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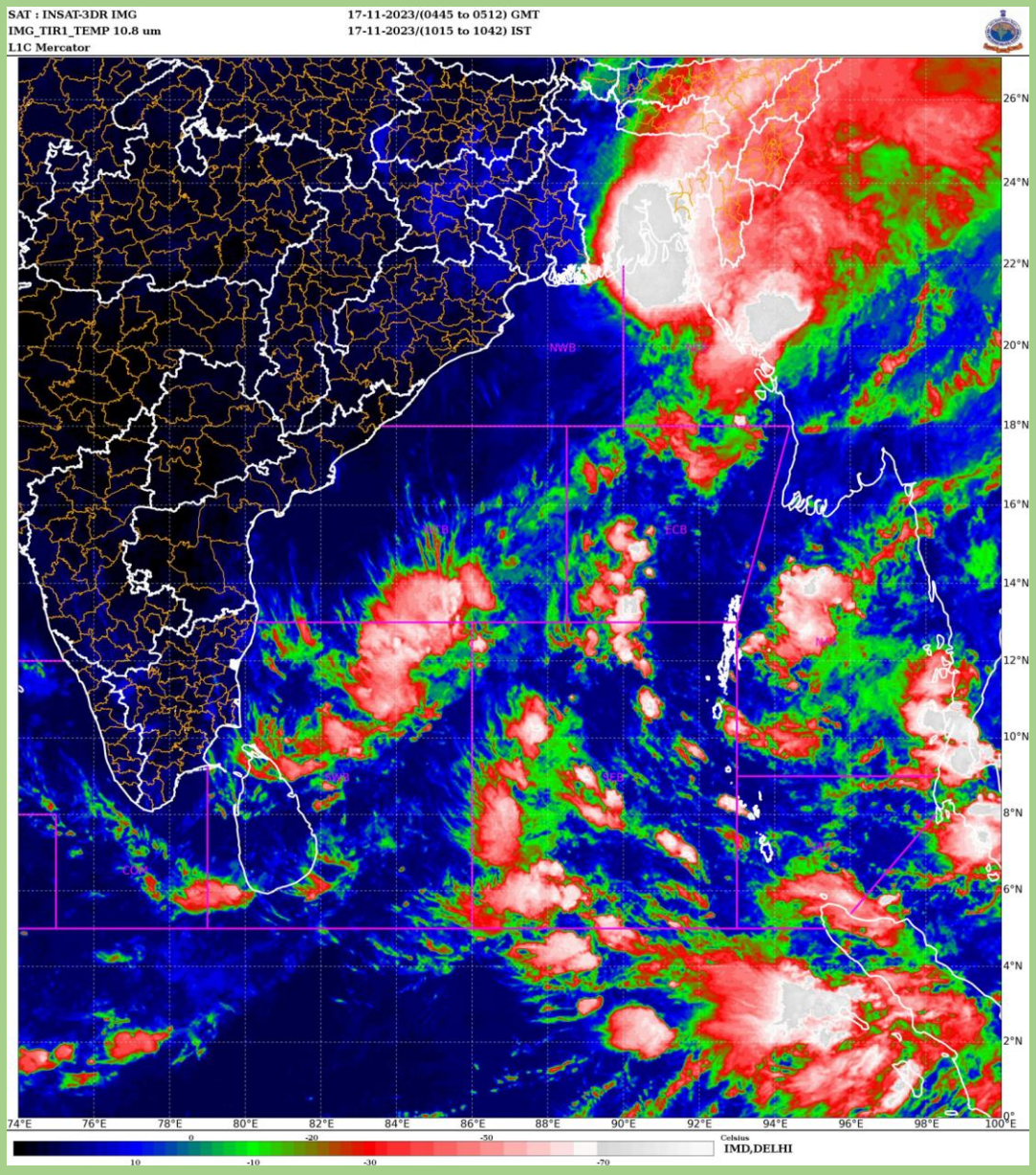
Severe Cyclonic Storm "MIDHILI" over the Bay of Bengal (15th-18th November, 2023): A Report



Typical satellite imagery during life period of severe fcyclonic storm "MIDHILI" at 0500 UTC of 17th November (0730 IST of 17th November 2023)

Cyclone Warning Division
India Meteorological Department

New Delhi

Severe Cyclonic Storm "MIDHILI" over the Bay of Bengal (15th-18th November, 2023): A Report

1. Life History of "MIDHILI":

- An upper air **Cyclonic Circulation** lay over Gulf of Thailand in the morning (0830 hours IST/0300 UTC) of 12th November. It emerged into South Andaman Sea in the morning (0830 hours IST/0300 UTC) of 13th November.
- Under it's influence, a **Low Pressure Area** formed over southeast Bay of Bengal (BoB) and adjoining Andaman & Nicobar Islands in the early morning (0530 hours IST/0000 UTC) of 14th November.
- It lay as a **Well Marked Low Pressure Area** over southeast & adjoining central BoB in the evening (1730 hours IST/1200 UTC) of 14th November.
- It concentrated into a **Depression** over westcentral BoB in the morning (0830 hours IST/0300 UTC) of 15th November, 2023.
- It moved nearly northwards till the midnight (2330 hours IST) of 15th November & thereafter gradually recurved north-northeastwards and intensified into a **Deep Depression** in the early morning (0530 hours IST/0000 UTC) of 16th November.
- Continued to move further north-northeastwards, it intensified into the **Cyclonic Storm "Midhili" (pronounced as "Midhili")** over Northwest Bay of Bengal in the early morning (0530 hours IST/0000 UTC) of 17th November, 2023.
- It intensified further into **Severe Cyclonic Storm** over the same region off Bangladesh coast in the noon (1430 hours IST/0900 UTC of 17th November, 2023.
- Further, moving north-northeastwards, it crossed Bangladesh coast close to east of Patuakhali near 22.3N/90.5E during 0900-1000 UTC of 17th November as a Severe Cyclonic Storm with the maximum sustained wind speed of 50 knots (85-95 kmph gusting to 105 kmph)
- Thereafter, it moved northeastwards and weakened gradually into a deep depression over Tripura and adjoining Bangladesh in the midnight (2330 hours IST/1800 UTC) of 17th November.
- Further moving northeastwards, it weakened into a depression over Tripura and adjoining Bangladesh & Mizoram in the early morning (0530 hours IST/0000 UTC) and into a low pressure area over North Tripura and neighbourhood in the forenoon (0830 hours IST/ 0300 UTC) of 18th November.
- 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 Severe Cyclonic Storm "MIDHILI" over BoB during 15th – 18th November, 2023

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
15.11.23	0300	14.5	86.8	1.5	1006	25	3	D
	0600	14.7	86.6	1.5	1006	25	3	D
	1200	15.3	86.4	1.5	1006	25	3	D
	1800	16.0	86.4	1.5	1006	25	3	D
16.11.23	0000	16.9	86.8	2.0	1004	30	4	DD
	0300	17.4	87.0	2.0	1004	30	4	DD
	0600	17.9	87.3	2.0	1004	30	4	DD
	1200	18.6	87.7	2.0	1004	30	4	DD
	1800	19.1	88.0	2.0	1004	30	4	DD
17.11.23	0000	20.1	88.5	2.5	1002	35	6	CS
	0300	20.7	89.1	2.5	1000	40	8	CS
	0600	21.2	89.5	2.5	998	45	10	CS
	0900	21.8	90.0	2.5	996	50	12	SCS
	Crossed Bangladesh coast close to east of Patuakhali near 22.3N/90.5E during 0900-1000 UTC of 17th November as a Severe Cyclonic Storm with the maximum sustained wind speed of 50 knots (85-95 kmph gusting to 105 kmph).							
	1200	22.8	90.8	-	1000	35	8	CS
	1500	23.1	91.1	-	1006	35	6	CS
	1800	23.3	91.3	-	1010	30	4	DD
18.11.23	0000	23.7	91.7	-	1010	20	2	D

	0300	Weakened into a Low Pressure area over North Tripura and Neighbourhood.

ECP: Estimated Central Pressure, C.I. No.: Current Intensity No., ∆P: Pressure drop at centre, Kt: Knots, 1 kt= 1.85 kmph, MSW: Maximum Sustained surface Wind, D: Depression, DD: Deep Depression, CS: Cyclonic Storm, SCS: Severe Cyclonic Storm

2. Salient Features

I. Midhili was the second cyclone over BoB in the post-monsoon season of 2023 and fifth cyclone of the year over NIO.
II. It crossed Bangladesh coast near Khepupara as a cyclonic storm.
III. Climatologically, about 210 cyclones (MSW ≥ 35 kts) developed over the BoB during 1891-2022 post monsoon seasons (Fig. 3a). Out of all these storms, 42 crossed Bangladesh coasts (Fig. 3b).
IV. Movement: "Midhili" initially moved northwestwards till 1200 UTC of 15th November, 2023. It then moved northward for the next 6 hours. Thereafter, it moved north-northeastward till landfall (0900-1000 UTC of 17th November, 2023) and thereafter (Fig.3a). It moved with a 6-hourly average translational speed of 16.3 kmph.
V. Maximum sustained wind speed and estimated central pressure:
The system reached it's peak intensity of 40 knots at 0600 UTC of 17th November and maintained it's peak intensity for the next 3 hours. The minimum central pressure of 998 hPa was observed during the period of 0600 UTC to 0900 UTC of 17th November, 2023 and the associated central pressure drop was about 8 hPa (Fig.3b).
VI. **Track length:** The track length of "Midhili" was 1105 km.

3. Monitoring of SCS, "MIDHILI"

India Meteorological Department (IMD) maintained round the clock watch over the north Indian Ocean and the cyclone was monitored since 13th November, about 2 days prior to formation of depression on 15th November and 4 days prior to the landfall of system over Bangladesh coast. The information about the system was first released in the weekly extended range outlook issued by IMD on 2nd November indicating formation of cyclonic circulation/low pressure area over southwest & adjoining westcentral BoB during the week 2 (10-16 November, around 14th November. Further, the extended range outlook issued on 9th November (**Fig. 6**), indicated formation of depression around 17th November with moderate probability (34-67%) about 6 days ahead of formation over westcentral BoB and 8 days in advance of landfall over Bangladesh.

The cyclone was monitored with the help of available satellite observations from INSAT 3D and 3DR, SCAT SAT, ASCAT, microwave imageries and available ships & buoy observations in the region. Various global models and dynamical-statistical models run by Ministry of Earth Sciences (MoES) institutions including IMD, NCMRWF, IITM & INCOIS and guidance from models from various international agencies under bilateral arrangement 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. which was further value added to arrive at consensus forecast by considering various prognostic & diagnostic features, observational features, initial conditions and consistency of individual models etc. 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 imageries from INSAT 3D (R) are presented in **Fig.7**.

4. Operational Forecast Performance:

i) Pre-Genesis Forecast performance

- First information about likely cyclogenesis over southwest & adjoining westcentral BoB during the week (17th -23rd Nov), around 17th was issued in the extended range outlook issued on 9th Nov. about 6 days prior to formation of depression on 15th Nov. (**Fig. 6**)
- The tropical Weather Outlook issued on 13th Nov. indicated likely formation of an upper air cyclonic circulation around 13th, low pressure area around 14th and depression around 15th with low probability. Since then the Daily Tropical Weather Outlooks issued indicated formation of depression over BoB around 15th. (**Fig. 7**)
- Actually, a cyclonic circulation from Gulf of Thailand emerged into South Andaman Sea on 13th November; a low pressure area formed over southeast Bay of Bengal (BoB) and adjoining Andaman & Nicobar on 14th November and depression over westcentral BoB on 15th November, 2023.
- The daily report under Tropical Cyclone Forecasting Programme (TCFP) for North Indian Ocean issued since 9th Nov., gave detailed discussion of environmental features prevailing over the BoB and guidance from various models.

ii) Operational track, intensity and landfall forecast performance

- The track forecast errors for 12, 24 and 48 hrs lead period were 87, 172 and 366 km respectively against the long period average (LPA) errors (2018-22) of 46, 74 and 112 respectively (**Fig. 10a**). For all lead periods, the operational track forecast errors were higher than Long Period Average Errors because the system moved very fast and the cross track errors were very high.
- The absolute error (AE) of intensity (wind) forecast for 24 and 48 hrs lead period were 2.5and 6.3 knots against the LPA errors of 7.4 and 10.5 knots during 2018-22 respectively (**Fig.11a**). The skill in intensity forecast based on AE for 24 and 48 hrs lead period was 83 and 76% against the LPA skill of 55 and 74% during 2018-22 respectively (**Fig.11b**). For all lead periods, the intensity forecast errors were less than the Long Period Average errors.
- The root mean square error (RMSE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 4.3 and 7.5 knots against the LPA errors of 9.3 and 13.1 knots during 2018-22 respectively (**Fig.12a**). The skill in intensity forecast based on RMSE for 24 and 48 hrs lead period was 82 and 73% against the LPA skill of 42 and 61% during 2018-22 respectively (**Fig.12b**).
- The landfall point forecast errors for 12, 24 and 36 hrs lead period were 13.3, 45.4 and 46.8 km respectively against the LPA errors (2018-22) of 16, 26.2 and 34 km during 2018-22 respectively (**Fig.13a**). The landfall point forecast errors were higher than the LPA errors, as the trough in westerly shifted the track eastwards. It's impact on the track could not be captured by the models and hence the operational forecasters.

❖ The landfall time forecast errors for 12, 24 and 36 hrs lead period were 1.5, 9.5 and 9.5 hours respectively against the LPA errors (2018-22) of 1.7, 2.8 and 4.3 hours during 2018-22 respectively (**Fig.13b**). The landfall time errors were also higher than the LPA errors as the cyclone moved very fast under the influence of trough in westerly.

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… +96 hrs lead period commencing from 14th November 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 along with cone graphics, commencing from 14th November.
- **Adverse weather warning bulletins:** The tropical cyclone forecasts along with expected adverse weather like gale wind, state of sea for BoB 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 Odisha, West Bengal, Andhra Pradesh, Tamil Nadu, Puducherry, Andaman & Nicobar Islands, Tripura, Mizoram, Manipur, Nagaland, Assam and Meghalaya. 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. From cyclone “MIDHILI” the advisories for winds & sea condition over south & central AS were also provided to WMO and WMO/ESCAP PTC member countries including Bangladesh.
- **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 fishermen were also presented in graphics along with 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 Mumbai, Cyclone warning centres at Thiruvananthapuram &

Ahmedabad, Meteorological Centra Goa & Karnataka to ports, fishermen, coastal and high sea shipping community.

- **Fishermen Warning:** Regular warnings for fishermen for deep Sea of Arabian Sea were issued since 14th November.
- **Advisory for international Civil Aviation:** The Tropical Cyclone Advisory Centre (TCAC) bulletin for International Civil Aviation were issued every six hourly to all meteorological watch offices in Asia Pacific region for issue of significant meteorological information (SIGMET) by Meteorological Watch Offices. 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 since 14th Nov and in daily cyclone forecasting programme report commencing from 9th November.
- **Director General of Meteorology** had online briefing meeting with DG Bangladesh during the cyclone.

Statistics of bulletins issued by Cyclone Warning Division, RSMC New Delhi and different offices are given in Table 2-3.

Table 2: Bulletins issued by Cyclone Warning Division, New Delhi

S. No.	Bulletin type	No. Of Bulletins	Issued to
1	(A)National Bulletin (B) Special Message	18 1	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, Ministry of Science & Technology, Secretary MOES, Headquarter Integrated Defence Staff, Director General Doordarshan, All India Radio, PIB MOES, UNI, DG National Disaster Response Force, Director, Punctuality, Indian Railways, Chief Secretary: Government of Odisha, West Bengal, Andhra Pradesh, Tamil Nadu, Puducherry, Andaman & Nicobar Islands, Tripura, Manipur, Mizoram, Nagaland, Assam, Meghalaya.
2	RSMC Bulletin	21	1. IMD's website 2. WMO/ESCAP member countries through GTS and E-mail.
3	GMDSS Bulletins	7	1. IMD website, RSMC New Delhi website 2. Transmitted through WMO Information System (WIS) to Joint WMO/IOC Technical Commission for Ocean and Marine Meteorology (JCOMM)
4	Tropical Cyclone Advisory Centre Bulletin	8	1. Met Watch offices in Asia Pacific regions and middle east through GTS to issue Significant Meteorological information for International Civil Aviation 2. WMO's Aviation Disaster Risk Reduction (ADRR), Hong Kong through ftp 3. RSMC website
5	Tropical	7	Modelling group of IMD, National Centre for

	Cyclone Vital Statistics		Medium Range Weather Forecasting Centre (NCMRWF), Indian National Centre for Ocean Information Services (INCOIS), Indian Institute of Technology (IIT) Delhi, IIT Bhubaneswar etc.
6	Warnings through SMS	Frequently	SMS to disaster managers at national level and concerned states (every time when there was change in track, intensity and landfall characteristics) 4,19,581 to General Public and disaster manages along the west coast of India by IMD Headquarters
7	Warnings through Social Media	Daily	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).
8	Press Release	4	Disaster Managers, Media persons by email and uploaded on website
9	Press Briefings	Daily	Regular briefing daily
10	Hourly Bulletin	-	-

9. Damage report

According to an official report in Tripura, the storm fully damaged 12 houses, severely damaged 72 houses and partly damaged 255 houses. The cyclone accompanied by rainfall also damaged crops in various parts of the state but luckily there was no report of any loss of life. The total loss occurred by the cyclonic storm could not be ascertained till the last information came in. Sources said, Sadar is one among the 23 sub-divisions to receive the highest rainfall on Friday. All the rivers were flowing below the expected flood level till Saturday evening. Meanwhile, moderate to dense fog occured at isolated pockets over all districts of Tripura till morning of November 19.

As per media reports from Bangladesh, Cyclone Midhili wreaked havoc across the coastal districts of Chattogram, Cox's Bazar, Noakhali, Feni, and Lakshmipur, damaging crops, primarily affecting Aman paddy and winter vegetables. It caused widespread floods and power outages, extensive damage to buildings, cell phone towers, trees etc. in Bangladesh. Some damage photographs are presented at **Fig. 16**.

10. Acknowledgements:

India Meteorological Department (IMD) and RSMC New Delhi duly acknowledge contribution from WMO and WMO/ESCAP member countries including Sri Lanka, Bangladesh, Myanmar and Thailand for observational data. The contribution from all the stakeholders and disaster management agencies who contributed to the successful monitoring, prediction and early warning service of SCS Midhili is also duly acknowledged. 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) Chennai & Kolkata, Cyclone Warning Centres Bhubaneswar, Visakhapatnam, Regional Meteorological Centre Guwahati, Meteorological Centres, Port Blair, Imphal, Kohima, Itanagar, Shillong Aizawl and Doppler Weather Radar Station at Kolkata and Agartala and all coastal observatories of Odisha and West Bengal is acknowledged. The contribution from Numerical Weather Prediction Division, Satellite and Radar Divisions, Surface & Upper Air Instruments Divisions, Agromet Advisory Services Division, Information System and Services Division, National Weather Forecasting Centre and Cyclone Warning Division at IMD is also duly acknowledged.

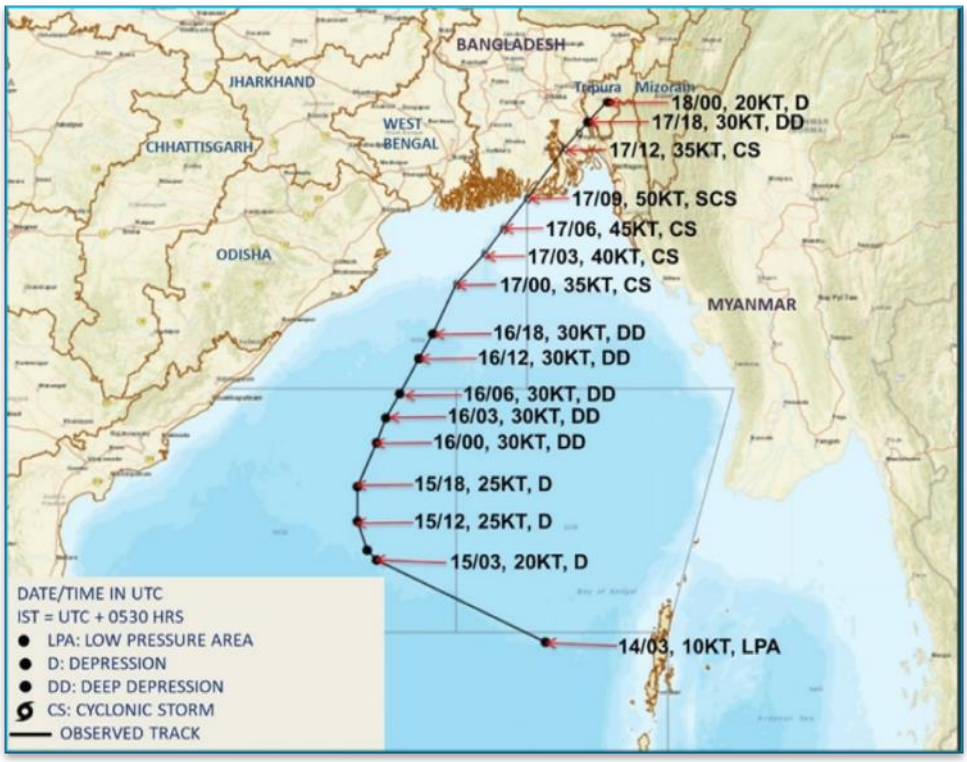


Fig. 1: Observed track of severe cyclonic storm 'MIDHILI" over Bay of Bengal during 15th – 18th November, 2023.

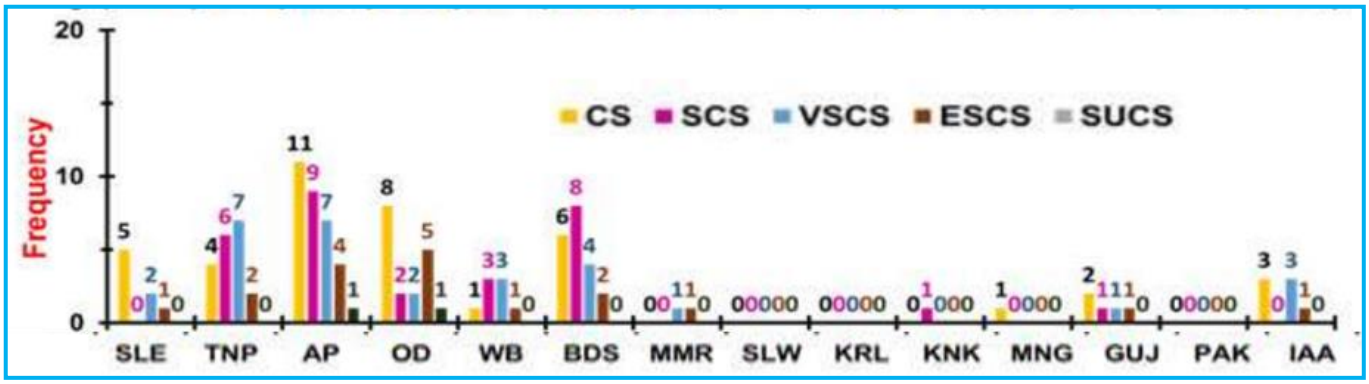


Fig. 2: Frequency of cyclones crossing Bangladesh coast during 1965-2022

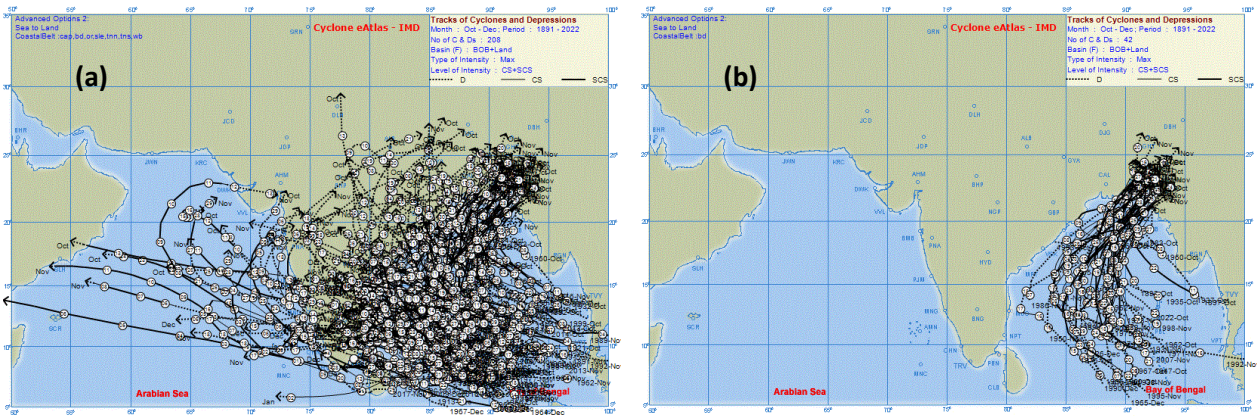


Fig. 3: (a) Tracks of cyclones (maximum sustained wind speed (MSW) ≥ 34 knots) and (b) tracks of cyclones crossing Bangladesh coast during the period 1891-2022 post monsoon seasons.

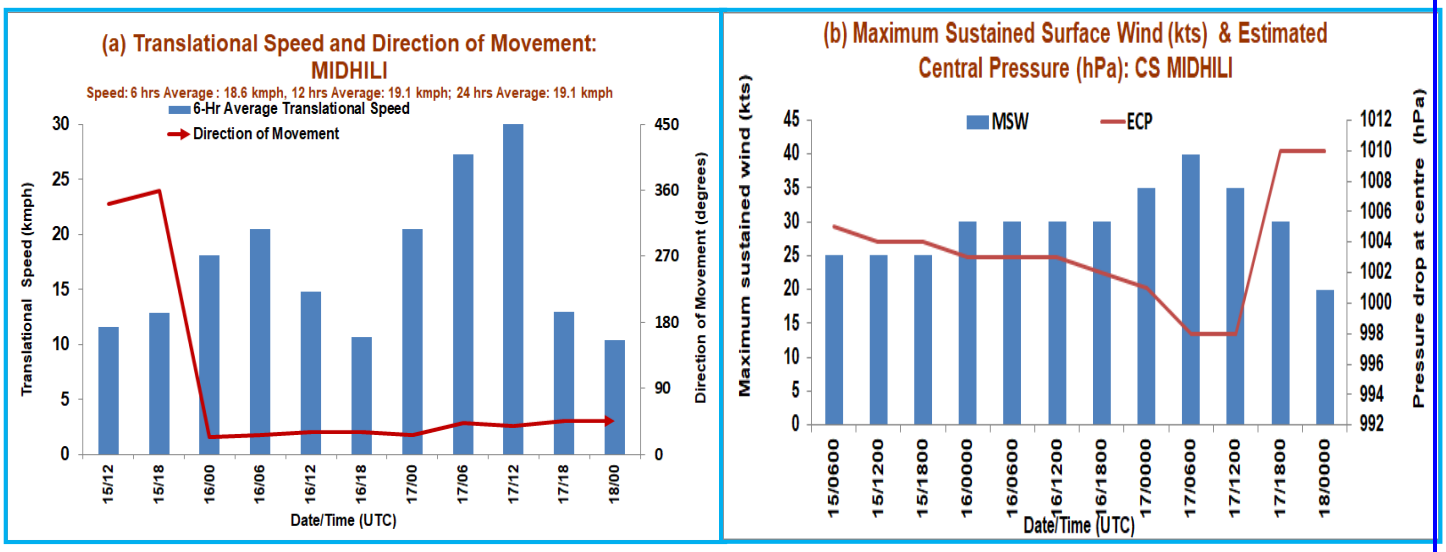


Fig. 4: (a) 6-hourly translational speed & direction of movement and (b) maximum sustained wind speed & estimated central pressure during life cycle of CS "MIDHILI"

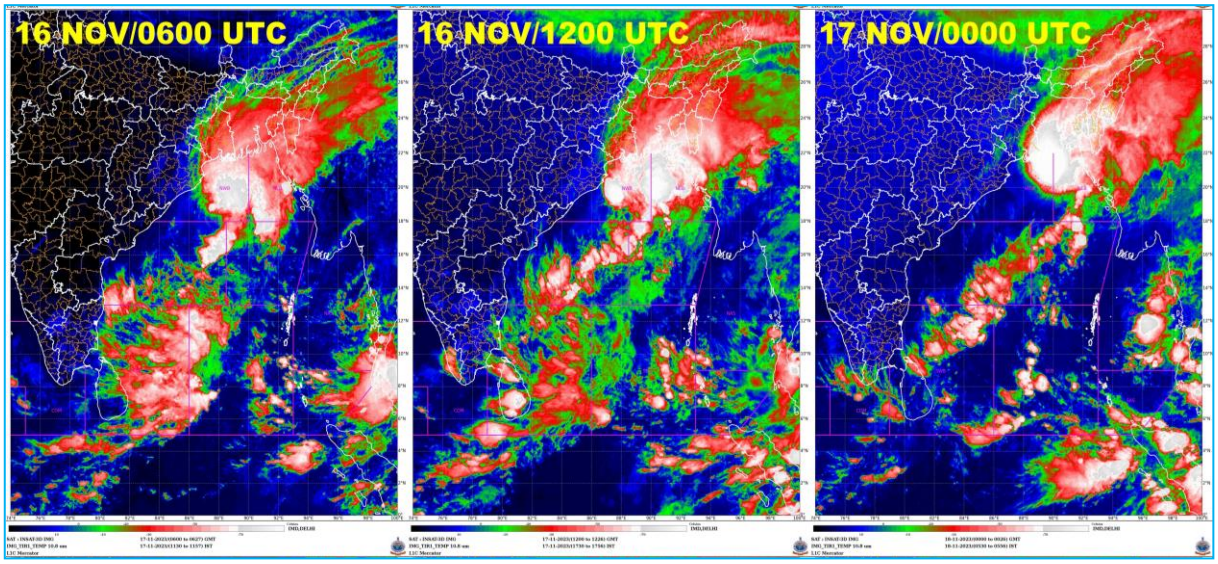


Fig. 5: INSAT-3D enhanced colored imageries during life cycle of SCS MIDHILI (15-18 November, 2023)

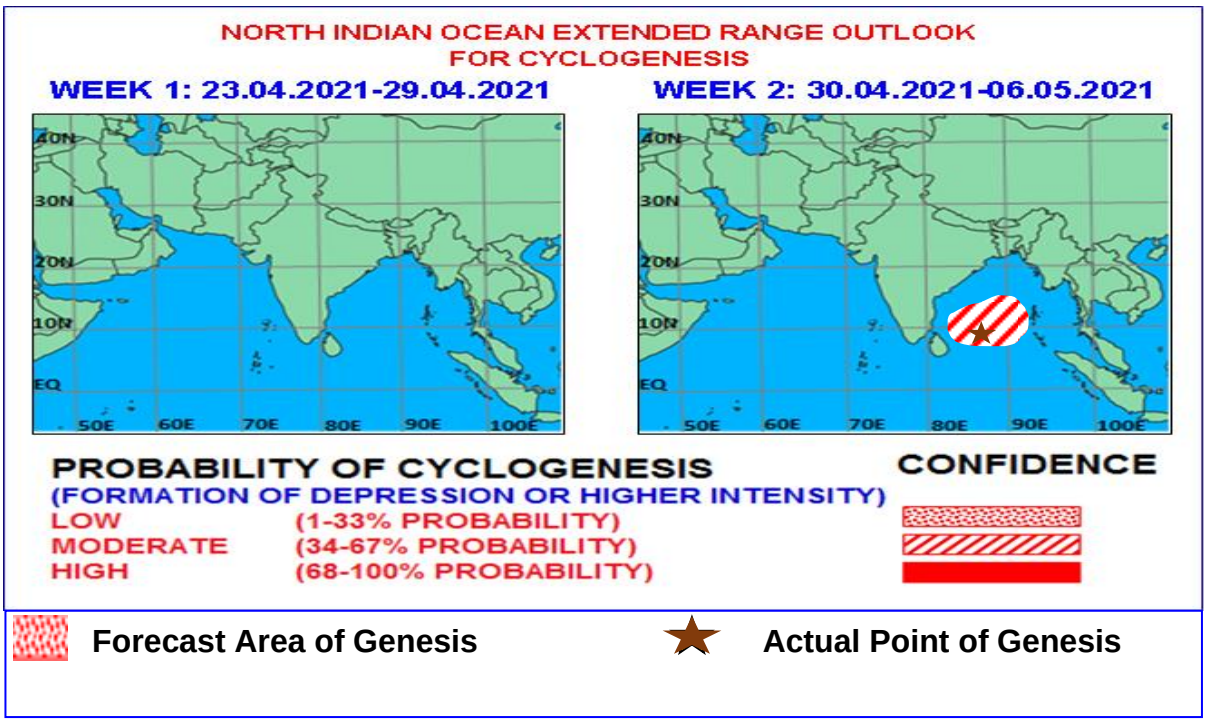


Fig. 6: Weekly extended range outlook issued by IMD on 12th October about 8 days prior to formation of depression on 20th October and 11 days prior to the landfall of system over Yemen coast indicating formation of depression over southeast AS during the week 2 (20-26 October, around 20th Octobe

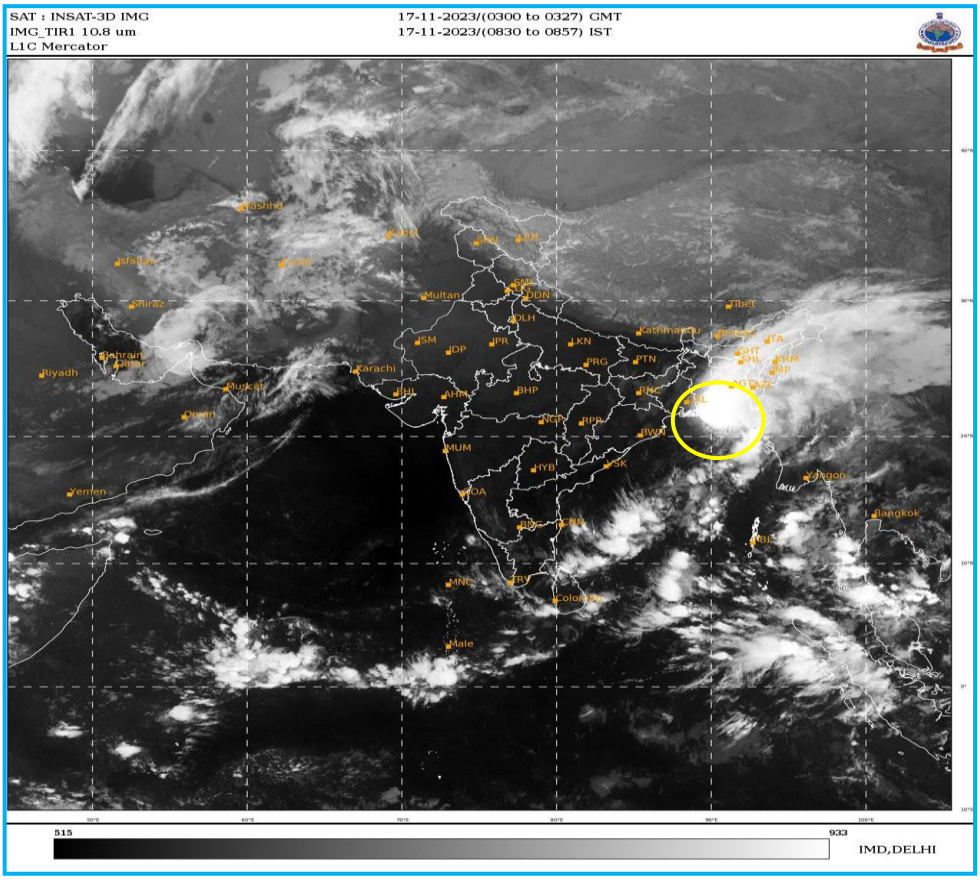


Fig.7: Typical INSAT 3D imagery showing SCS Midhili

ANOTHER UPPER AIR CYCLONIC CIRCULATION LAY OVER SOUTHWEST BAY OF BENGAL AND NOW EXTENDS UPTO MIDDLE TROPOSPHERIC LEVELS AT 0300 UTC OF TODAY, THE 13TH NOVEMBER 2023.

SCATTERED TO BROKEN LOW AND MEDIUM CLOUDS WITH EMBEDDED INTENSE TO VERY INTENSE CONVECTION LAY OVER SOUTH & CENTRAL BAY OF BENGAL, ANDAMAN SEA AND TENASSERIM COAST.

PROBABILITY OF CYCLOGENESIS (FORMATION OF DEPRESSION) DURING NEXT 168 HRS:

24 HOURS	24-48 HOURS	48-72 HOURS	72-96 HOURS	96-120 HOURS	120-144 HOURS	144-168 HOURS
NIL	NIL	LOW	MODERATE	HIGH	-	-

PROBABILITY OF CYCLOGENESIS (FORMATION OF DEPRESSION):
NIL: 0%. LOW: 1-33%. MODERATE: 34-66% AND HIGH: 67-100%

Fig. 8: Tropical Weather Outlook dated 13th November indicating likely formation of an upper air cyclonic circulation around 13th, low pressure area around 14th and depression around 15th with low probability (1-33%).

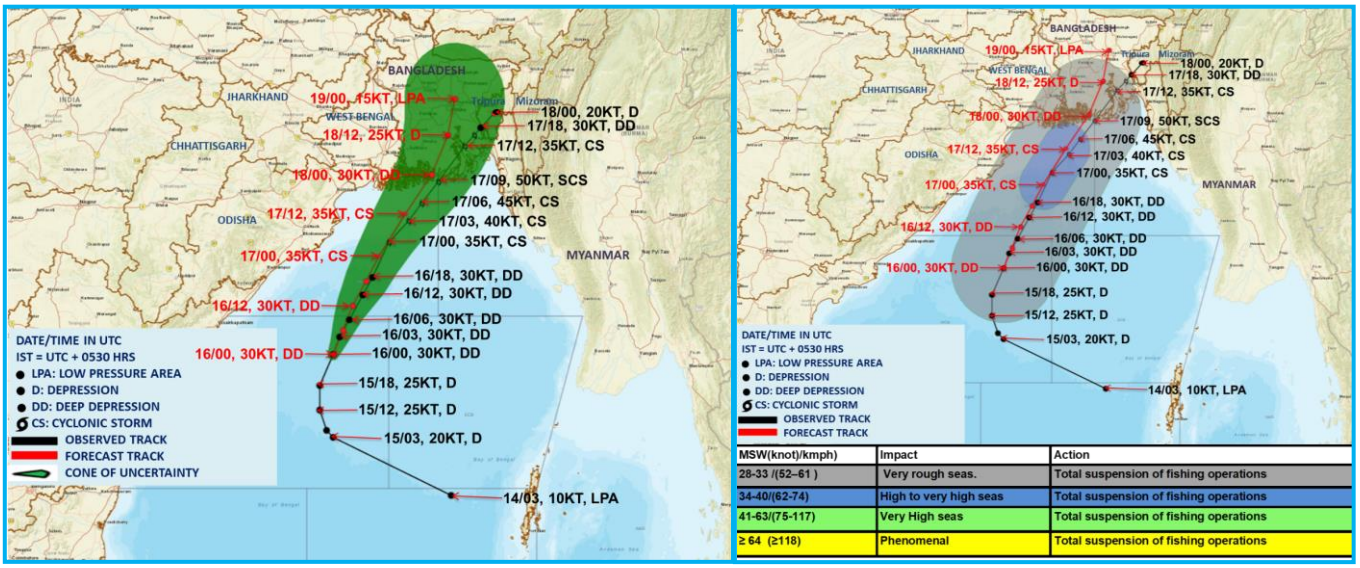


Fig. 9: Observed track and forecast track & intensity issued based on 0000 UTC observation of 16th November about 33 hours ahead of landfall.

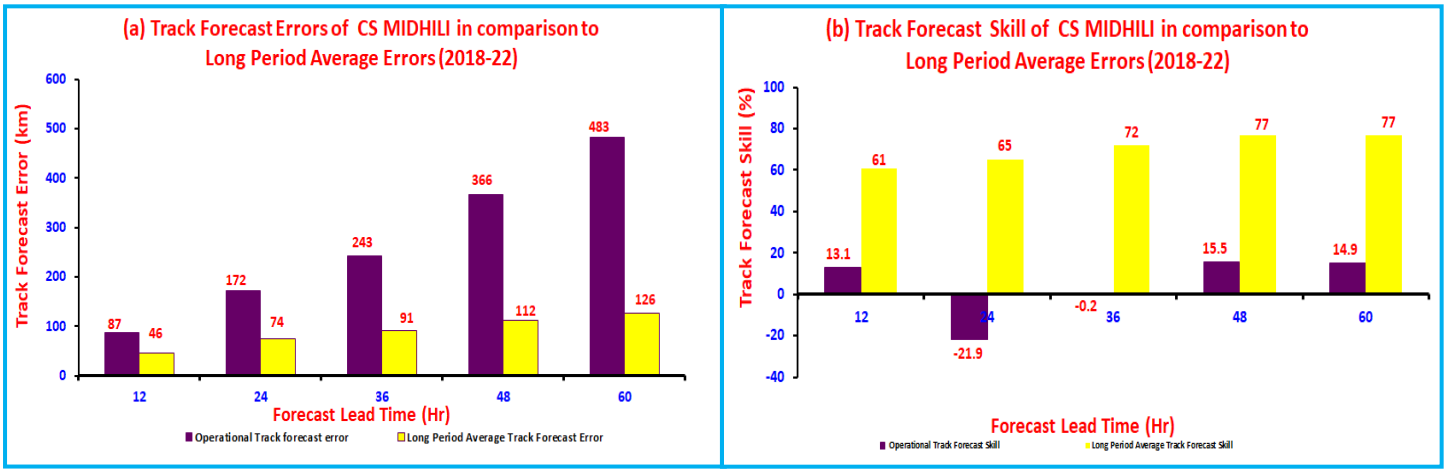


Fig. 10: (a) Track forecast errors and (b) track forecast skill against the long period average (LPA) errors (2018-22).

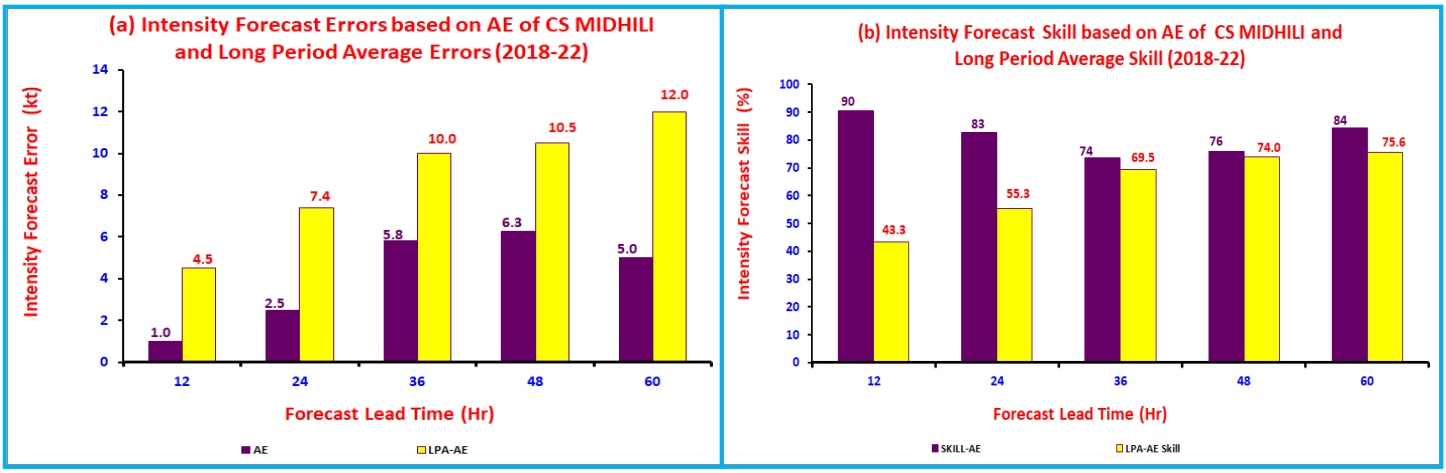


Fig. 11: (a) Absolute error (AE) in intensity forecast (b) intensity forecast skill based on AE against the long period average (LPA) errors (2018-22).

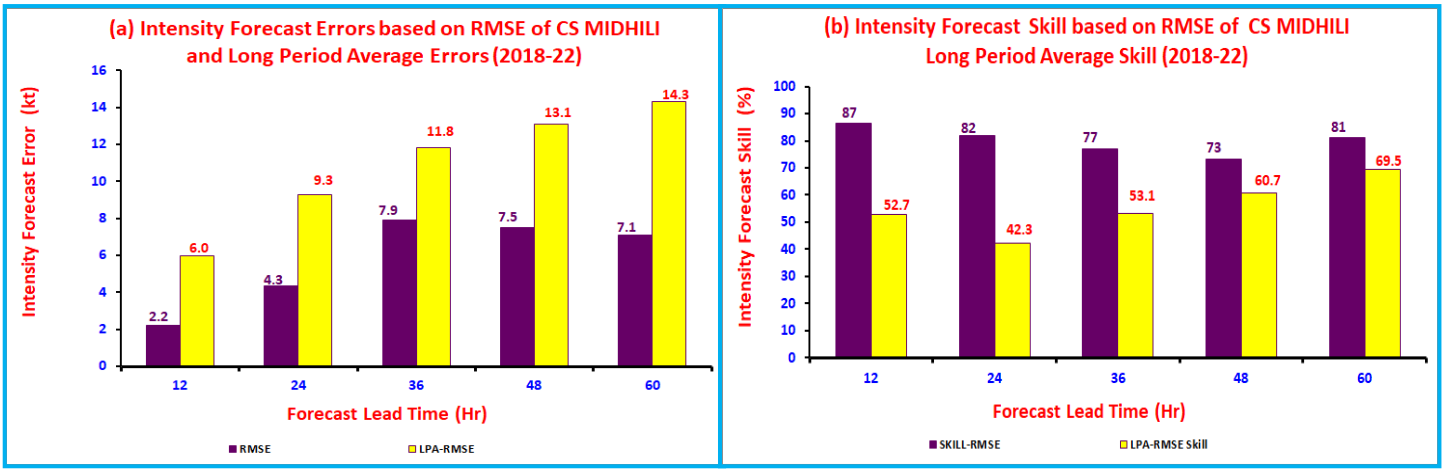


Fig. 12: (a) Root Mean Square Error (RMSE) in intensity forecast and (b) Intensity forecast skill against the long period average (LPA) errors (2018-22)

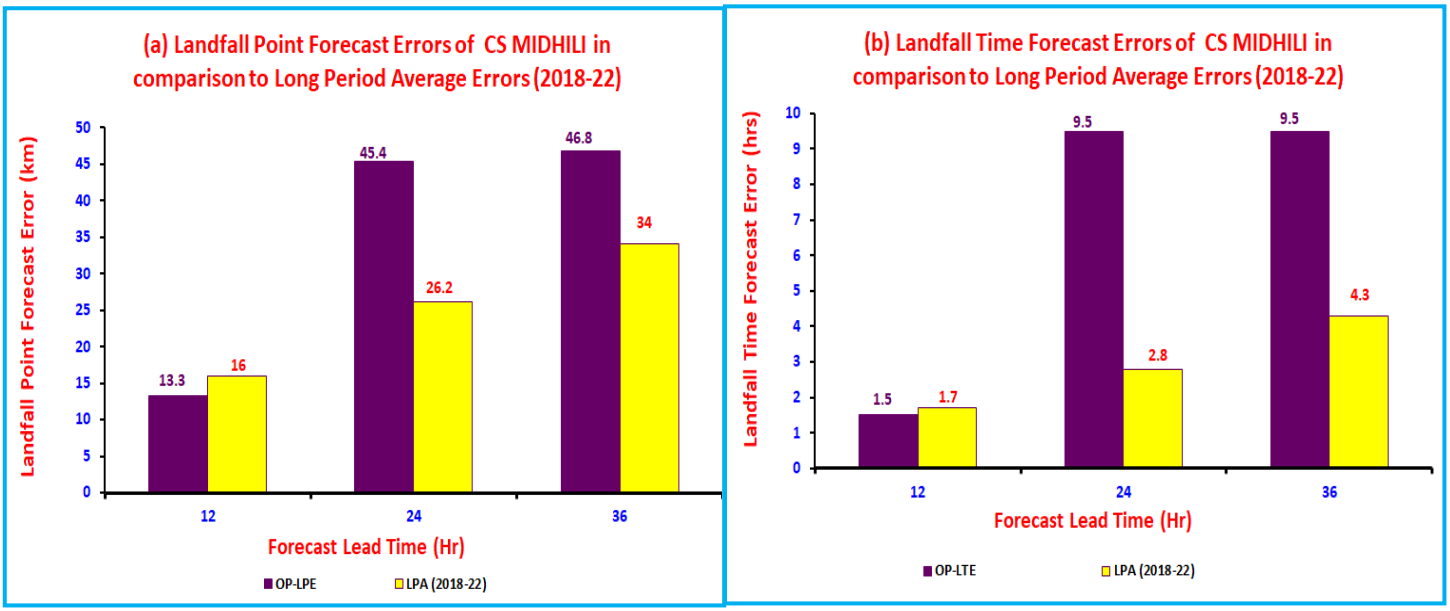
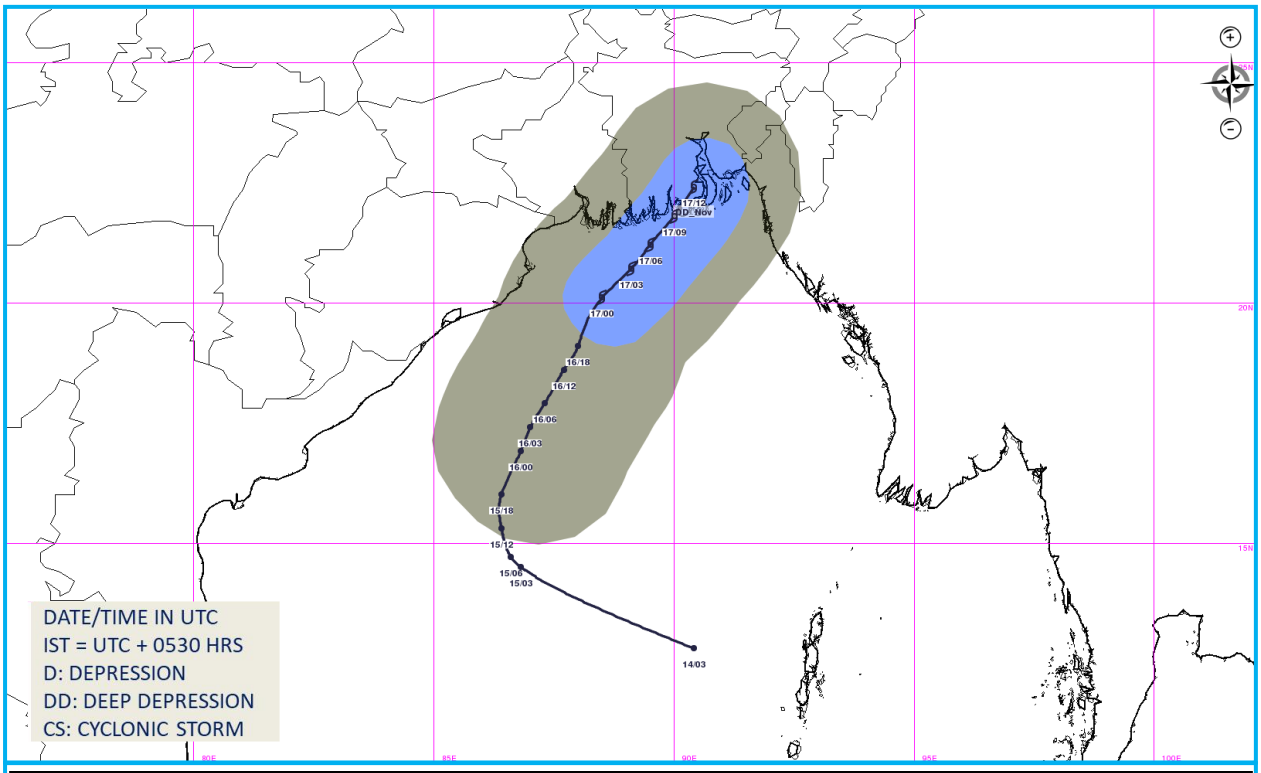


Fig. 13: (a) Landfall point and (b) time error against the long period average (LPA) errors (2018-22)



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

Fig. 14: Estimated MSW during the life cycle of SCS MIDHILI

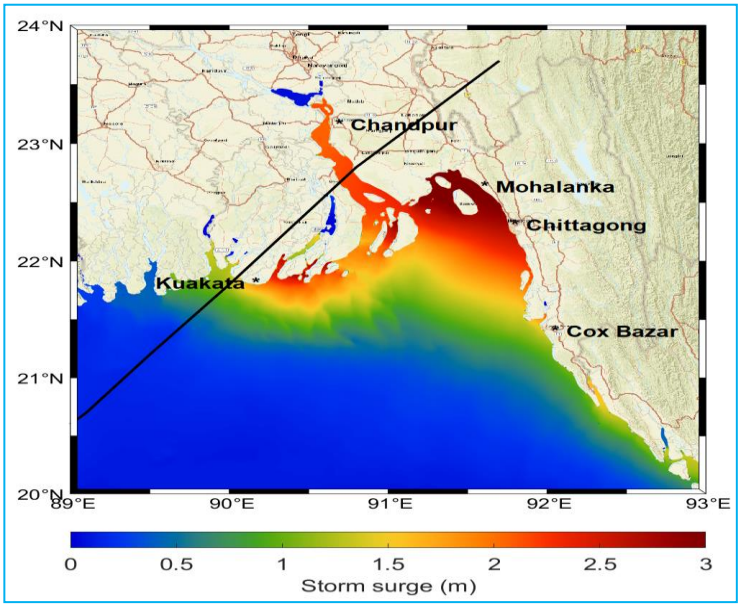


Fig. 15: Estimated Storm Surge due to SCS MIDHILI.

Fig. 16: Extensive damage to residential areas, crops and fishing ports in northeast India & Bangladesh due to SCS Midhili.

_____X_____X_____X_____