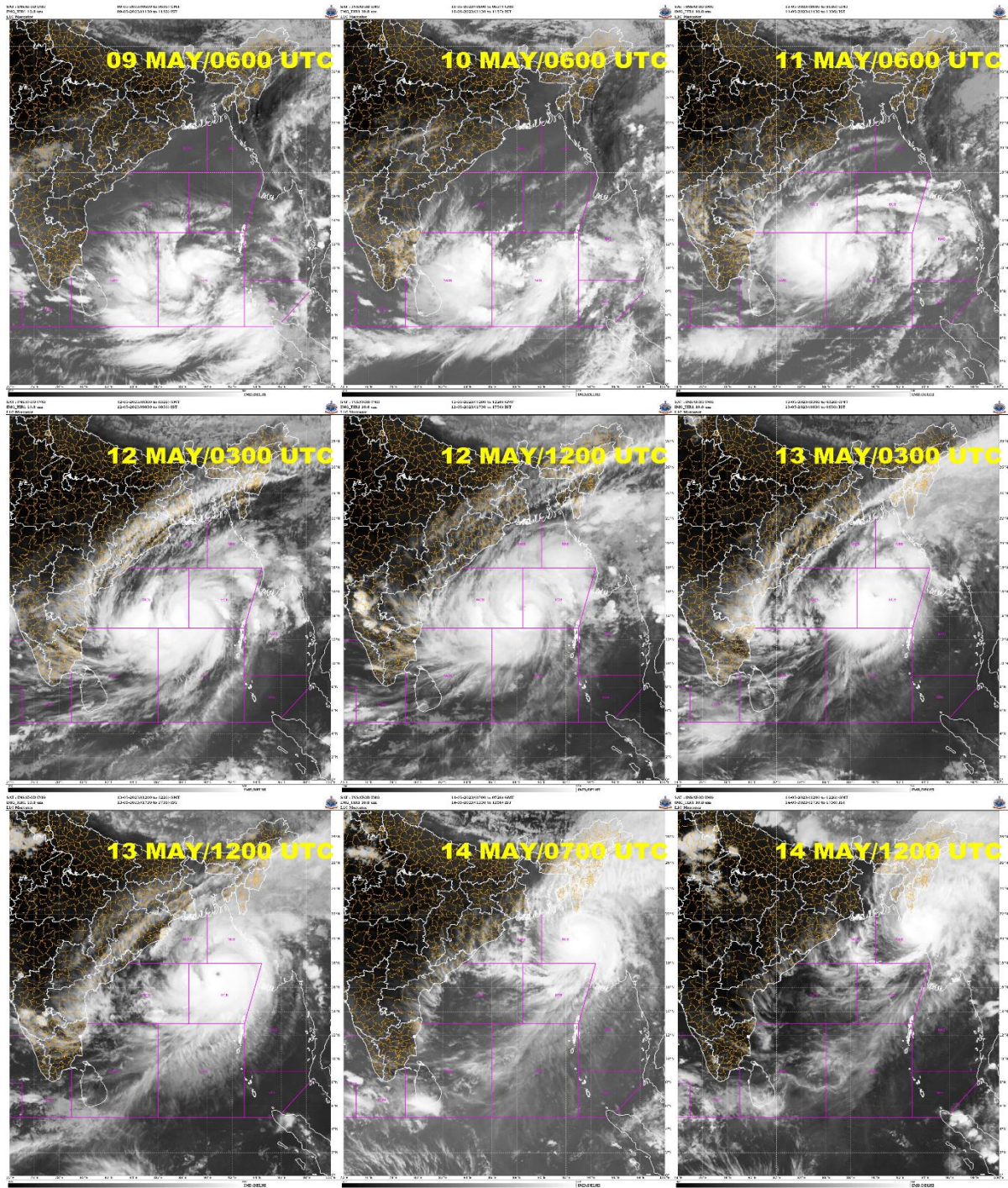
Fig. 12: (a) Damaged house in Mizoram and (b) Fallen trees (Hindustan Times, 16 May)

ANNEXURE

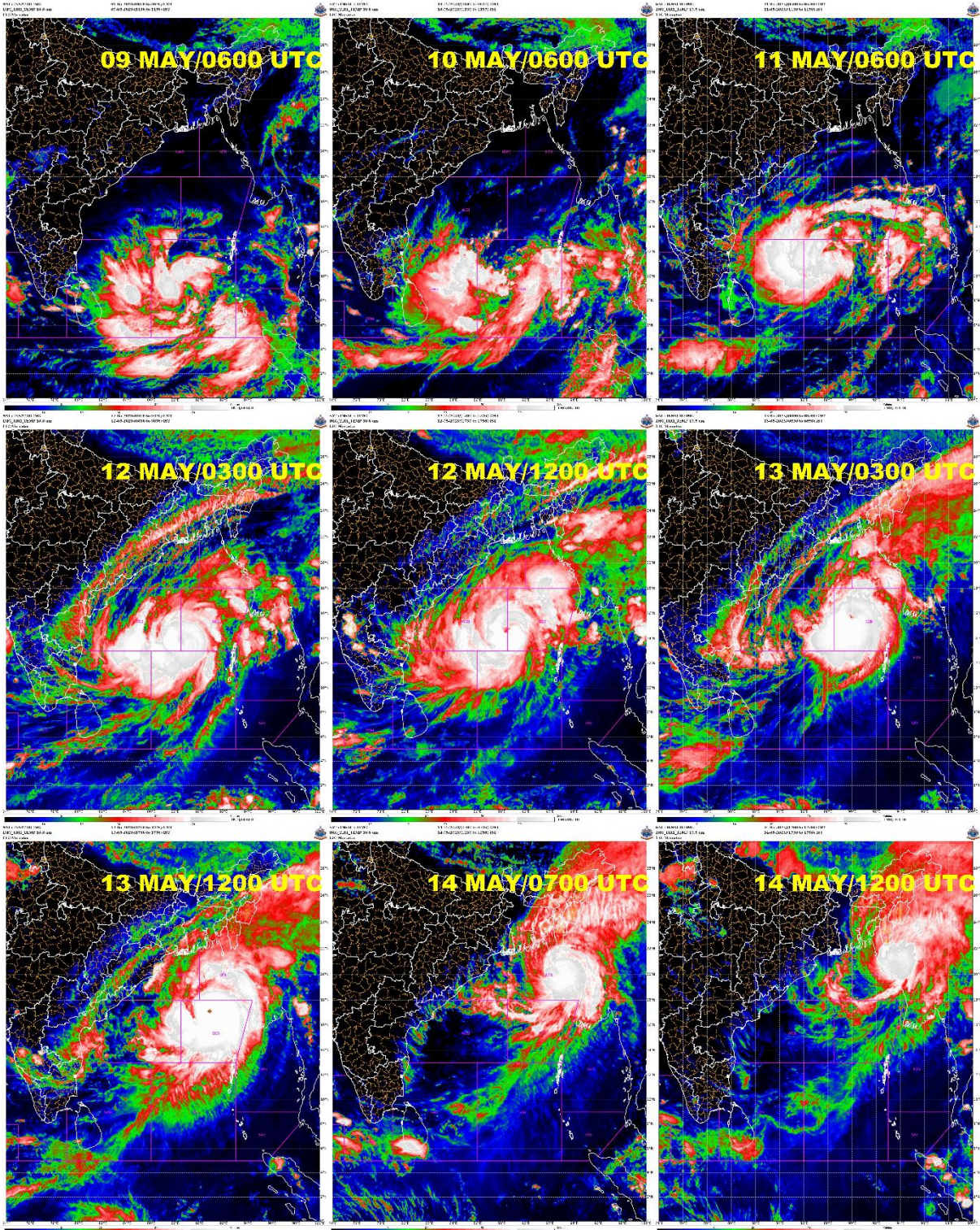
INSAT-3D Visible Imagery during ESCS Mocha (09th to 14th MAY 2023)



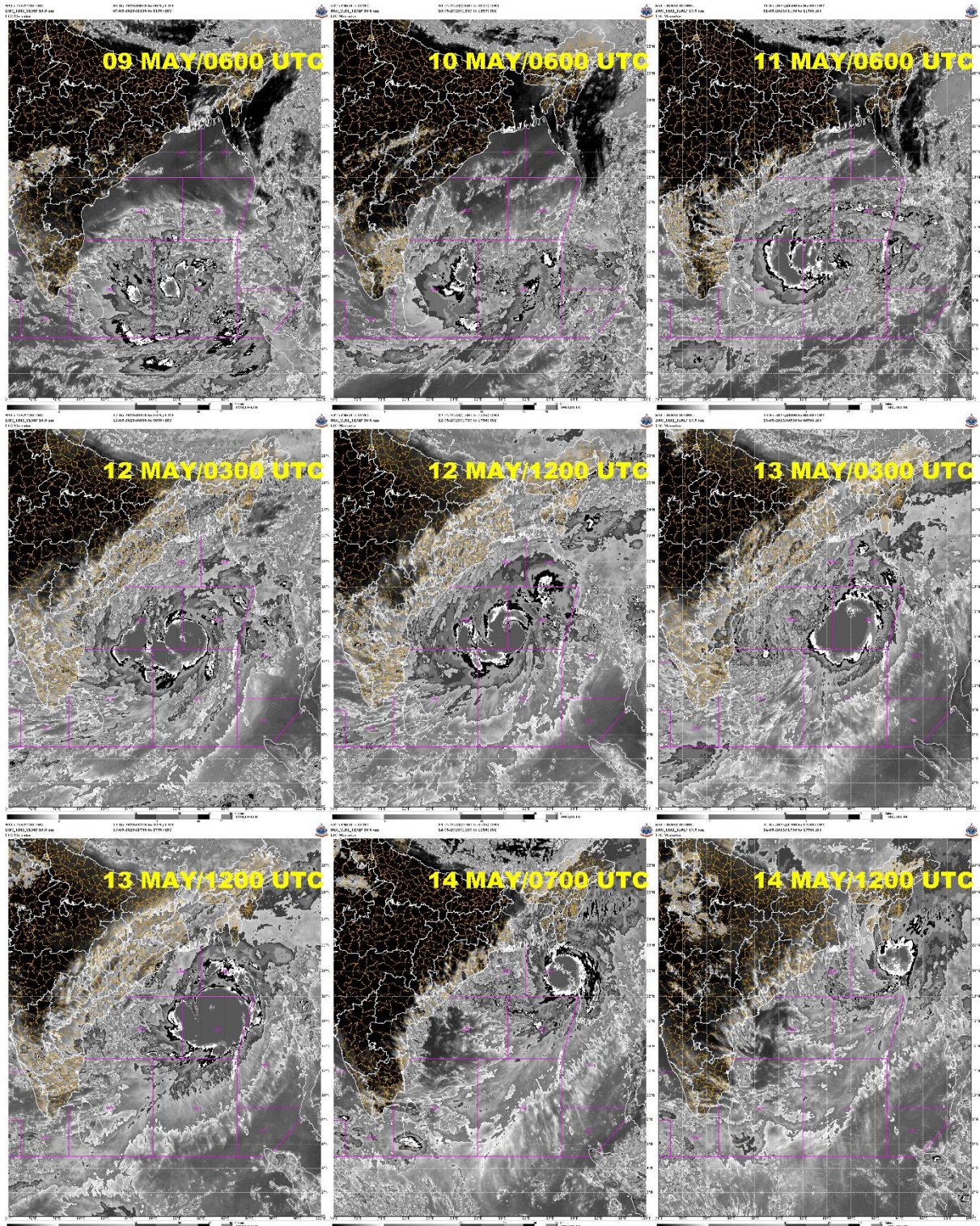
INSAT-3D IR-1 Imagery during ESCS Mocha (09th to 14th MAY 2023)



INSAT-3D Enhanced Coloured Imagery during ESCS Mocha (09th to 14th MAY 2023)



INSAT-3D BD-Curve Imagery during ESCS Mocha (09th to 14th MAY 2023)



Cox's Bazar Radar images during landfall of ESCS Mocha.

