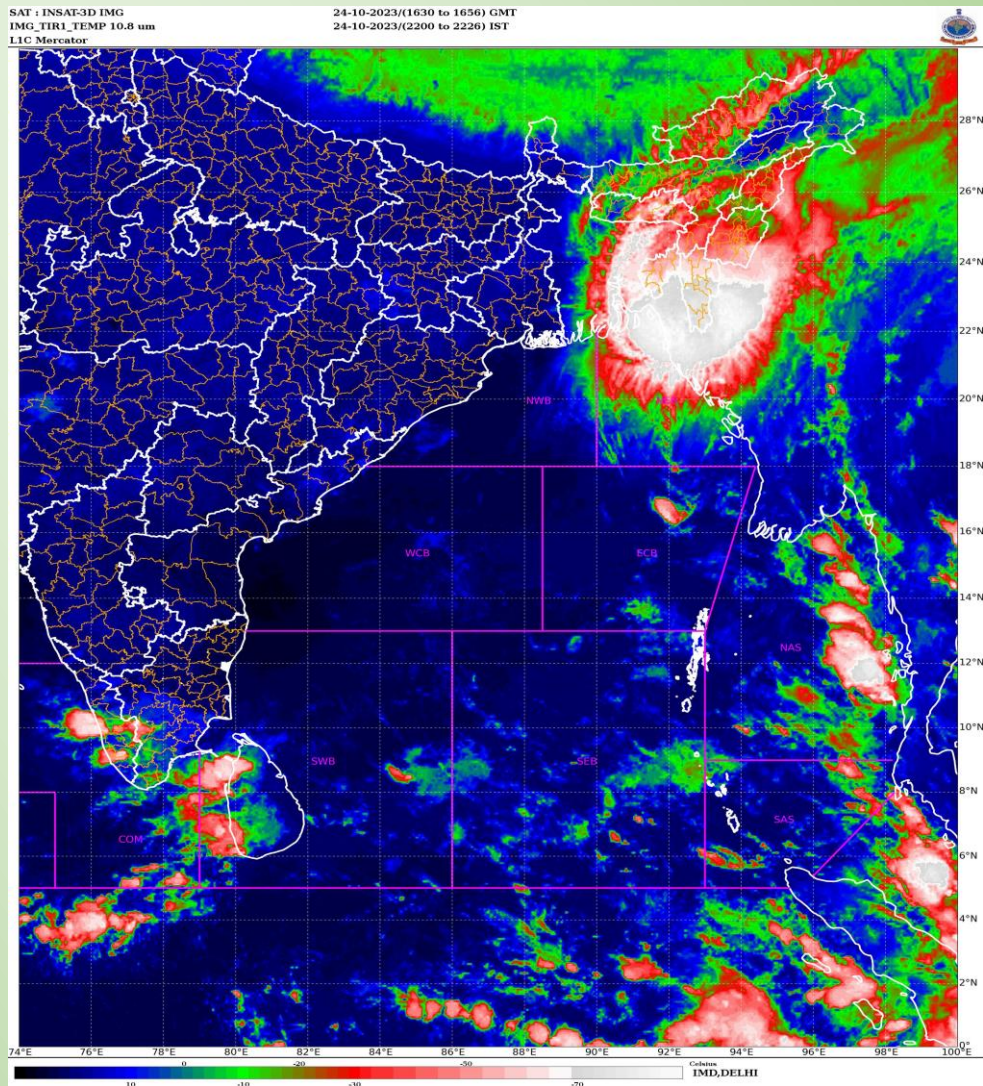




Extremely Severe Cyclonic Storm “HAMOON” over the Bay of Bengal (21st - 25th October, 2023): A Report



Typical satellite imagery during landfall of very severe cyclonic storm “HAMOON” at
2000 UTC of 24th October
(0130 IST of 25th October 2023)

Cyclone Warning Division
India Meteorological Department

New Delhi

Extremely Severe Cyclonic Storm “HAMOON” over the Bay of Bengal (21st-25th October, 2023): A Report

1. Life History of “HAMOON”:

- A **Cyclonic Circulation** (cycir) formed over southeast Bay of Bengal (BoB) and adjoining Andaman Sea on 17th October. It gradually moved west-northwestwards and lay as a cycir over southeast BoB on 19th October.
- Under its influence a **Low Pressure Area** formed over southwest and adjoining southeast BoB in the early morning (0530 hrs IST/0000 UTC) of 20th October, 2023.
- It lay as a **Well Marked Low pressure Area (WML)** over southeast and adjoining central BoB in the morning (0830 hours IST of 21st Oct).
- It concentrated into a **Depression (D)** over westcentral BoB in the midnight (2330 hrs IST/1800 UTC) of 21st October.
- It moved initially northwestwards for some time, then recurved gradually north-northeastwards and intensified into a **Deep Depression (DD)** in the evening (1730 hrs IST/1200 UTC) of 22nd October 2023 over westcentral BoB.
- Continuing to move further north-northeastwards, it intensified into the **Cyclonic Storm (CS) “HAMOON” pronounced as “HAMOON”** in the evening (1730 hrs IST/1200 UTC) of 23rd October 2023 over westcentral & adjoining southwest BoB.
- Thereafter, it moved northeastwards and intensified into a severe cyclonic storm (SCS) in the early morning (0530 hrs IST/0000 UTC) of 24th October over westcentral BoB.
- Continuing to move further northeastwards, it rapidly intensified into a **Very Severe Cyclonic Storm (VSCS) over the same region in the same morning** (0830 hrs IST/0300 UTC) of 24th October.
- Thereafter, it entered into an area with high vertical wind shear, and it weakened into an **SCS** in the evening (1200 UTC) of 24th October.
- Weakening trend continued and “HAMOON” crossed Bangladesh Coast to the south of Chittagong near (21.90 N/91.90 E) between 2330 hours IST of 24th October - 0030 hours IST of 25th October (1800 UTC and 1900 UTC of 24th October) as a severe cyclonic storm with maximum sustained wind speed of 90-100 kmph gusting to 110 kmph.
- Thereafter, continuing to move north-eastwards, it weakened rapidly into a **DD** over coastal Bangladesh in the morning (0830 hours IST/0300 UTC), into a **D** over southwest Mizoram & adjoining Bangladesh & Myanmar in the noon (1130 hours IST/0600 UTC) and into a WML over Mizoram and adjoining areas of Manipur and Myanmar the evening (1730 hours IST/1200 UTC) of 25th October.
- 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 Very Severe Cyclonic Storm HAMOON over BoB during 21st – 25th Oct, 2023

| Date | Time (UTC) | Lat. | Lon. | CI No | ECP (hPa) | MSW (kt) | ΔP (hPa) | Category |
|----------|------------|--|------|-------|-----------|----------|------------------|----------|
| 21.10.23 | 1800 | 14.7 | 86.4 | 1.5 | 1003 | 25 | 3 | D |
| | 2100 | 14.8 | 86.3 | 1.5 | 1003 | 25 | 3 | D |
| 22.10.23 | 0000 | 14.9 | 86.3 | 1.5 | 1003 | 25 | 3 | D |
| | 0300 | 15.0 | 86.2 | 1.5 | 1003 | 25 | 3 | D |
| | 0600 | 15.3 | 86.2 | 1.5 | 1003 | 25 | 4 | D |
| | 0900 | 15.6 | 86.2 | 1.5 | 1002 | 25 | 4 | D |
| | 1200 | 15.8 | 86.3 | 2.0 | 1001 | 30 | 5 | DD |
| | 1500 | 16.4 | 86.4 | 2.0 | 1001 | 30 | 5 | DD |
| | 1800 | 16.4 | 86.5 | 2.0 | 1001 | 30 | 5 | DD |
| 23.10.23 | 2100 | 16.4 | 86.6 | 2.0 | 1001 | 30 | 5 | DD |
| | 0000 | 16.7 | 86.7 | 2.0 | 1001 | 30 | 5 | DD |
| | 0300 | 17.0 | 86.8 | 2.0 | 1001 | 30 | 5 | DD |
| | 0600 | 17.4 | 87.0 | 2.0 | 1000 | 30 | 6 | DD |
| | 0900 | 17.9 | 87.2 | 2.0 | 1000 | 30 | 6 | DD |
| | 1200 | 18.3 | 87.3 | 2.5 | 999 | 35 | 7 | CS |
| | 1500 | 18.7 | 87.6 | 2.5 | 998 | 40 | 8 | CS |
| | 1800 | 19.1 | 88.0 | 3.0 | 998 | 40 | 8 | CS |
| 24.10.23 | 2100 | 19.3 | 88.4 | 3.5 | 994 | 50 | 12 | SCS |
| | 0000 | 19.7 | 88.8 | 3.5 | 990 | 55 | 16 | SCS |
| | 0300 | 20.0 | 89.5 | 4.0 | 984 | 65 | 22 | VSCS |
| | 0600 | 20.3 | 90.0 | 4.0 | 985 | 65 | 21 | VSCS |
| | 0900 | 20.6 | 90.4 | 4.0 | 986 | 65 | 20 | VSCS |
| | 1200 | 20.8 | 90.8 | 3.5 | 989 | 55 | 17 | SCS |
| | 1500 | 21.3 | 91.3 | 3.5 | 990 | 55 | 16 | SCS |
| | 1800 | 21.6 | 91.6 | 3.5 | 994 | 50 | 12 | SCS |
| | | Crossed Bangladesh Coast to the south of Chittagong near (21.90°N/91.90°E) between 1800 UTC and 1900 UTC as an SCS with maximum sustained wind speed of 50 knots gusting to 60 knots | | | | | | |
| 25.10.23 | 2100 | 22.0 | 92.0 | - | 996 | 45 | 10 | CS |
| | 0000 | 22.2 | 92.2 | - | 999 | 35 | 7 | CS |
| | 0300 | 22.4 | 92.4 | - | 1003 | 30 | 5 | DD |
| | 0600 | 22.7 | 92.7 | - | 1004 | 25 | 4 | D |
| | 1200 | Weakened into a Well-Marked Low Pressure Area (WML) over Mizoram and adjoining areas of Manipur and Myanmar | | | | | | |

ECP: Estimated Central Pressure, C.I. No.: Current Intensity No., ΔP : Pressure drop at centre,

Kt: Knots, 1 kt= 1.85 kmph, MSW: Maximum Sustained surface Wind

2. Salient Features

- 1) It was the fourth cyclonic storm over NIO region and 2nd cyclonic storm over BoB basin in the year 2023.
- 2) It crossed Bangladesh coast with MSW of 45 knots (75-85 kmph gusting to 95 kmph) on 24th October.
- 3) Climatologically, about 200 cyclonic storms (MSW \geq 62 kmph) developed over the BoB (**Fig. 2**) during 1965-2022. Out of these 46 crossed Bangladesh coasts (Fig. 2b).
- 4) **Twin cyclones:** “TEJ” during 20th - 24th October and “HAMOON” during the 21st - 25th October, 2023 developed over the Arabian Seas (AS) and BoB simultaneously. Such simultaneous occurrence of cyclones over both the basins is one of the rare events. In recent times such activity was observed which are given in the table 2. The track of these twins is shown in **Fig. 3**. Although, both the cyclones were overlapping life period

Table 2. Simultaneous Occurrence of cyclones over both Arabian Sea & Bay of Bengal

| Sl. | Year | Name of cyclones | Basin Name | Duration | Landfall/Dissipation Location |
|-----|------|-----------------------|-----------------------------|---|--|
| 1 | 2019 | SuCS Kyarr | Arabian Sea | 30 th October - 2 nd November | Dissipated over Sea |
| | | ESCS Maha | Arabian Sea | 30 th October - 7 th November | Dissipated over Sea |
| | | VSCS Bulbul | Bay of Bengal | 5 th - 7 th November | West Bengal coast |
| 2 | 2018 | VSCS Luban | Arabian Sea | 6 th - 15 th October | Yemen & adjoining Oman coasts |
| | | VSCS Titli | Bay of Bengal | 8 th - 13 th October | North Andhra Pradesh & South Odisha coasts |
| 3 | 1977 | VSCS | Bay of Bengal | 14 th - 20 th November | Andhra Pradesh coast (19 th Nov.) |
| | | VSCS (BoB) & SCS (AS) | Bay of Bengal & Arabian Sea | 09 th - 23 rd November | Tamil Nadu coast (12 th Nov.) & Karnataka coast (29 th Nov.) |

5) Rapid intensification and rapid weakening:

Although, the maximum intensity attained by the storm was a VSCS, it exhibited rapid intensification rendering a change of 35 knots in MSW speed within 18 hours from 30 knots (DD) at 0900 UTC of 23rd to a VSCS with MSW 65 knots at 0300 UTC of 24th October, 2023. As the system encountered favourable environmental conditions at the surface with 29-30°C Sea Surface Temperature (SST), low to moderate vertical wind shear, strong low level vorticity & convergence in the vicinity of the cyclonic disturbance along with strong divergence in the upper tropospheric levels at the top of the system.

The cyclone also encountered rapid weakening just after a few hours it attained maximum intensity. The intensity of the system changed from a VSCS (MSW:65 knots) at 0900 UTC of 24th October to a CS at 2100 UTC of the same day and after landfall to a Depression at 0600 UTC of 25th October. As soon as the system crossed

the ridge in mid-troposphere, it came under the grip of prevailing strong westerly winds at mid-upper troposphere, the system experienced high wind shear.

6) **Recurving track:**

“HAMOON” exhibited multiple recurvature in its track. In the Initial genesis stage, it moved north-northwestwards 22nd October till 1130 hrs IST/0600 UTC followed by northwards movement till evening (1730 hours IST/ 1200 UTC). It then started to gradually recurve northeastwards following steering and the wind pattern in mid-tropospheric level at the periphery of a ridge ran near latitude 15°N. The cyclone continued its north-northeastwards movement track till evening of 23rd October (1730 hrs IST/1200 UTC). Thereafter, as the system reached north of the ridge line, under the influence of deep trough in westerlies, the system moved northeastwards till it made landfall between 1900-2000 UTC (0030-0130 hrs IST) of 24th October over Bangladesh coast (**Fig.1**).

7) **Maximum Sustained wind speed and estimated central pressure:**

The system reached its peak intensity of 65 knots at 0300 UTC of 24th October to become a VSCS and maintained its peak intensity till 0900 UTC of the same day. The estimated central pressure during this period was 985 hPa with pressure drop of about 20 hPa. (**Fig. 4**)

3. **Monitoring of VSCS, “HAMOON”**

India Meteorological Department (IMD) maintained round the clock watch over the north Indian Ocean and the cyclone was monitored since 12th October, about 9 days prior to formation of depression on 21st October and 07 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 12th October (**Fig. 5a**), indicating formation of depression over southeast BoB during the week 2 (20-26 October, around 20th October with low probability (1-33%). Further, the extended range outlook issued on 19th October (**Fig. 5b**), indicated formation of depression on 21st October with high probability (68-100%) about 02 days ahead of formation over westcentral BoB and 5 days in advance of landfall over Bangladesh coast. The tropical Weather Outlook issued on 17th Oct. indicated formation of an upper air cyclonic circulation, low pressure area around 20th and depression around 21st. Since then the Daily Tropical Weather Outlooks issued indicated formation of depression over BoB around 21st (**Fig. 6**)

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. 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**. The INSAT 3D imageries during entire life cycle of the system, ASCAT and microwave imageries are placed in Annexure to this report.

4. Operational Forecast Performance:

i) Pre-Genesis Forecast performance

- ❖ First information about likely cyclogenesis over southeast BoB during the week (20th -26th Oct), around 21st was issued in the extended range outlook issued on 12th Oct. about 9 days prior to formation of depression on 21st Oct. **(Fig. 5(a))**
- ❖ The tropical Weather Outlook issued on 17th Oct. indicated formation of an upper air cyclonic circulation, low pressure area around 20th and depression around 21st. Since then the Daily Tropical Weather Outlooks issued indicated formation of depression over BoB around 21st **(Fig. 6)**
- ❖ Actually, a cyclonic circulation formed over southeast BoB on 17th Oct., low pressure area formed over southwest & adjoining southeast BoB on 20th and depression over westcentral BoB on 21st October. The cyclogenesis (formation of depression) was predicted 9 days ahead.
- ❖ The daily report under Tropical Cyclone Forecasting Programme (TCFP) for North Indian Ocean issued on 17th Oct., Detailed discussion of environmental features prevailing over the BoB and guidance from various models. Since 17th Oct., onwards, the system was continuously monitored and discussed in TCFP report.
- ❖ The first advisory based on 1800 UTC of 21st on formation of depression indicated initial northwest movement till 22nd / 0600 UTC, followed by gradual north-northeastward recurvature towards Bangladesh-West Bengal coast.
- ❖ Regular 6/3 hourly warnings were provided since then till the weakening of system into a well-marked low pressure area.
- ❖ The forecast based on 1200 UTC (1130 IST) of 22nd indicated, crossing of cyclone over Bangladesh coast between Khepupara and Chittagong around 25th October evening as a deep depression (about 03 days ahead of landfall). Observed track and forecast track & intensity issued based on 1200 UTC observation of 22nd October about 3 days ahead of landfall is presented in **Fig.8**.
- ❖ The warning was further updated and the bulletin issued at 0000 UTC (0530 IST) of 24th indicated the system to cross Bangladesh coast as a cyclonic storm around 1200 UTC of 25th October.
- ❖ The warning was further updated and the bulletin issued on 0600 UTC of 24th indicated the system to cross on Bangladesh coast around 2100 UTC of 24th October.

ii) Operational track, intensity and landfall forecast performance

- ❖ The track forecast errors for 12, 24, 48 and 72 hrs lead period were 58, 114, 263 and 394 km respectively against the long period average (LPA) errors (2018-22) of 46, 74, 112, and 153 km respectively **(Fig. 9a)**. For all lead periods upto 48 hours, the operational track forecast errors were comparable to LPA errors. The track forecast skill for 12, 24, 48 and 72 hrs lead period was 38, 38, 30 and 33% respectively against the long period average (LPA) errors (2018-22) of 61, 65, 77, and 78% respectively **(Fig. 9b)**. The operational 48 hrs track forecast

error was higher, as “HAMOON” had multiple recurvatures and rapid intensification. Both the situations adversely affected the forecast. Studies show that track & intensity are correlated. Increased error in track led to increased error in intensity prediction and vice-versa. Similarly recurving tracks are difficult to predict compared to straight moving cyclones.

- ❖ The absolute error (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 10.5, 16.4 and 6.7 knots against the LPA errors of 7.4, 10.5 and 14.0 knots during 2018-22 respectively (**Fig.10a**). The skill in intensity forecast based on AE for 24, 48 and 72 hrs lead period was 61, -4.6 and 82.6% against the LPA skill of 55, 74 and 77% during 2018-22 respectively (**Fig.10b**). 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. However, the errors for longer lead period (96 and 120 hrs) are comparable to long period average, as the weakening of the system prior to landfall was well captured based on environmental conditions and also by the models.
- ❖ The root mean square error (RMSE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 13.7, 18.8 and 9.1 knots against the LPA errors of 9.3, 13.1 and 16.8 knots during 2018-22 respectively (**Fig.11a**). The skill in intensity forecast based on RMSE for 24, 48 and 72 hrs lead period was 61, 15 and 81% against the LPA skill of 42, 61 and 73% during 2018-22 respectively (**Fig.11b**).
- ❖ The landfall point forecast errors for 24, 48 and 72 hrs lead period were 88.9, 176.0 km respectively against the LPA errors (2018-22) of 34, 52.6 km during 2018-22 respectively (**Fig.12a**).
- ❖ The landfall time forecast errors for 24, 36, 48 and 72 hrs lead period were 6.0, 8.0, 8.0 hours respectively against the LPA errors (2018-22) of 4.3, 4.5 and 5.9 hours during 2018-22 respectively (**Fig.12b**). The system moved faster under the influence of westerly trough which couldn't be captured operationally.

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 20th October till the system weakened into an LPA. The above forecasts were issued from the stage of depression 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 and ≥ 34 knots wind in four quadrants of cyclone was issued alongwith cone graphics, commencing from 21st October.
- **Adverse weather warning bulletins:** The tropical cyclone forecasts alongwith expected adverse weather like gale wind, state of sea for Bay of Bengal (north & central) 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. 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 “HAMOON” the advisories for winds & sea condition over north & central BoB were also provided to WMO and WMO/ESCAP PTC member countries including Bangladesh and Myanmar.

- **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 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, Cyclone warning centres at Bhubaneshwar, Visakhapatnam, Regional Meteorological Centra Kolkata and Guwahati, Meteorological Centra Agartala 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 18th October.
- **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 Officers. 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 20th Oct in daily cyclone forecasting programme bulletin commencing from 17th Oct.

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 | 40 | 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 Defense Staff, Director General Doordarshan, All India Radio, PIB MOES, UNI, DG National Disaster Response Force, Director, Punctuality, Indian Railways, Chief Secretary: Government of Kerala, Karnataka, Goa, Maharashtra, Gujarat ,Daman |

| | | | |
|----|---|------------|---|
| | | | & Diu ,Dadra and Nagar Haveli |
| 2 | RSMC Bulletin | 42 | 1. IMD's website 2. WMO/ESCAP member countries through GTS and E-mail. |
| 3 | GMDSS Bulletins | 16 | 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 | 12 | 1. Met Watch offices in Asia Pacific regions and middle east through GTS to issue Significant Meteorological information for International Civil Aviation 2. WMO's Aviation Disaster Risk Reduction (ADRR), Hong Kong through ftp 3. RSMC website |
| 5 | Tropical Cyclone Vital Statistics | 12 | Modelling group of IMD, National Centre for Medium Range Weather Forecasting Centre (NCMRWF), Indian National Centre for Ocean Information Services (INCOIS), Indian Institute of Technology (IIT) Delhi, IIT Bhubaneswar etc. |
| 6 | Warnings through SMS | Frequently | SMS to disaster managers at national level and concerned states (every time when there was change in track, intensity and landfall characteristics) 4,19,581 to General Public 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 | 7 | Disaster Managers, Media persons by email and uploaded on website |
| 9 | Press Briefings | Daily | Regular briefing daily |
| 10 | Hourly Bulletin | - | - |

8. Realized Weather

As estimated the MSW of 90-100 kmph gusting to 110 kmph (50 knots gusting to 60 knots) were observed during landfall. The estimated MSW and wind distribution in different quadrant during the life cycle of VSCS HAMOON is presented in **Fig. 13**.

IMD predicted storm surge of height 1.0-1.5 m to inundate the low lying areas of Bangladesh between Khepupara and Chittagong. The estimated surge is presented in **Fig.14**.

9. Damage report

As per media reports from Bangladesh, VSCS Hamoon caused 3 deaths in Bangladesh. It caused widespread floods and power outages, extensive damage to buildings, cell phone towers, trees etc. in Bangladesh. Some damage photographs are presented in **Fig. 15**.

10. Acknowledgements:

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. India Meteorological Department (IMD) and RSMC New Delhi duly acknowledge contribution from WMO and WMO/ESCAP member countries including Yemen and Oman. All the stake holders and disaster management agencies who contributed to the successful monitoring, prediction and early warning service of VSCS HAMOON. The support from various Divisions/Sections of IMD including Area Cyclone Warning Centre (ACWC) Kolkata, Cyclone Warning Centre Bhubaneshwar, Visakhapatnam, and Meteorological centres Agartala. Numerical Weather Prediction Division, Satellite and Radar Division, Surface & Upper air instruments Divisions, and Information System and Services Division of IMD is also duly acknowledged.

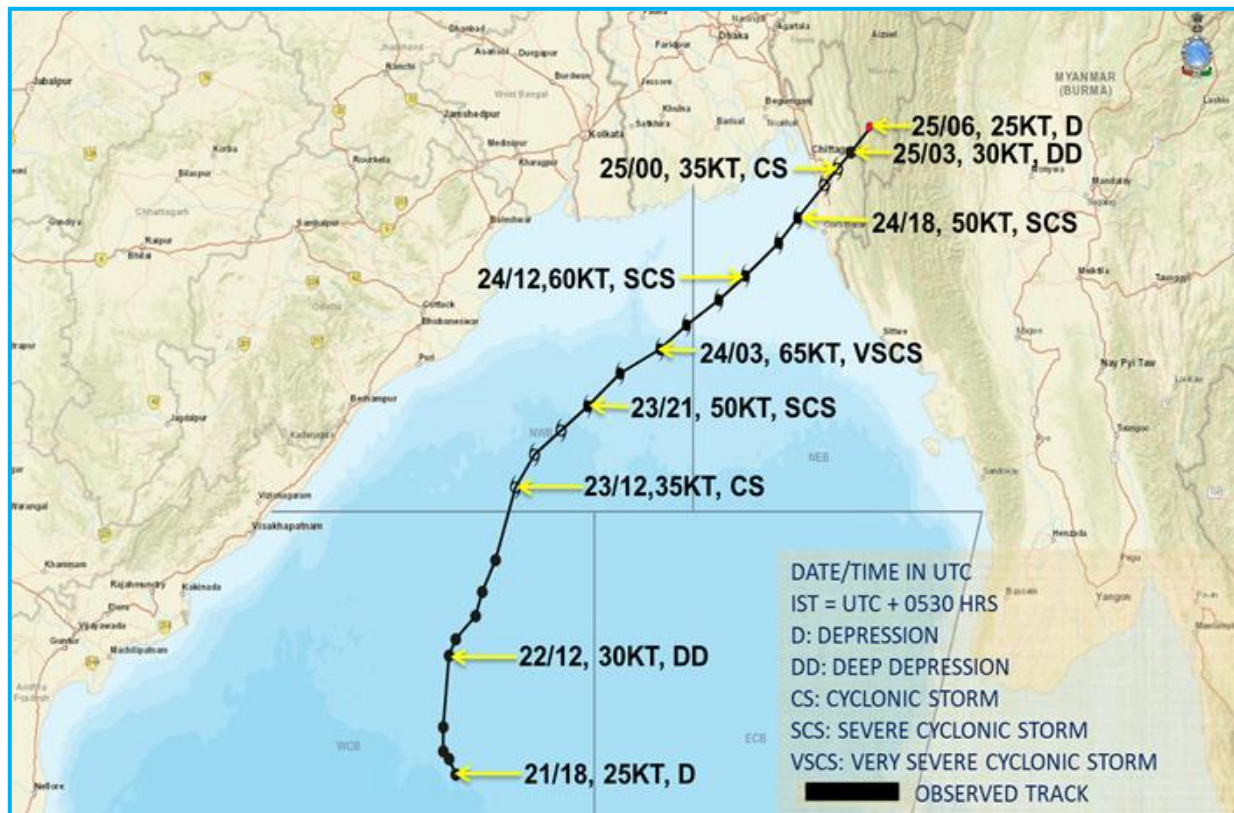


Fig. 1: Observed track of very severe cyclonic storm “HAMOON” during 21-25 October, 2023

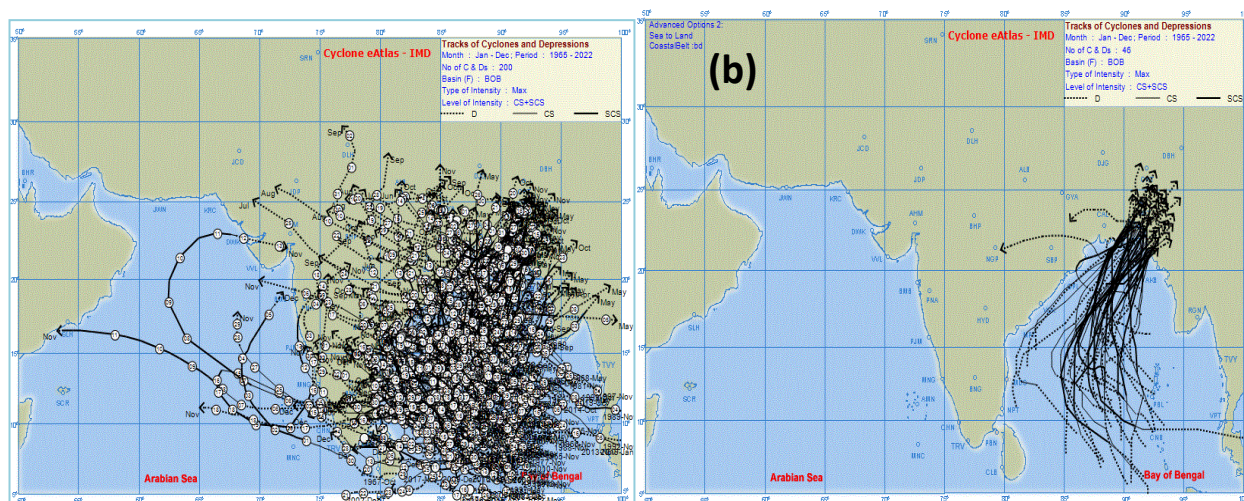


Fig. 2: Climatological tracks of (a) all cyclones (MSW≥62 kmph) developing over Bay of Bengal and (b) cyclonic storms (MSW ≥62 kmph) crossing Bangladesh coasts during satellite era (1965-2022)

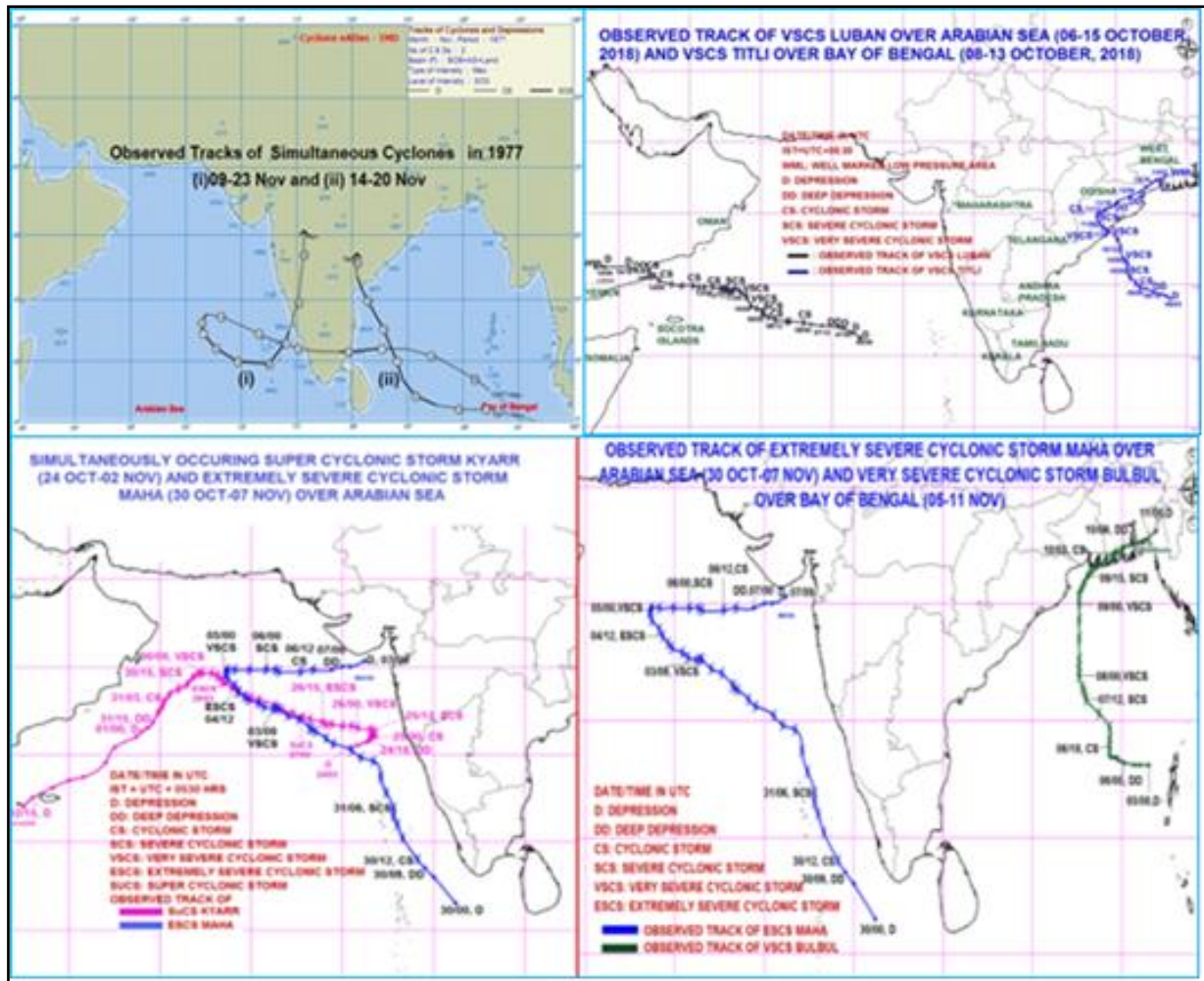


Fig. 3: Tracks of twin cyclones over the Arabian Sea and Bay of Bengal during (a) 1977, (b) 2018 and (c) 2019

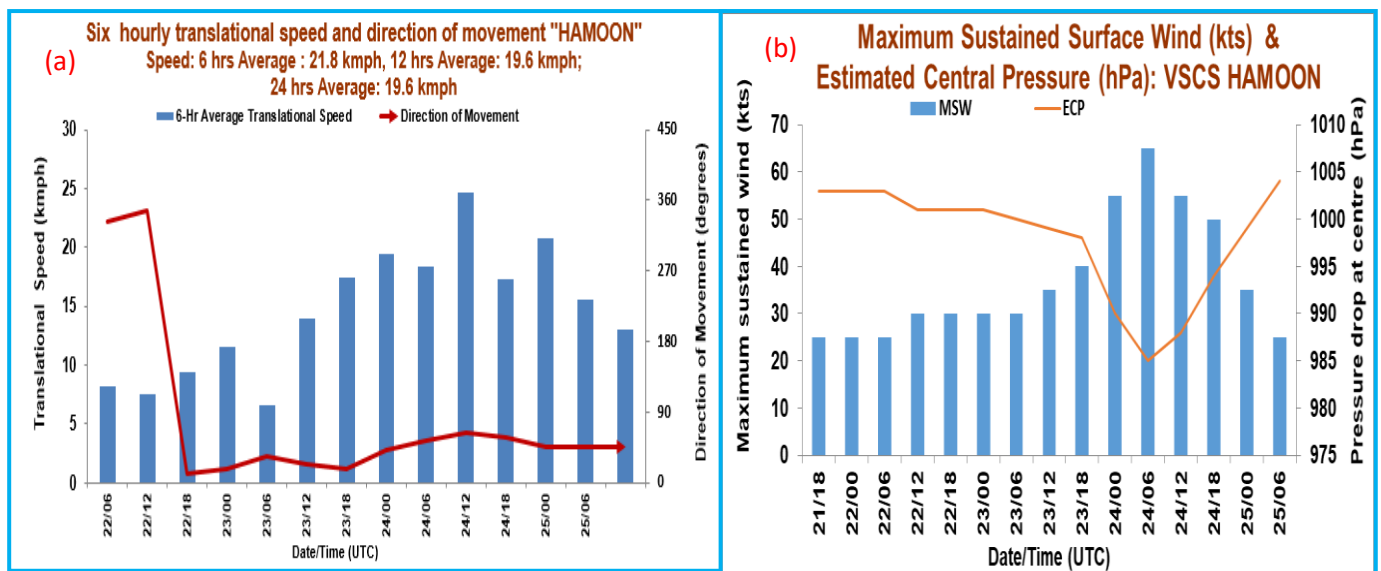


Fig. 4: (a) 6-hourly translational speed & direction of movement and (b) maximum sustained wind speed & estimated central pressure during life cycle of VSCS "HAMOON"

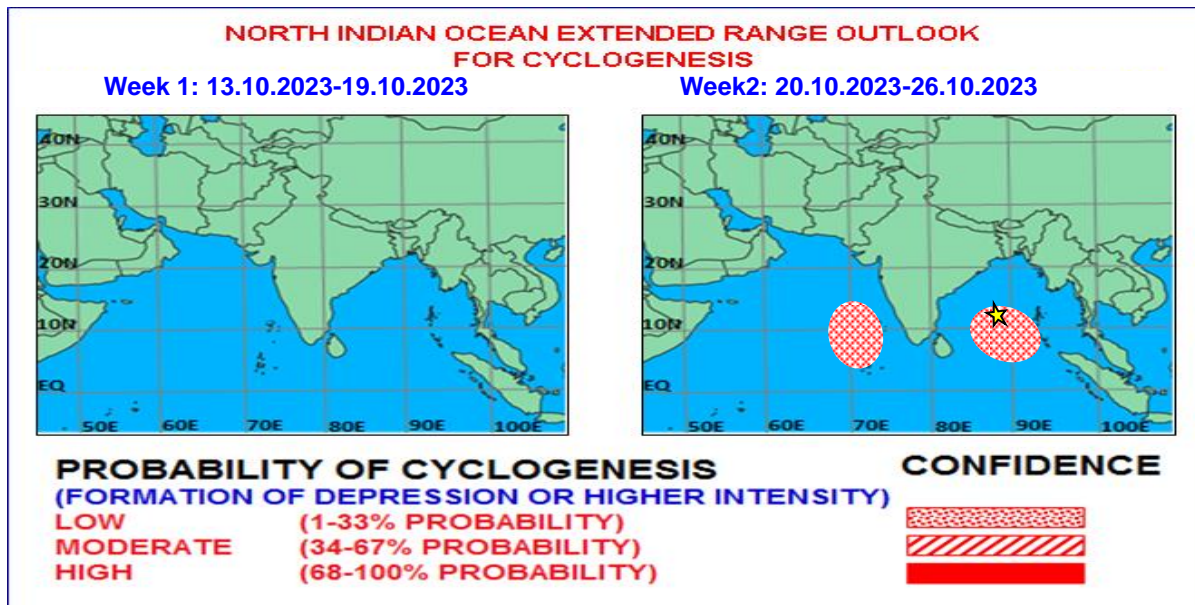


Fig. 5(a): Weekly extended range outlook issued by IMD on 12th October about 9 days prior to formation of depression on 21st October and 12 days prior to the landfall of system over Bangladesh coast indicating formation of depression over central BoB during the week 2 (20-26 October, around 20th October with low probability (1-33%).

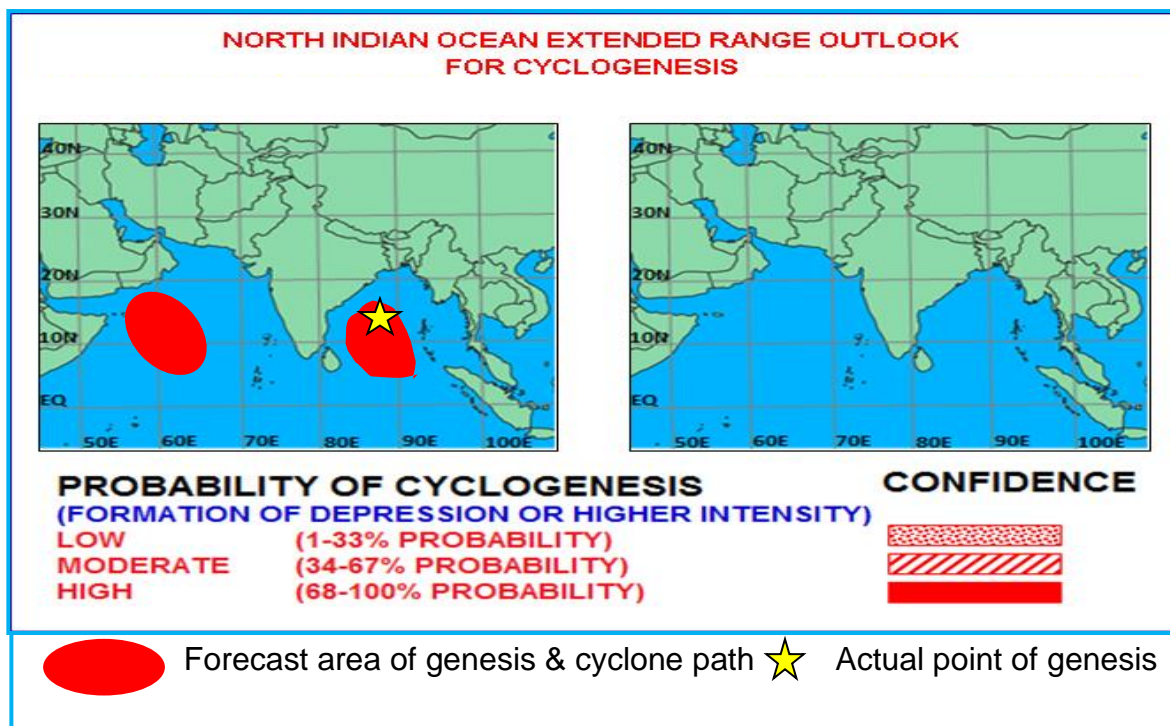


Fig. 5(b): Weekly extended range outlook issued by IMD on 19th October indicating formation of depression around 21st October with high probability (68-100%) about 1 day ahead of formation over central BoB and 4 days in advance of landfall over Bangladesh.

A CYLONIC CIRCULATION LAY OVER SOUTHEAST BAY OF BENGAL AND ADJOINING ANDAMAN SEA EXTENDING UPTO 3.1 KM ABOVE MEAN SEA LEVEL, AT 0300 UTC OF 17TH OCTOBER, 2023. IT IS LIKELY TO MOVE WEST-NORTHWESTWARDS AND UNDER ITS INFLUENCE A LOW-PRESSURE AREA IS LIKELY TO FORM OVER CENTRAL PARTS OF BAY OF BENGAL AROUND 20TH OCTOBER.

SCATTERED TO BROKEN LOW AND MEDIUM CLOUDS WITH EMBEDDED INTENSE TO VERY INTENSE CONVECTION LAY OVER SOUTH BAY OF BENGAL AND SOUTH ANDAMAN SEA. SCATTERED LOW AND MEDIUM CLOUDS WITH EMBEDDED ISOLATED MODERATE TO INTENSE CONVECTION LAY OVER EASTCENTRAL BAY OF BENGAL AND NORTH ANDAMAN SEA.

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 | NIL | NIL | NIL | LOW | LOW |

Fig. 6: Tropical Weather Outlook dated 17th October indicating an upper air cyclonic circulation and formation of low pressure area around 20th and depression around 21st with moderate probability (34-66%).

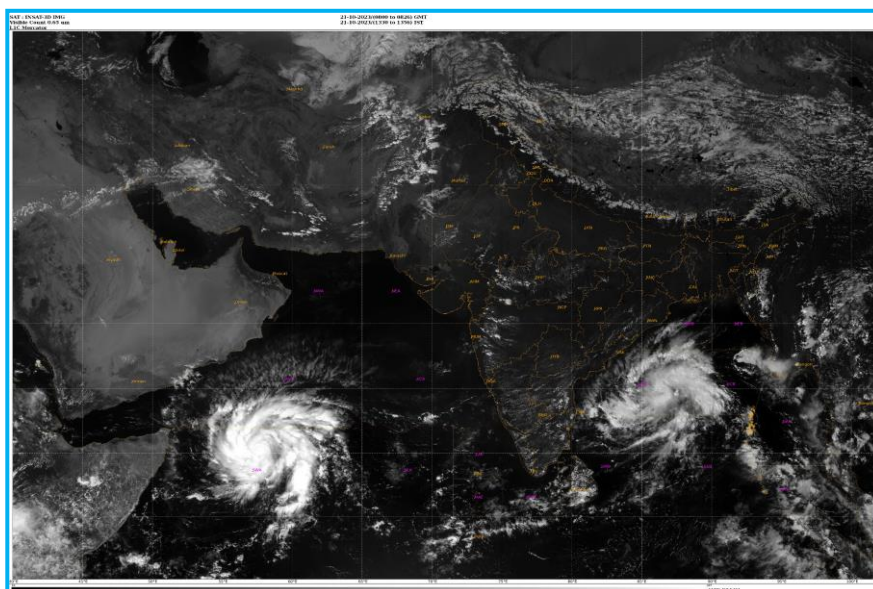


Fig.7: Typical INSAT 3D (R) imagery showing twin Cyclones

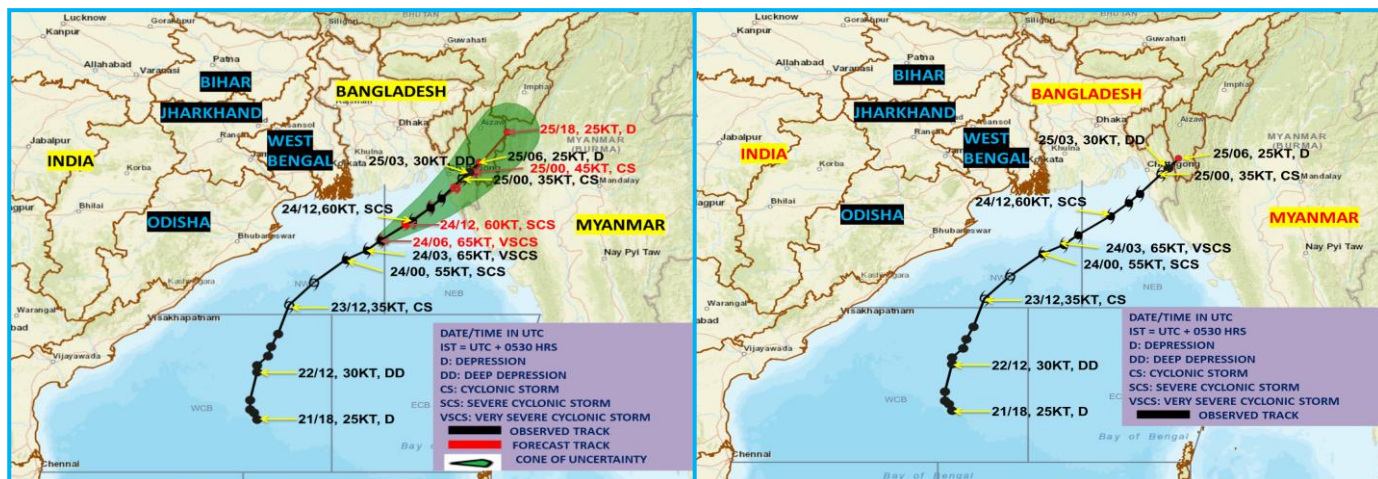


Fig. 8: Observed track and forecast track & intensity issued based on 0600 UTC observation of 24th October about 14 hours ahead of landfall.

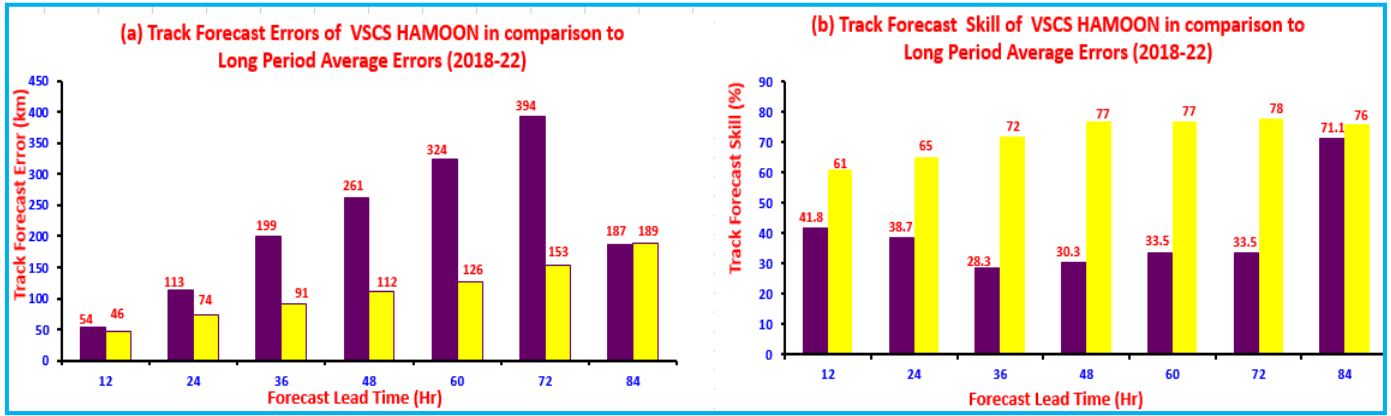


Fig. 9: (a) Track forecast errors and (b) track forecast skill against the long period average (LPA) errors (2018-22).

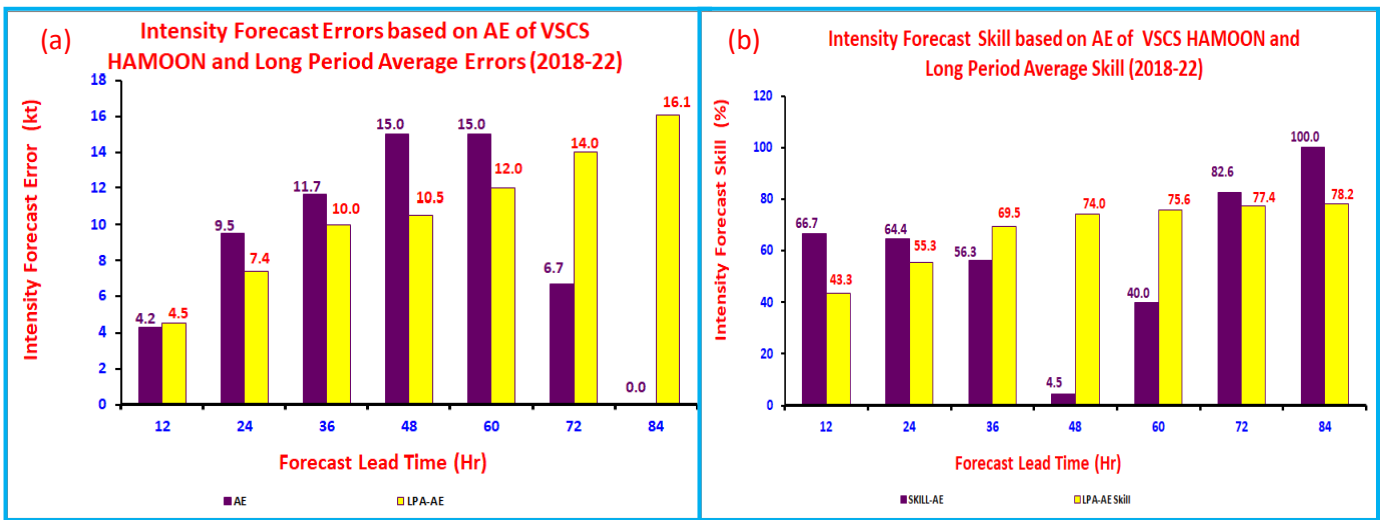


Fig. 10: (a) Intensity forecast errors (AE) and (b) intensity forecast skill against the long period average (LPA) errors (2018-22).

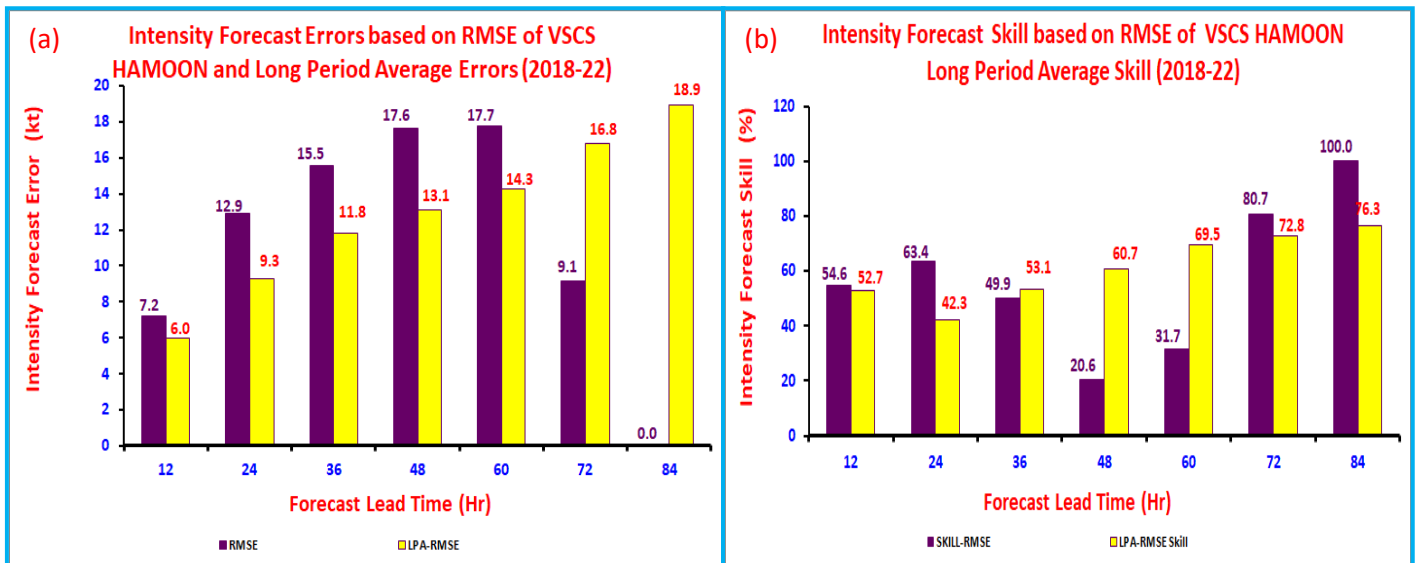


Fig. 11: (a) Intensity forecast errors (RMSE) and (b) Intensity forecast skill against the long period average (LPA) errors (2018-22).

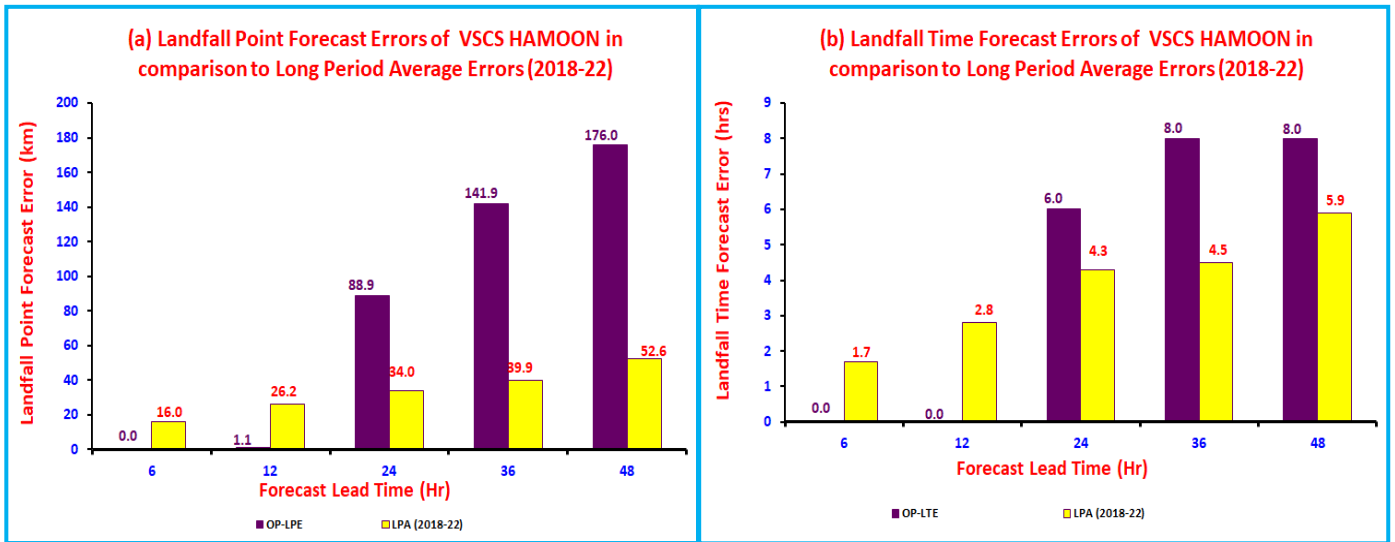


Fig. 12: (a) Landfall point and (b) time error against the long period average (LPA) errors (2018-22).

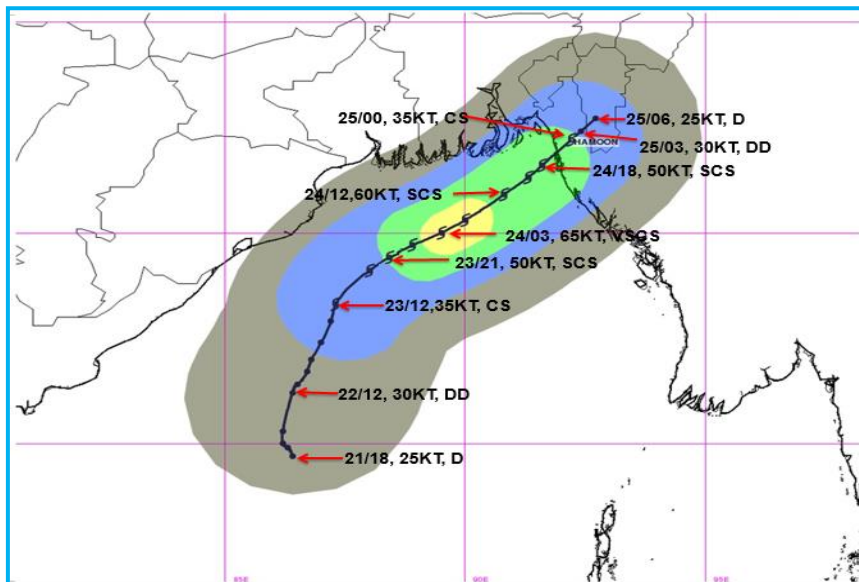


Fig. 13: The estimated MSW during the life cycle of VSCS HAMOON

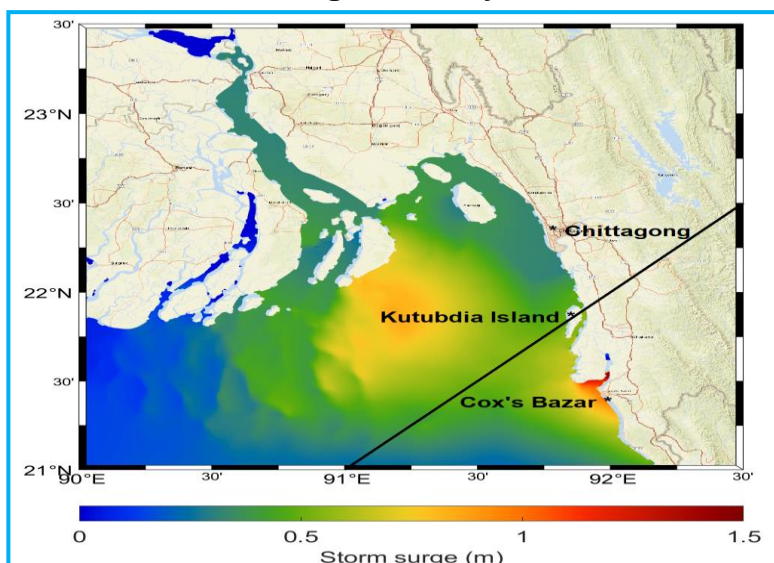


Fig. 14: The estimated Storm Surge during the life cycle of VSCS HAMOON

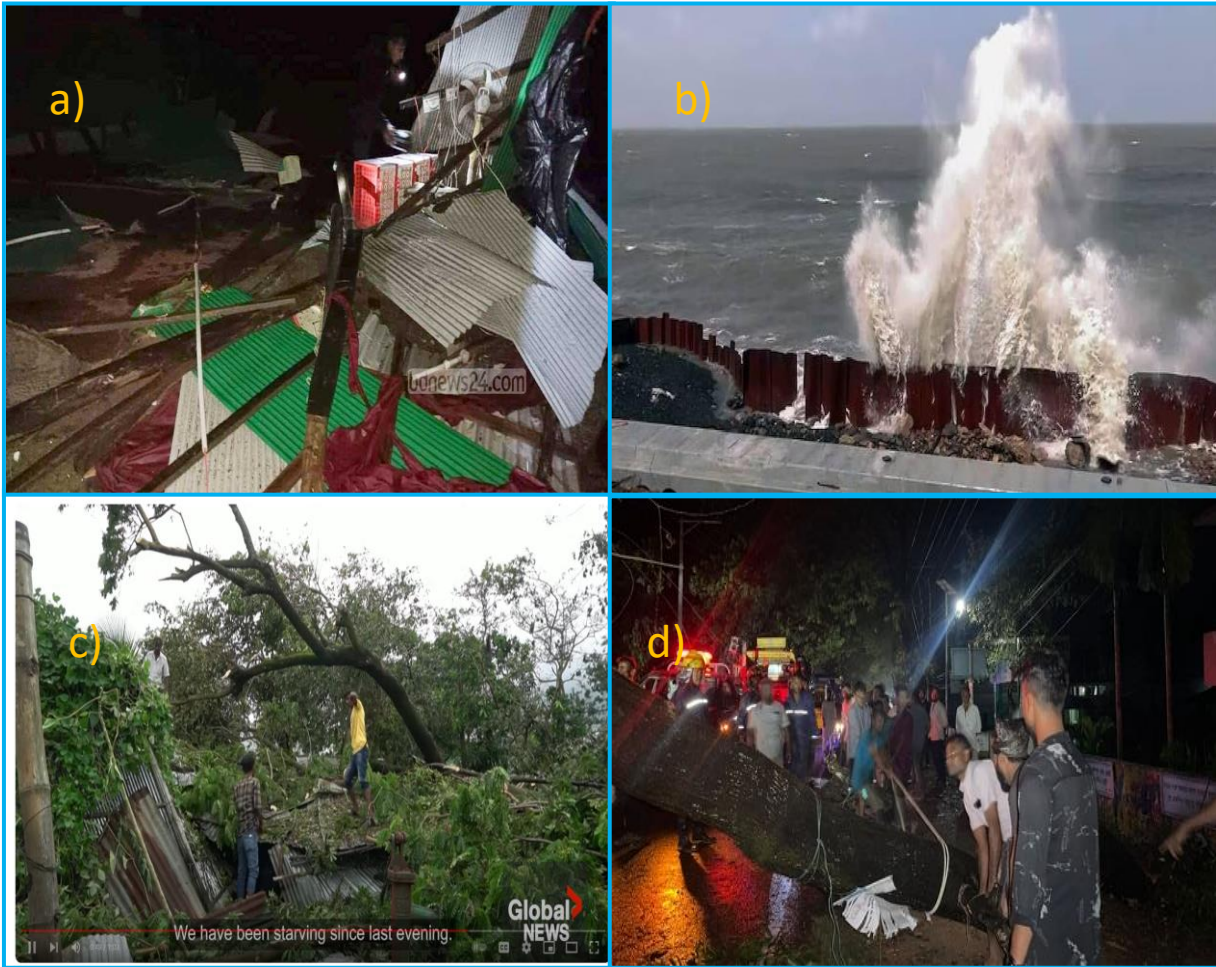


Fig. 15 (a) Cyclone Hamoon leaves long trail of destruction in Cox's Bazaar.(bdnews24.com 2nd Nov 2023) (b) Cyclone Hamoon: Two killed; at least 275,000 people flee to shelters in Bangladesh (Hindustan Times) (c) Cyclone Hamoon slams Bangladesh, killing at least 3 (Global News Youtube). <https://www.youtube.com/watch?v=WYOGoya1PME> (d) Cyclone Hamoon crosses Bangladesh's coastal belt killing 3 and injuring 60 other.