



Cyclonic Storm SITRANG over the BoB (22nd-25th October, 2022): A Report

1. Life History of SITRANG:

- A low pressure area formed over North Andaman Sea and adjoining areas of south Andaman Sea & Southeast Bay of Bengal (BoB) in the early morning (0530 hrs IST/0000 UTC) of 20th October, 2022. It lay as a well marked low pressure area over north Andaman Sea and adjoining southeast BoB in the evening (1730 hours IST/1200 UTC) of 21st October.
- Under favourable environmental conditions, it concentrated into a depression over southeast and adjoining eastcentral BoB close to Andaman Islands in the forenoon (0830 hrs IST/0300 UTC) of 22nd October, 2022.
- It moved northwestwards and intensified into a deep depression over westcentral BoB in the early morning (0530 hrs IST/0000 UTC) of 23rd October.
- Thereafter, it moved nearly northwards and intensified into the cyclonic storm (CS) "SITRANG" in the evening (1730 hrs IST/1200 UTC) of 23rd October. It then gradually recurved north-northeastwards and crossed Bangladesh coast between Tinkona and Sandwip close to Barisal (near 22.15^oN/90.35^oE) in the night of 24th October during 2130 to 2330 hours IST/ 1600 to 1800 UTC of 24th October as a cyclonic storm with maximum sustained wind speed of 80-90 kmph gusting to 100 kmph.
- Continuing to move north-northeastwards, it weakened into a deep depression over northeast Bangladesh in the early hours (0230 hours IST of 25th/2100 UTC of 24th), into a depression over interior Bangladesh in the early morning (0530 hours IST/ 0000 UTC) of 25th October and into a well marked low pressure area over northeast Bangladesh & adjoining Meghalaya in the forenoon (0830 hours IST/0300 UTC) of 25th October, 2022.
- The observed track of the system is presented in **Fig. 1**.

2. Salient Features

- Recurving track:** CS Sitrang initially moved northwestwards under the influence of southeasterly winds in middle and upper tropospheric levels prevailing to the south of ridge near 20^oN till 23rd morning, thereafter it recurved gradually north-northeastwards from 23rd night under the influence of trough in westerlies and an anticyclone to its east over Myanmar.
- Fast movement:** CS Sitrang exhibited very fast movement on 24th under the influence of westerly trough, anticyclone over Myanmar and interactions with land. 6 hourly average translational speed of the system was about 21.8 kmph against the normal of 12.9 kmph for CS category over the BoB during post monsoon season. It moved very fast with a speed of about 50 kmph during 1200-1800 UTC of 24th while crossing Bangladesh coast (**Fig. 2**). Such a high translational speed (about 40 kmph) was last observed during extremely severe cyclonic storm, Sidr (11-16 November, 2007) which crossed Bangladesh coast around 1700 UTC of 15th November, 2007 near 89.8^oE.
- Short life period:** The life period of the storm (depression to depression) was about 69 hours (2 days and 21 hours) against the long period average (LPA) (1990-2013) of about 88 hours (3 days & 16 hrs) for CS category over the BoB during post-monsoon season.

- (iv) **Sheared Storm:** The satellite observations detected the sheared nature of the convective clouds in association with the cyclonic storm due to the formation of the system in an environment with moderate vertical wind shear. The clouds were sheared to the north of the cyclone centre. The environmental vertical wind shear impacted the storm motion and intensification of the system during its short life period..
- (v) **Damage Potential and Power Dissipation Index:** The Accumulated Cyclone Energy (a measure of damage potential) and Power Dissipation Index (a measure of loss) in association with CS Sitrang were 0.97×10^4 knots² and 0.40×10^6 knots³ respectively against the normal of 1.00×10^4 knots² and 0.40×10^6 knots³ for CS during post monsoon season over the BoB based on the data during 1990-2020.

3. Monitoring of Cyclonic Storm, SITRANG:

India Meteorological Department (IMD) maintained round the clock watch over the north Indian Ocean and the cyclone was monitored since 6th October, about 11 days prior to the formation of cyclonic circulation over eastcentral BoB and adjoining North Andaman Sea on 17th October, 14 days prior to formation of low pressure area over North Andaman Sea on 20th October and 16 days prior to actual genesis (formation of depression) on 22nd October. The information about the system was first released in the weekly extended range outlook issued by IMD on 6th October. The cyclone was monitored with the help of available satellite observations from INSAT 3D and 3DR, polar orbiting satellites and available ships & buoy observations in the region. On the day of landfall observations from Bangladesh Meteorological Department were utilised for monitoring the system. Various global models and dynamical-statistical models run by Ministry of Earth Sciences (MoES) institutions including IMD, NCMRWF, IITM and INCOIS were utilized to predict the genesis, track, landfall and intensity of the cyclone as well as associated severe weather. A digitized forecasting system of IMD was utilized for analysis and comparison of various numerical weather prediction model guidance, decision making process and warning products generation. Typical satellite based imageries from INSAT 3D (R) and sea surface wind based on Advanced Scatterometer (ASCAT) are presented in **Fig.3**.

4. Forecast Performance:

i) Genesis Forecast

- First information about likely formation of cyclonic circulation over eastcentral & adjoining North Andaman Sea during the week 14th-20th October, with low probability (1-33%) of its intensification into a depression (cyclogenesis) was issued in the extended range outlook issued by IMD on 6th October.
- Subsequent information about likely formation of low pressure area around 20th and its intensification into depression (cyclogenesis) with moderate confidence (34-67%) during beginning of the week 21-27 October was indicated in the extended range outlook issued on 13th October (**Fig.4a**).
- Further in the extended range outlook issued on 20th October, it was indicated with high confidence (68-100%) that a depression would form over eastcentral & adjoining southeast BoB around 22nd October, intensify into a cyclonic storm over westcentral and adjoining eastcentral BoB by 24th October. It was also indicated that the system would exhibit north-northeastwards recurvature and reach near West Bengal - Bangladesh coasts by 25th (about 102 hours prior to landfall over Bangladesh) (**Fig.4b**).

- The formation of cyclonic circulation on 18th and formation low pressure area on 20th under its influence was predicted on 15th October.
- The daily tropical weather outlook issued at 0700 UTC of 19th October indicated the formation of cyclonic circulation over north Andaman Sea and neighbourhood. It further stated that under its influence, a low pressure area would form over southeast and adjoining eastcentral BoB on 20th which would concentrate into a depression by 22nd morning over central BoB and into a cyclonic storm over westcentral BoB during subsequent 48 hours. Actually, the low pressure area formed on 20th, which became depression on 22nd morning and a cyclonic storm on 23rd evening.

ii) Operational track, intensity and landfall forecast performance

The operational track, intensity and landfall point & time forecast errors are presented in Fig.4-6.

- ❖ The track forecast errors for 24, 48 and 60 hrs lead period were 82, 126 and 205 km respectively against the long period average (LPA) errors (2017-21) of 73, 106, and 122 km respectively (**Fig. 5**). The relatively higher error in the track forecast for 48 and 60 hrs was mainly due to the fast movement of the cyclone during evening and night of 24th October under the influence of westerly trough to the west of cyclone centre and also the fact that Sitrang had followed a recurving track.
- ❖ The landfall point forecast errors for 24, 48 and 60 hrs lead period were 17.4, 33.5, 35.0 km respectively against the LPA errors (2017-21) of 31.9, 61.5 and 61.1 km during 2017-21 respectively (**Fig.6**). The pre-genesis forecast issued at 0300 UTC of 21st October (about 3.5 days prior to landfall) indicated landfall over Bangladesh coast with an error of about 82.5 km against the LPA error of about 120 km for 84 hours lead period. **Though, it was a recurving track, the landfall point errors were appreciably less than the LPA errors for all lead period.**
- ❖ The landfall time forecast errors for 24, 48 and 60 hrs lead period were 3.0, 5.0 and 5.5 hours respectively against the LPA errors (2017-21) of 2.5, 5.0 and 5.3 hours during 2017-21 respectively (**Fig.6**). **For all lead periods, the landfall time errors were comparable to the LPA errors.**
- ❖ The absolute error (AE) of intensity (wind) forecast for 24, 48 and 60 hrs lead period were 6.2, 8.2 and 12.7 knots against the LPA errors of 7.8, 11.5 and 12.7 knots during 2017-21 respectively (**Fig.7**). **The error in intensity forecast were appreciably less than the LPA errors for all lead periods.**
- ❖ Typical observed and forecast track based on 0830 hours IST/0300 UTC of 22nd October on formation of depression (63 hours prior to landfall) demonstrating accuracy in forecast is presented in **Fig. 8**.

iii)Forecast and realised severe weather:

(a) Heavy Rainfall

- Warning for isolated heavy rainfall on 24th over coastal districts of Odisha (Puri, Jagatsinghpur, Kendrapara districts) and isolated heavy rainfall over coastal districts (Balasore and Bhadrak districts) on 25th was issued on 21st. It was modified on 24th morning with only light to moderate rainfall forecast over the above areas.
- Warning for isolated heavy rainfall on 24th and isolated heavy to very heavy rainfall on 25th over coastal districts of West Bengal (South and north 24 Parganas, east Medinipur) was issued on 21st.

- Warning for isolated heavy rainfall over Assam, Meghalaya, Nagaland, Manipur, Mizoram, Tripura on 24th and isolated heavy to very heavy rainfall over these areas on 25th was issued on 21st. Further updates were provided regularly till 25th October.

Realised rainfall during past 24 hrs ending at 0830 IST of 25th October 2022:

Light to moderate rainfall occurred at isolated places over Odisha and at a few places over coastal West Bengal. Rainfall occurred at most places with extremely heavy rainfall at isolated places over Meghalaya; isolated heavy to very heavy rainfall over Arunachal Pradesh and isolated heavy rainfall over Assam and Manipur.

24 hours accumulated heavy rainfall (≥ 7 cm) ending at 0830 hours IST of 25th October is given below:

- ❖ Meghalaya: Mawphlang (Dist East Khasi Hills) 25, Pynursla (Dist East Khasi Hills) 25, Williamnagar (Dist East Garo Hills) 23, Shora (Dist East Garo Hills) 22, Secretariat_Hills(ARG) (Dist East Garo Hills) 21, Shillong (AWS) (Dist East Khasi Hills) 21, Shillong C.S.O. (Dist East Khasi Hills) 20, Mawkyrwat (ARG) (Dist South West Khasi Hills) 18, Barapani (Dist Ribhoi) 18, Nongstoin (Dist West Khasi Hills) 13, Khliehriat (Dist East Jaintia Hills) 12, Baghmara (Dist South Garo Hills) 10;
- ❖ Arunachal Pradesh: Bomdila (Dist West Kameng) 12, Kalaktang (Dist West Kameng) 10, Kibithu (Dist Anjaw) 9, Basar (Dist West Siang) 8, Ziro (Dist Lower Subansiri) 8, Koloriang (Dist Kurung Kumey) 7, Jung_ARG (Dist Tawang) 7, Kabu Basti (Dist West Siang) 7, Palin(ARG) (Dist Kra Daddi) 7;
- ❖ Assam: Khanapara (Dist Kamrup Metropolitan) 10, Dudhnoi Kvk(AWS) (Dist Goalpara) 9, Khetri (ARG) & Chandmari (Dist Kamrup Metropolitan) 9, Drf & GoibARGaon (Dist Baksa) 8, Pandu, Nongpoh (Dist Rhibhoi) 8, Goibergaon (Dist Baksa) 8, Udaipur (Dist Tinsukia) 8, Umrangshu (ARG) (Dist West Karbi Anglong) 7, Motunga (Dist Tamulpur) 7, Nalbari (Dist Nalbari) 7, Tamulpur (Dist Baksa) 7, Chandrapur ARG (Dist Kamrup (Rural)) 7, Kheronighat (Dist Karbi Anglong) 7, Guwahati (Dist Kamrup (M)) 7;
- ❖ Manipur: Ukhrul (Dist Ukhrul) 10, Ukhrul AWS (Dist Ukhrul) 9, Churachandpur (Dist Churachandpur) 7, Senapati (Dist Senapati) 7;

The spatial distribution of rainfall based on satellite and raingauge based merged dataset prepared by MoES during 22nd – 25th October is shown in **Fig. 9**.

(b) Wind:

- The maximum sustained wind speed of 90-100 gusting to 110 kmph was predicted along & off Bangladesh coast during 24th evening to 25th morning, and 80-90 kmph gusting to 100 kmph along & off 24 Parganas districts and 60-70 gusting to 80 kmph along & off east Medinipur district of West Bengal coast and 50-60 kmph gusting to 70 kmph along & off Balasore district and 45-55 gusting to 65 kmph along & off remaining districts of north coastal Odisha and over Mizoram and Tripura was predicted in the bulletin issued at 1300 hrs IST of 22nd.
- It was modified as 70-90 kmph gusting to 100 kmph along & off 24 Parganas districts and 60-70 gusting to 80 kmph along & off east Medinipur district of West Bengal coast and 45-55 kmph gusting to 65 kmph along & off Balasore district and 40-50 gusting to 60 kmph along & off remaining districts of north coastal Odisha and over Mizoram and Tripura was predicted in the bulletin issued at 1220 hrs IST of 23rd.
- It was modified as 40-50 kmph gusting to 60 kmph along & off Balasore district and 35-45 gusting to 55 kmph along & off remaining districts of north coastal Odisha and 50-60 kmph gusting to 70 kmph over Tripura, 45-55 gusting to 65 kmph over Mizoram, south Assam and

adjoining areas of east Meghalaya and Manipur was predicted in the bulletin issued at 1200 hrs IST of 24th.

Estimated maximum sustained wind (MSW) speed of intensity 80-90 kmph gusting to 100 kmph prevailed along & off Bangladesh coast during landfall. MSW of intensity 60-70 kmph gusting 80 kmph prevailed along & off North and South 24 Parganas including Sunderbans forest area during the time of landfall. Kolkata reported MSW of 44 kmph at 1647 IST of 24th October. MSW of 50-60 kmph gusting to 70 kmph prevailed over Tripura and 40-50 kmph gusting to 60 kmph over Meghalaya, South Assam & adjoining Mizoram and along and off north Odisha coast. The estimated wind distribution in association with the system is given in **Fig.10**.

(c) Forecast and realised storm surge:

First information about the expected storm surge of height about 2.0 m above astronomical tide for Bangladesh coast was issued in the special tropical weather outlook issued at 0630 UTC (1200 IST) of 23rd October at the stage of deep depression about 60 hours prior to landfall. storm surge of height about 1 meter above astronomical tide for West Bengal coast (South and north 24 Parganas including Sunderbans) was issued on 23rd October (1200 IST/0630 UTC).

The peak storm surge of about 1.7 m above astronomical tide occurred around Sitakund area of Bangladesh, whereas the maximum storm surge of about 0.5 m occurred along the West Bengal coast (Sunderbans) (**Fig. 10**). This peak storm surge occurred near Sitakund at a distance of about 130 km to the right of the cyclone's landfall point mainly because of the strong onshore winds in the cyclone's right forward quadrant at a distance equal to radius of maximum wind and the funnelling shape of the head BoB along the coastal stretch between Chattogram and Sitakund of Bangladesh. **The estimated storm surge at the time of landfall is presented in Fig. 11.**

Thus, the genesis, forecast track, intensity and landfall were reasonably predicted well in advance alongwith the adverse weather advisories for Bangladesh.

5. Warnings and advisories issued

- Considering the development of cyclonic storm over westcentral BoB, IMD issued first Special Message and Press Release at 1400 hours IST of 20th October on formation of low pressure area over North Andaman Sea and neighbourhood. It was also indicated that the system would intensify into a depression and cyclonic storm by 22nd and 24th October respectively. The movement of the system towards West Bengal-Bangladesh coasts was also predicted.
- Special Message and Press Release were further updated on 21st October along with the forecast track, intensity and wind distribution around the system centre upto next 5 days. It was also indicated that the system would cross Bangladesh coast and Bangladesh & adjoining West Bengal coasts would be worst impacted by the storm. **Thus, the landfall of the cyclone with a wind speed of 90-100 kmph gusting to 110 kmph was predicted by IMD when the system was a low pressure area over Andaman Sea and three and a half days in advance of landfall time of the cyclone.**
- **Pre cyclone watch** for West Bengal coast was issued at 1300 hours IST of 22nd October with the formation of depression over southeast & adjoining eastcentral BoB (about 60 hours prior to landfall of Sitrang over Bangladesh coast).

- **Cyclone Alert** for West Bengal coast was issued with intensification of depression into deep depression over eastcentral BoB at 0900 hrs IST of 23rd (about 40 hours prior to landfall of Sitrang).
- It was upgraded as **Cyclone Warning** for West Bengal coast and was issued at 0230 hours IST of 24th October (about 20 hours prior to landfall of Sitrang).

A total of 23 National bulletins including 2 special messages for national and state level disaster managers, 6 press releases for print & electronic media, 3 Special Messages from Director General of IMD for high level disaster management officers, 23 tropical cyclone advisories & special tropical weather outlook for WMO/ESCAP Panel member countries including Bangladesh & Myanmar, 9 tropical cyclone advisories for International Civil Aviation, 11 advisories for sea area under Global Maritime Distress Safety System, 17 customised location specific bulletins for offshore/onshore operators, daily video updates, regular updates on social media (Facebook, WhatsApp, Twitter), SMS to disaster managers, general public, fishermen and farmers were issued by IMD Headquarter along with similar action by state level offices at Andhra Pradesh, Odisha, West Bengal and Andaman & Nicobar Islands and INCOIS for fishermen. Regular messages were also sent to Bangladesh & Myanmar through WhatsApp in association with this system.

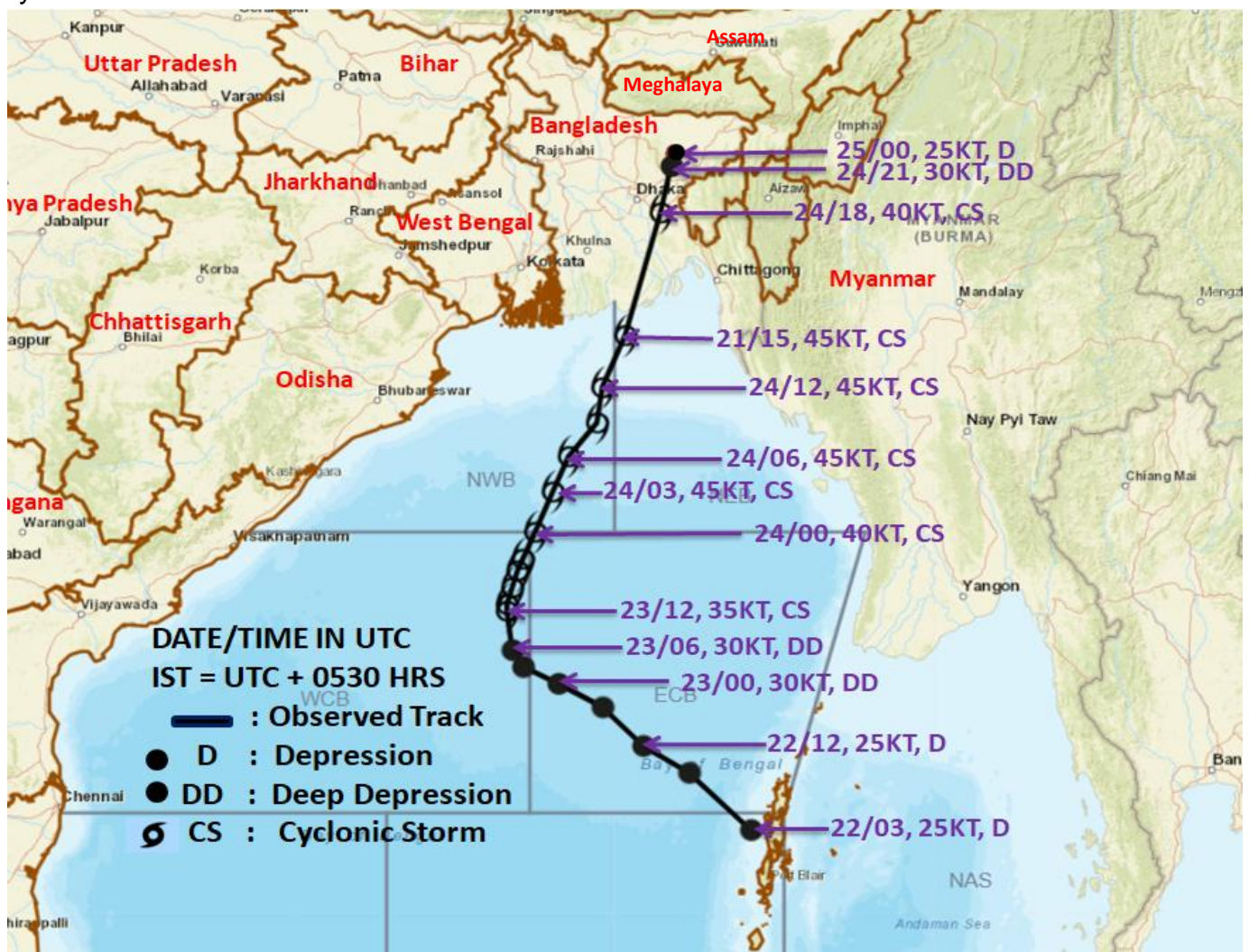


Fig. 1: Observed track of cyclonic storm 'SITRANG' over the BoB during 22nd- 25th October, 2022

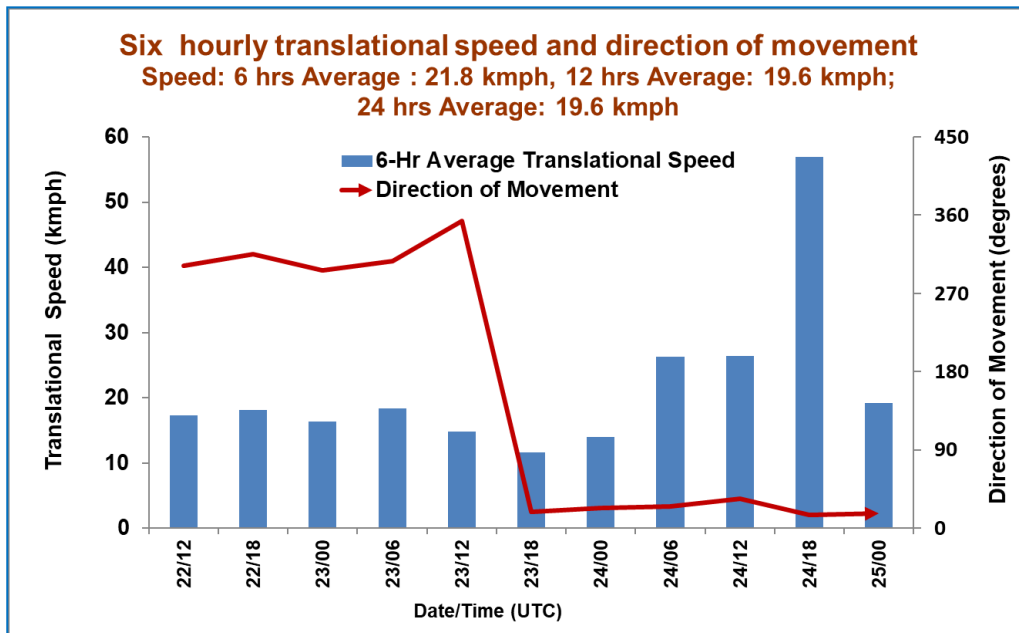


Fig. 2: Past six hourly average translational speed ending at date/time mentioned in the X-axis and direction of movement of cyclonic storm ‘SITRANG’ over the BoB during 22nd- 25th October, 2022 indicating very high speed of the system during 22/1200 UTC to 22/1800 UTC just before landfall against the average translational speed of 21.8 kmph during the entire life cycle

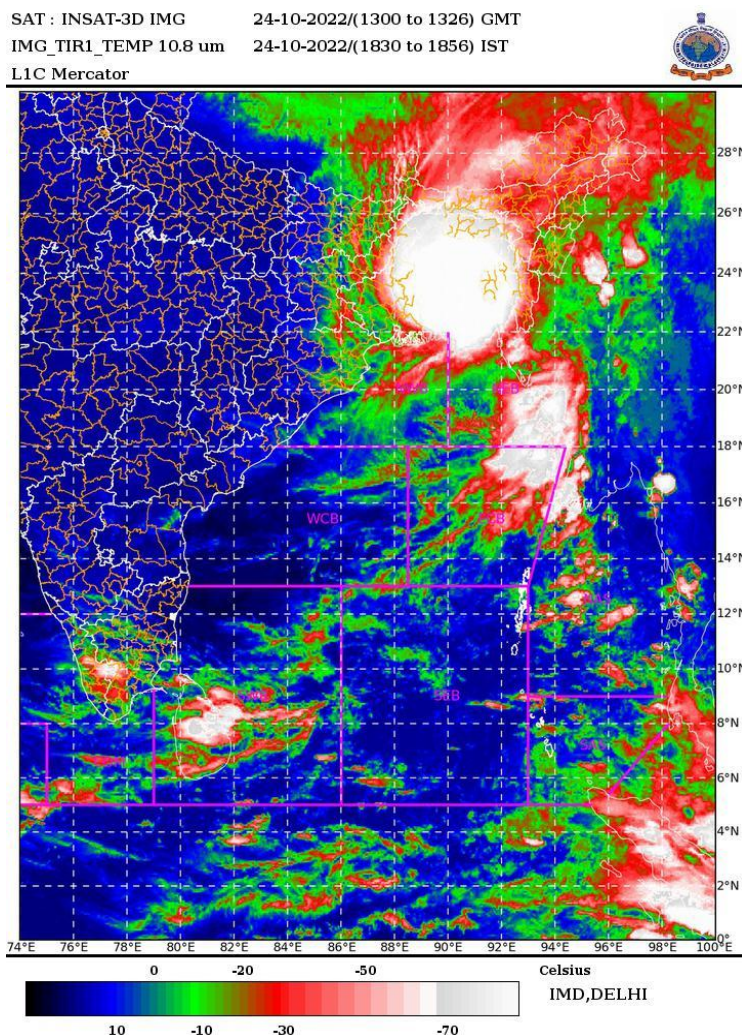


Fig. 3 (a): Typical INSAT 3D (R) imagery at 1300 UTC OF 24TH October

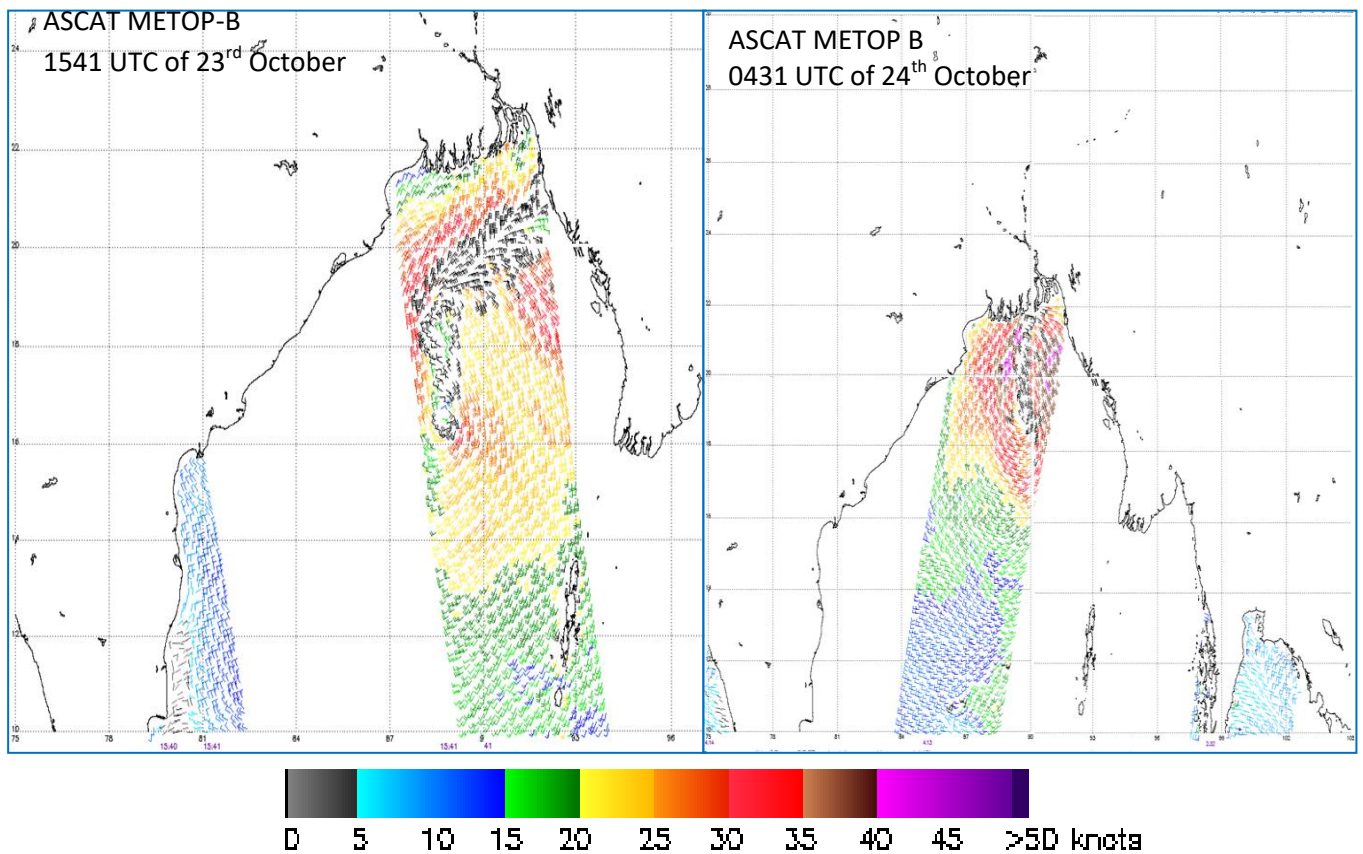


Fig. 3 (b): Typical scatterometer winds at 1541 UTC of 23rd October indicating MSW of 35 knots and 0431 UTC of 24th October indicating MSW of 45 knots in association with the system

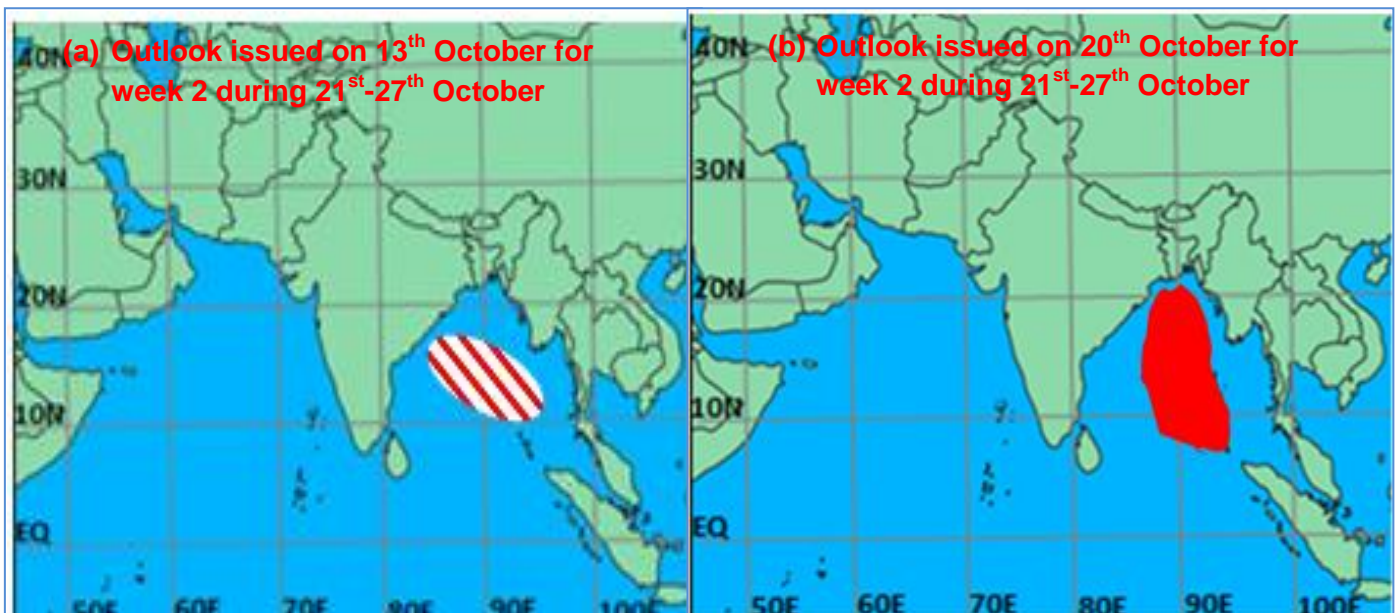


Fig. 4: Extended range outlook issued on 13th October (9 days prior to formation of depression on 22nd) and 20th October (about 4 days prior to landfall indicating movement towards Bangladesh with high confidence)

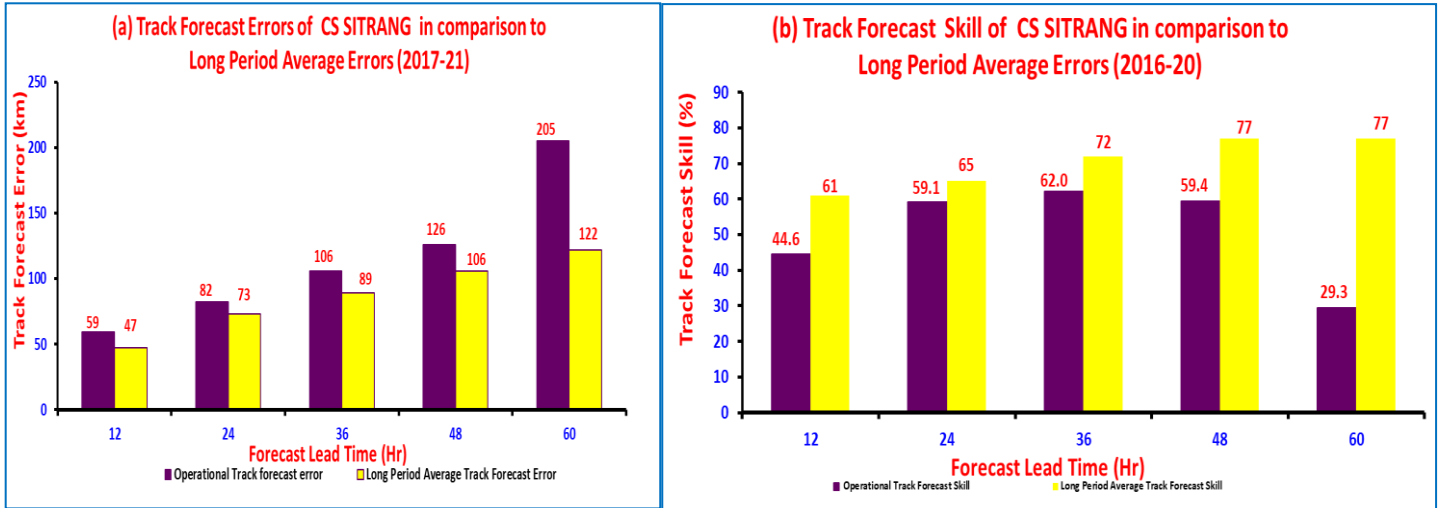


Fig.5: Operational track forecast errors and skill compared to long period average during 2017-21

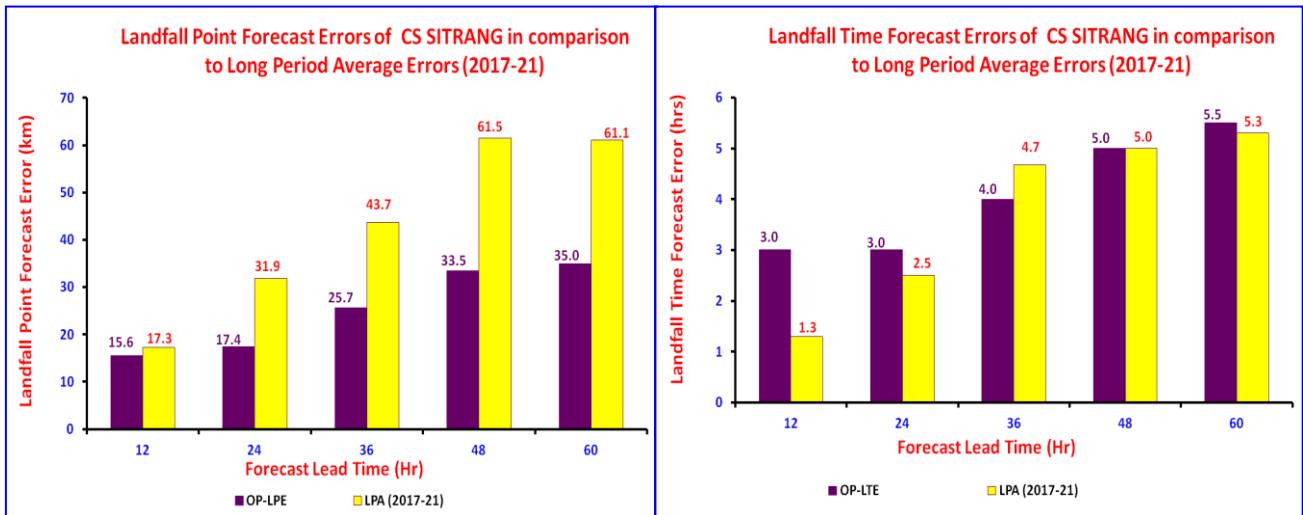


Fig.6: Operational landfall point and time forecast errors and skill compared to long period average during 2017-21

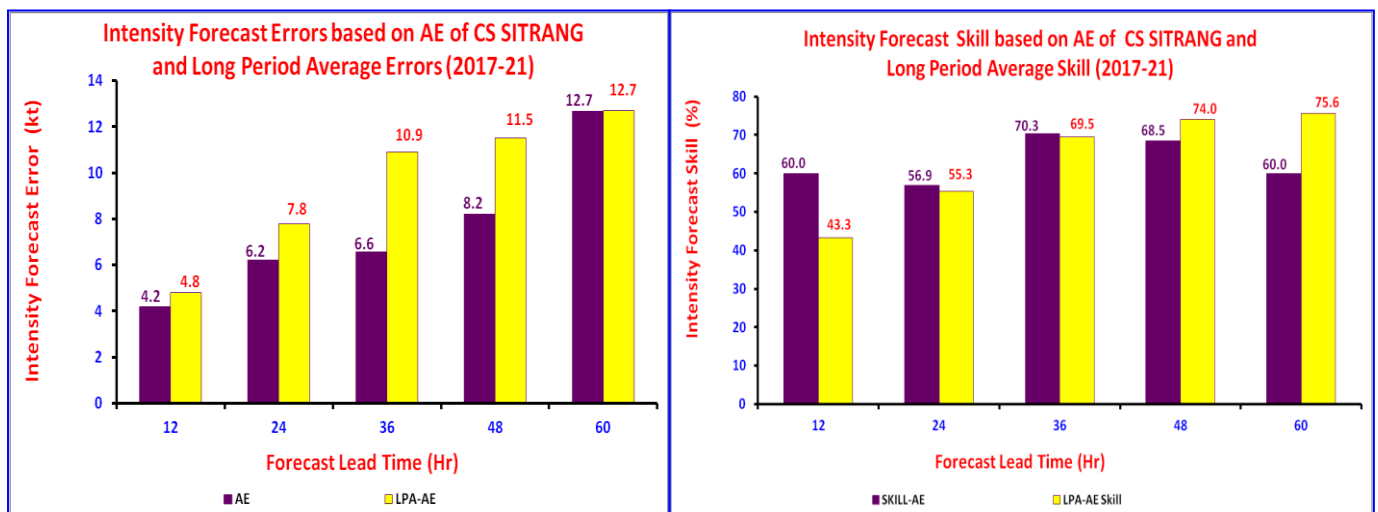


Fig.7: Operational intensity forecast errors and skill compared to long period average during 2017- 21

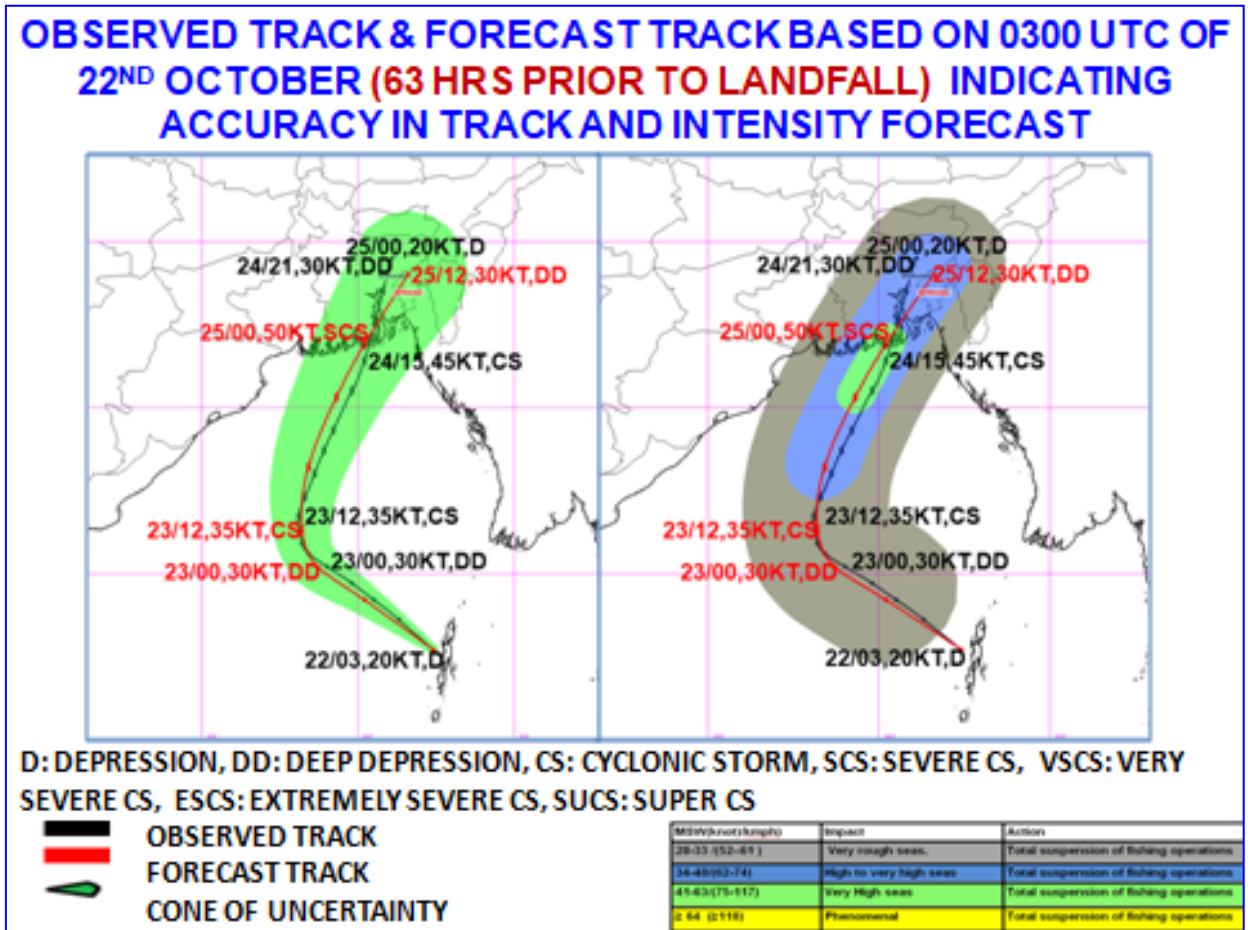


Fig.8: Observed and forecast track issued at 0830 hours IST of 22nd October (63 hours prior to landfall)

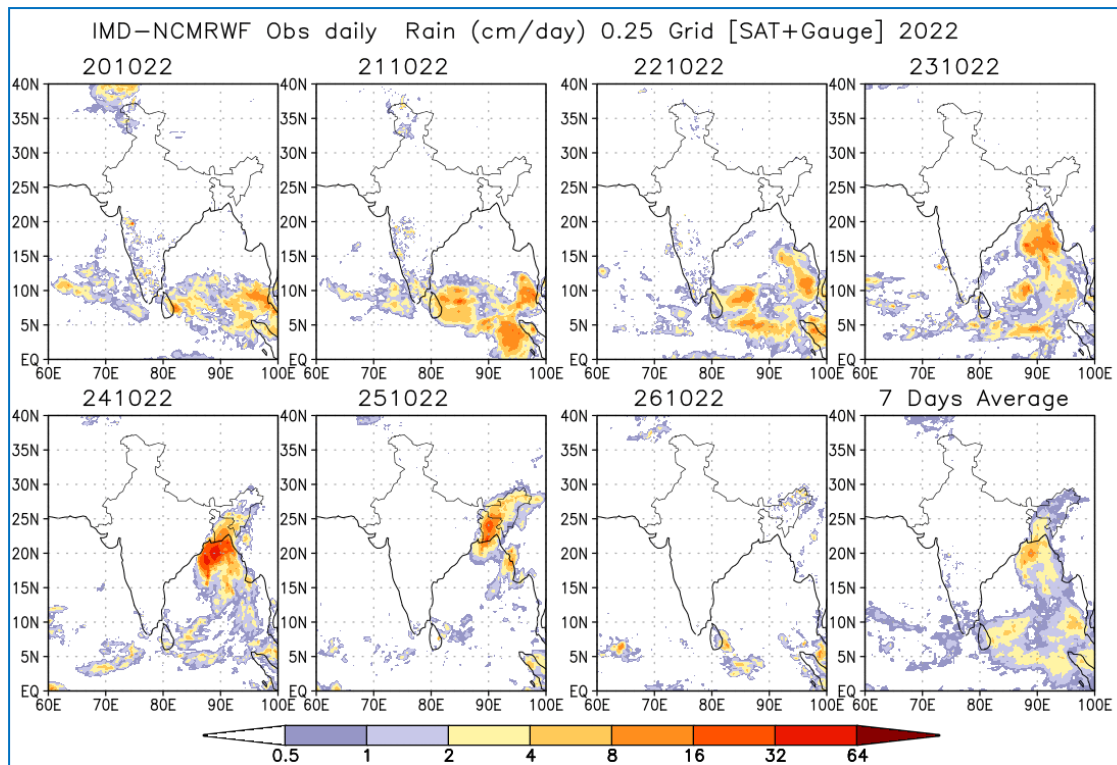


Fig.9: MoES Satellite gauge merged rainfall ending at 0300 UTC of date during 20th-26th October, 2022

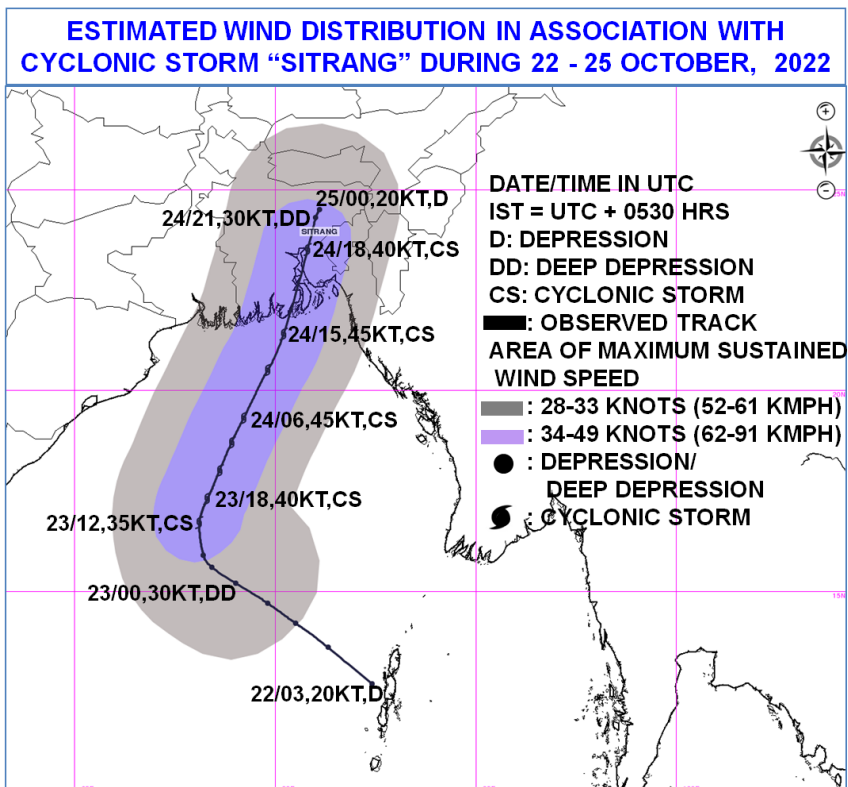


Fig.10: Estimated maximum sustained wind speed distribution in association with cyclonic storm Sitrang

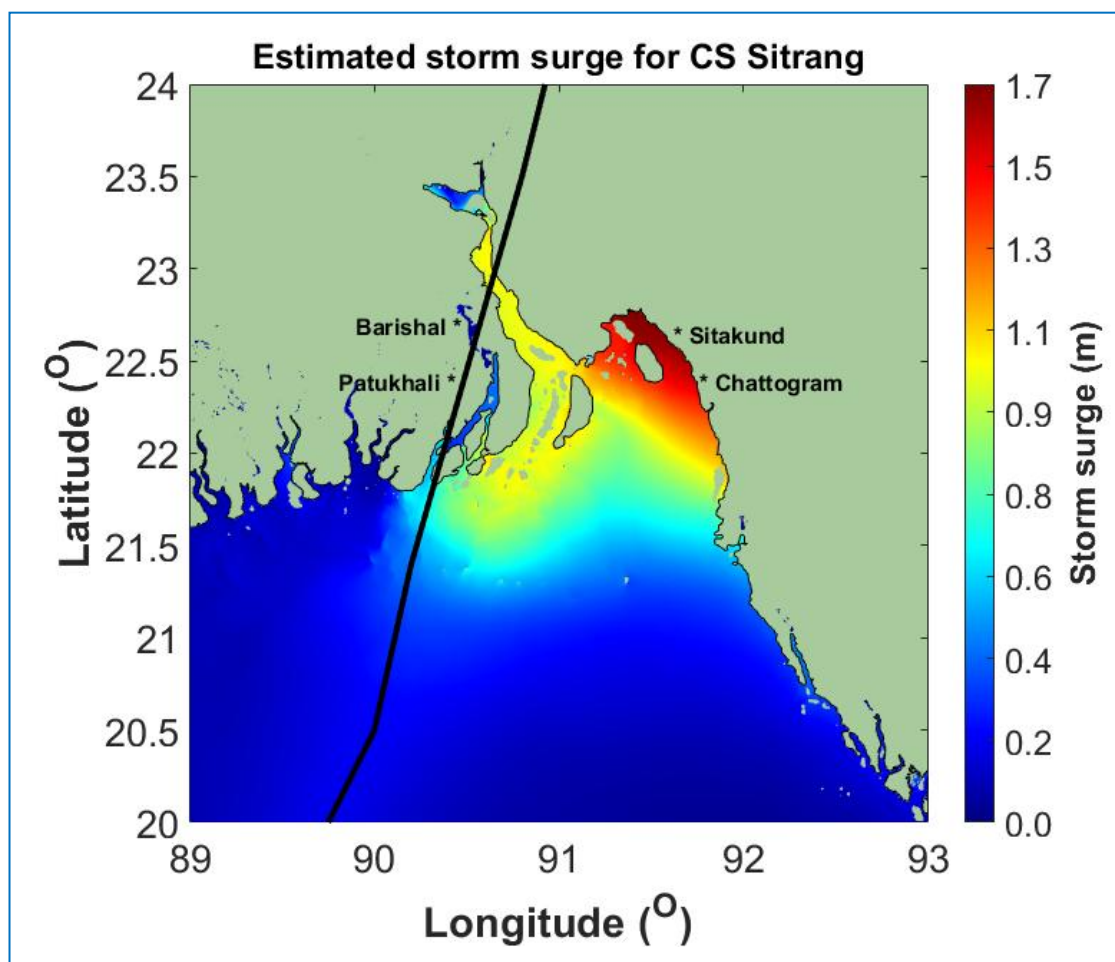


Fig.11: Estimated storm surge in association with CS Sitrang