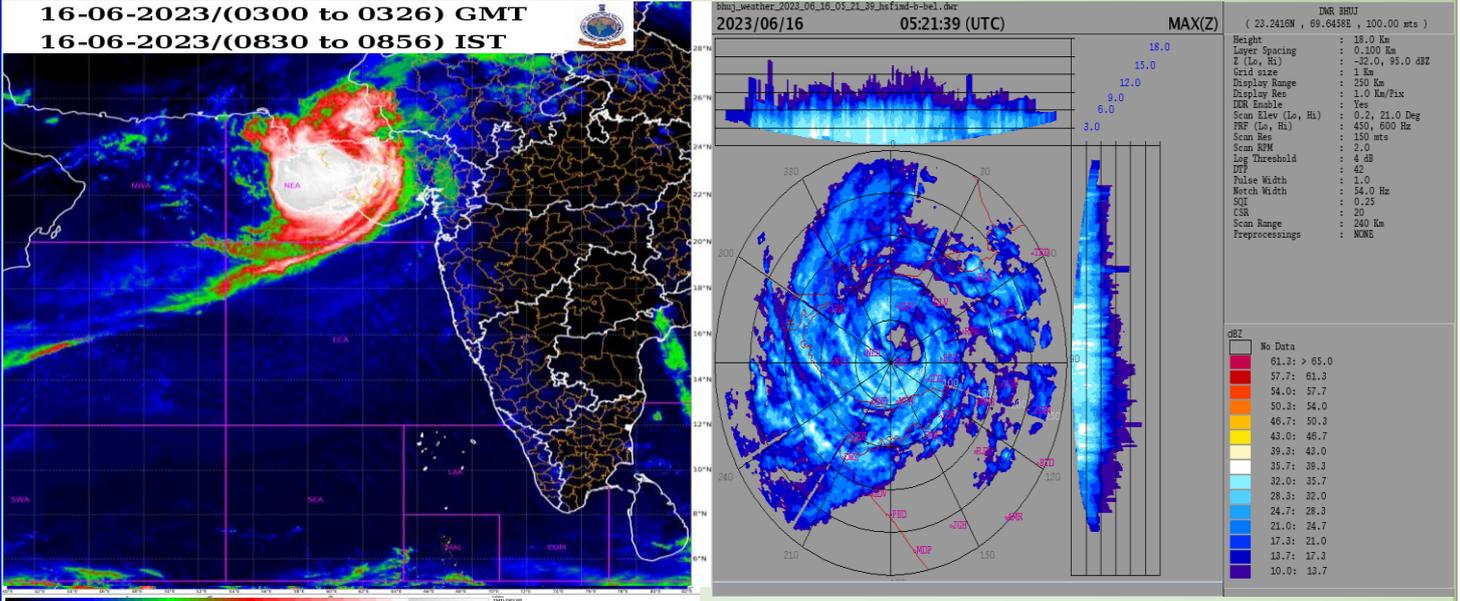




Extremely Severe Cyclonic Storm “BIPARJOY” over the ARABIAN Sea (6th-19th June, 2023): A Report

16-06-2023/(0300 to 0326) GMT
16-06-2023/(0830 to 0856) IST



Typical satellite and radar imagery during life cycle of
extremely severe cyclonic storm “BIPARJOY”

Cyclone Warning Division
India Meteorological Department
New Delhi
June 2023

Extremely Severe Cyclonic Storm “BIPARJOY” over the Arabian Sea (6th-19th June, 2023): A Report

1. Life History of “BIPARJOY”:

- An upper air **Cyclonic Circulation** formed over the Southeast Arabian Sea (AS) in the morning (0830 hrs IST/0300 UTC) of 5th June, 2023. Under its influence a **Low Pressure Area** formed over the same region in evening (1730 hrs IST/1200 UTC) and **Well Marked Low Pressure Area** (WML) in the same midnight (2330 hrs IST/1800 UTC).
- It concentrated into a **Depression** in the early morning (0530 hrs IST/0000 UTC) of 6th June over Southeast AS.
- It moved nearly northwards and intensified into a **Deep Depression (DD)** over the same region around noon (1130 hrs IST/0600 UTC) & into the **Cyclonic Storm (CS) "BIPARJOY"** pronounced as "BIPORJOY" over eastcentral and adjoining southeast AS in the evening (1730 hrs IST/1200 UTC) of 6th June.
- Continuing to move further nearly northwards, it intensified into a **Severe Cyclonic Storm (SCS)** over eastcentral AS in the early morning (0530 hrs IST/0000 UTC) and into a **Very Severe Cyclonic Storm (VSCS)** over the same region around noon (1130 hrs IST/0600 UTC) of 7th June.
- During 7th to 11th June, it followed a recurving track, moving gradually north-northwestwards for some time, then north-northeastwards & finally northwards.
- While moving northwards, it intensified into an **Extremely Severe Cyclonic Storm (ESCS)** over eastcentral AS in the early morning (0530 hrs IST/0000 UTC) of 11th June.
- It then moved north-northeastwards for sometime and then northwards till early morning (0530 hours IST/0000 UTC) of 12th maintaining the intensity of ESCS
- It then moved north-northwestwards and weakened into a **VSCS** around midnight (2330 hours IST/1800 UTC) of 12th June, 2023 over northeast and adjoining eastcentral AS.
- It continued to move nearly north-northwestwards till 13th noon, then northwards till 14th forenoon and then northeastwards with gradual weakening in intensity till 15th forenoon.
- It then moved northeastwards and crossed Saurashtra & Kutch and adjoining Pakistan coasts between Mandvi (Gujarat) and Karachi (Pakistan) close to Jakhau Port (Gujarat) near latitude 23.28°N and longitude 68.56°E between 2230 and 2330 hours IST of 15th June, 2023 as a **VSCS** with maximum sustained wind speed (MSW) of 115-125 kmph (65 knots) gusting to 140 kmph (75 knots).
- After landfall, it weakened into an **SCS** in the same midnight (2330 hours IST/ 1800 UTC) over Saurashtra & Kutch about 10 km north of Jakhau Port (Gujarat).
- Thereafter, it moved east-northeastwards and weakened into a **CS** in the morning (0830 hours IST/0300 UTC) of 16th June over Saurashtra & Kutch. It then moved northeastwards and weakened into a **DD** around midnight (2330 hours IST/1800 UTC) of 16th June over Southeast Pakistan and adjoining Southwest Rajasthan and Kutch.
- Continuing to move east-northeastwards, it weakened into a depression over South Rajasthan and adjoining North Gujarat in the morning (0830 hours IST/0300 UTC) of 18th June and into a WML over central parts of Northeast Rajasthan and neighbourhood in the morning (0830 hours IST/0300 UTC) of 19th June.
- 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 “BIPARJOY” over Arabian Sea during 06th – 19th June, 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
06.06.23	0000	11.3	66.0	1.5	1000	25	3	D
	0300	11.5	66.0	1.5	1000	25	3	D
	0600	11.9	66.0	2.0	999	30	5	DD
	1200	12.1	66.0	2.5	998	35	6	CS
	1500	12.3	66.0	2.5	998	35	7	CS
	1800	12.5	66.0	2.5	996	40	8	CS
	2100	12.5	66.0	3.0	996	45	10	CS
07.06.23	0000	12.6	66.1	3.5	990	55	15	SCS
	0300	12.7	66.2	3.5	988	60	18	SCS
	0600	12.8	66.3	4.0	983	65	21	VSCS
	0900	13.1	66.3	4.0	983	65	21	VSCS
	1200	13.3	66.2	4.0	983	65	22	VSCS
	1500	13.4	66.2	4.0	983	65	22	VSCS
	1800	13.6	66.0	4.0	980	70	24	VSCS
	2100	13.7	66.0	4.0	980	70	26	VSCS
08.06.23	0000	13.9	66.0	4.5	978	75	28	VSCS
	0300	14.0	66.0	4.5	978	75	28	VSCS
	0600	14.1	66.0	4.5	978	75	28	VSCS
	0900	14.3	66.0	4.5	978	75	28	VSCS
	1200	14.4	66.0	4.5	978	75	28	VSCS
	1500	14.5	66.0	4.5	978	75	28	VSCS
	1800	14.6	66.0	4.5	978	75	28	VSCS
	2100	14.6	66.0	4.5	978	75	28	VSCS
09.06.23	0000	14.7	66.2	4.5	978	75	28	VSCS
	0300	14.8	66.4	4.0	980	70	24	VSCS
	0600	15.0	66.6	4.0	980	70	24	VSCS
	0900	15.3	66.9	4.0	980	70	24	VSCS
	1200	15.5	67.1	4.0	982	65	24	VSCS
	1500	15.7	67.3	4.0	982	65	24	VSCS
	1800	16.0	67.4	4.0	978	70	24	VSCS
	2100	16.3	67.4	4.0	976	70	24	VSCS
10.06.23	0000	16.5	67.4	4.5	974	75	28	VSCS
	0300	16.7	67.4	4.5	972	75	28	VSCS
	0600	16.8	67.4	4.5	970	75	28	VSCS
	0900	16.9	67.4	4.5	966	80	32	VSCS
	1200	17.1	67.3	4.5	964	80	32	VSCS
	1500	17.3	67.3	4.5	964	80	32	VSCS
	1800	17.4	67.3	4.5	962	85	36	VSCS
	2100	17.6	67.3	4.5	962	85	36	VSCS
11.06.23	0000	17.9	67.4	5.0	960	90	40	ESCS

	0300	18.0	67.6	5.0	958	90	40	ESCS
	0600	18.2	67.7	5.0	958	90	40	ESCS
	0900	18.4	67.7	5.0	958	90	40	ESCS
	1200	18.6	67.7	5.0	958	90	40	ESCS
	1500	18.7	67.7	5.0	958	90	40	ESCS
	1800	18.9	67.7	5.0	958	90	40	ESCS
	2100	19.0	67.7	5.0	958	90	40	ESCS
12.06.23	0000	19.2	67.7	5.0	958	90	40	ESCS
	0300	19.4	67.7	5.0	958	90	40	ESCS
	0600	19.6	67.6	5.0	958	90	40	ESCS
	0900	19.7	67.5	5.0	958	90	40	ESCS
	1200	19.9	67.3	5.0	960	90	40	ESCS
	1500	20.0	67.2	5.0	960	90	40	ESCS
	1800	20.1	67.2	4.5	962	85	36	VSCS
13.06.23	2100	20.3	67.2	4.5	962	85	36	VSCS
	0000	20.6	67.0	4.5	962	85	36	VSCS
	0300	20.9	66.9	4.5	962	85	36	VSCS
	0600	21.0	66.7	4.5	962	85	36	VSCS
	0900	21.1	66.5	4.5	962	85	36	VSCS
	1200	21.3	66.5	4.5	962	85	36	VSCS
	1500	21.4	66.4	4.5	962	85	36	VSCS
	1800	21.7	66.3	4.5	962	85	36	VSCS
14.06.23	2100	21.7	66.3	4.5	964	85	36	VSCS
	0000	21.8	66.3	4.5	966	80	32	VSCS
	0300	21.8	66.3	4.5	966	80	32	VSCS
	0600	21.8	66.3	4.5	966	80	32	VSCS
	0900	21.9	66.5	4.5	966	80	32	VSCS
	1200	22.0	66.7	4.5	970	75	28	VSCS
	1500	22.1	66.8	4.5	970	75	28	VSCS
	1800	22.2	66.9	4.5	972	75	28	VSCS
15.06.23	2100	22.3	66.9	4.5	972	75	28	VSCS
	0000	22.4	67.0	4.0	974	70	26	VSCS
	0300	22.6	67.1	4.0	976	70	24	VSCS
	0600	22.7	67.3	4.0	976	65	21	VSCS
	0900	22.8	67.6	4.0	976	65	21	VSCS
	1200	22.9	68.0	4.0	976	65	21	VSCS
	1500	23.1	68.3	4.0	976	65	21	VSCS
	Crossed Saurashtra & Kutch and adjoining Pakistan coasts between Mandvi (Gujarat) and Karachi (Pakistan) close to Jakhau Port (Gujarat) near latitude 23.28°N and longitude 68.56°E during 1700 hours IST and 1800 hours IST.							
16.06.23	1800	23.3	68.6	-	980	60	18	SCS
	2100	23.4	68.9	-	982	50	12	SCS
	0000	23.4	69.2	-	978	50	12	SCS
	0300	23.5	69.5	-	978	45	10	CS
	0600	23.7	69.8	-	980	40	8	CS
	0900	23.9	70.0	-	984	40	8	CS
	1200	24.2	70.3	-	986	35	7	CS
	1500	24.5	70.7	-	987	35	6	CS
17.06.23	1800	24.6	70.9	-	988	30	4	DD
	0000	24.7	71.2	-	988	30	4	DD

	0300	25.0	71.5	-	988	30	4	DD
	0600	25.3	71.9	-	989	30	4	DD
	1200	25.6	72.5	-	990	25	3	D
	1800	25.8	72.8	-	991	25	3	D
18.06.23	0000	26.0	73.3	-	991	25	3	D
	0300	26.2	73.8	-	992	25	3	D
	0600	26.3	74.0	-	994	25	3	D
	1200	26.3	74.7	-	995	20	3	D
	1800	26.3	75.2	-	995	20	3	D
	0000	26.3	76.0	-	995	20	3	D
	0300	Weakened into a well-marked low pressure area over Northeast Rajasthan and neighbourhood						

2. Salient Features

- (i) It was the first cyclonic storm over the Arabian Sea in the year 2023.
- (ii) It developed during the onset phase of monsoon over Indian region.
- (iii) It crossed Saurashtra & Kutch coast close to Jakhau Port with maximum sustained wind speed (MSW) of 65 knots gusting to 75 knots (115-125 kmph gusting to 140 kmph) on 15th June.
- (iv) Climatologically, about 66 cyclonic storms (MSW \geq 62 kmph) developed over the AS (**Fig. 2a**) during 1965-2022. Out of these, 8 crossed Gujarat coast during the period (**Fig. 2b**).
- (v) **Long life period:** Biparjoy has been one of the longest duration cyclone over the North Indian Ocean (NIO) including the Bay of Bengal (BoB) and the Arabian Sea (AS) with a total life period of 13 days and 3 hours (depression to depression). The average life period of the very severe cyclonic storm category during monsoon season over the Arabian Sea is 6 days and 3 hours based on the data during 1990-2013. **Longest duration cyclone over the NIO developed over the BoB and weakened over the AS during 8th-23rd November, 1977 (Fig. 3) with a life period of 14 days and six hours.** In recent years, extremely cyclonic storm Kyarr (October, 2019) over AS had a life period of 9 days & 15 hours. It developed over eastcentral AS, had multiple recurvatures and weakened over southwest AS. Very Severe Cyclonic Storm Gaja (November, 2018) over southeast BoB had a life period of 9 days & 15 hours. It developed over southeast BoB, crossed southern peninsular region, emerged into Arabian Sea and weakened over southwest & adjoining southeast AS.
- (vi) **Slow speed:** Biparjoy moved very slowly during its life time with an average 12 hourly translational speed of 7.7 kmph against the average speed for VSCS category during monsoon season over the Arabian Sea of about 15 kmph based on data during 1990-2013 (**Fig. 4**). Biparjoy was centered between anticyclones one each over the central India to the east of the system and another over the Arabian Peninsula lying to the west of system area. The winds in the periphery of anticyclone over central India were pushing the system from south to north, while the peripheral winds associated with anticyclone over Arabian Peninsula were pushing the system from north to south. These opposing forces restricted the movement of the system.
- (vii) **Recurving track:** "BIPARJOY" exhibited a frequently changing track of movement during its life cycle. The movement explicitly depended upon the strength of the driving anticyclones present over central India and Arabian Peninsula. The cyclone changed its path about 9 times (**Fig.1**), resulting in relatively higher difficulty in predicting the path of the cyclone.
- (viii) **Track length:** It was 2525 km (depression to depression stage).

- (ix) **Rapid intensification:** There was rapid intensification of the system in the genesis and growing stage on 6th and 7th June.
- (x) **Diurnal variation in convective clouds:** Thereafter, the intensity of the system though increased, fluctuated diurnally. The convective clouds associated with the system showed large diurnal variations, picking up intensity twice in the afternoon and early hours.
- (xi) **Maximum sustained wind speed and estimated central pressure:** The system reached it's peak intensity of 90 knots at 0000 UTC of 11th June and maintained it's peak intensity till 1500 UTC of 12th June. The estimated central pressure during this period was 958 hPa with pressure drop of about 40 hPa at the centre **(Fig. 5)**.
- (xii) **Intensity after landfall:** After landfall, the system maintained it's intensity of cyclone while weakening gradually till midnight of 16th June (i.e. upto 24 hrs)
- (xiii) **Damage Potential and Loss:** The velocity flux, accumulated cyclone energy (measure of damage potential) and power dissipation index (measure of damage potential) were 30.03×10^2 knot, 22.94×10^4 knot², 18.05×10^6 knot³ against normal of 13.87×10^2 knot, 9.25×10^4 knot², 7.91×10^6 knot³ for ESCS over AS during pre-monsoon season based on the data during 1990-2020.
- (xiv) **Intense Rainfall Activity:** The system caused intense rainfall activity over Gujarat on 15th, 16th and 17th, over Rajasthan on 17th, 18th & 19th and over West Madhya Pradesh on 19th, 20th & 21st June.
- (xv) **Four Stage Warnings:**
Cyclone Watch for Saurashtra and Kutch coast was issued on 11th June at 0245 hours IST, about 4 days and 20 hours prior to landfall.
Cyclone Alert (Yellow Message) for Saurashtra and Kutch coast was issued on 11th June at 0945 hours IST, about 4 days and 13 hours prior to landfall.
Cyclone Warning (Orange Message) for Saurashtra and Kutch coast was issued on 12th June at 0930 hours IST, about 3 days and 13 hours prior to landfall.
Cyclone Warning (Red Message) for Saurashtra and Kutch coast was issued on 14th June at 0915 hours IST about 1 day and 14 hours prior to landfall.
- (xvi) **Forecast Accuracy:** Despite various unique and diverse characteristics, Biparjoy was monitored and predicted accurately by the India Meteorological Department (IMD). The landfall point forecast error for 24, 48, 72 and 96 hours lead period was 17, 23, 15 and 11 km against long period average (2018-22) of 26, 40, 76, 60 km respectively. The track forecast errors for 24, 48, 72, 96 and 120 hours lead period were 69, 104, 152, 194 and 238 km against long period average (2018-22) of 74, 112, 153, 208, 316 km respectively.
- (xvii) **Warning Dissemination:** IMD utilised all means of communication for early dissemination of advisories to disaster managers, media and general public. In association with this system, a total of 98 national bulletins for central & state level disaster management agencies, 103 special tropical weather outlook & tropical cyclone advisories for WMO & WMO/ESCAP member countries including Pakistan, 43 advisories for international civil aviation, 49 special bulletins for international shipping under Global Maritime Distress Safety System (GMDSS), 49 Special Fleet Forecast for Indian Navy, 40 fishermen warnings, 32.67 crores SMS through CAP Sachet to different users in the coastal districts of various states along the west coast, 5.63 crores SMS to fishermen through INCOIS, SMS to farmers, 2.7 lakhs SMS to registered users mainly general public in coastal states and central & state level disaster managers by IMD, 15 Press Releases, frequent updates on whatsapp, facebook & twitter.
- (xviii) **Personal Briefings by DG IMD:** DG IMD issued 9 Special Bulletins to central & state level disaster managers during 11th-19th June, daily Press Conference from 13th June in hybrid

mode with participation of media countrywide and WMO ESCAP member countries, 3 hourly briefings to media (8 in number) on the day of landfall with all briefings shared through whatsapp, facebook & twitter till landfall.

- (xix) **Hourly updates:** Hourly updates on cyclone and its warning was issued since 1130 IST of 15th and continued till 0230 IST of 16th (16 bulletins)

3. Monitoring of Extremely Severe Cyclonic Storm, “Biparjoy”

India Meteorological Department (IMD) maintained round the clock watch over the north Indian Ocean and the cyclone was monitored since 1st June, about 5 days prior to formation of depression on 6th June. The information about the system was first released in the weekly extended range outlook issued by IMD on 1st June (**Fig. 6**), indicating formation of depression over southeast AS during the week 1 (2-8 June, around 6th June).

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 Bhuj and Jaipur. 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 and 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 imageries from INSAT 3D (R) and imagery from Doppler Weather Radar at Bhuj are presented in **Fig.7**.

4. Operational Forecast Performance:

i) Pre-Genesis Forecast performance

- ❖ First information about likely cyclogenesis over southeast AS during the week (2nd -8th June), around 6th June was issued in the extended range outlook issued on 1st June.
- ❖ First information about likely formation of cyclonic circulation over southeast AS around 5th June and subsequent formation of low pressure area during next 48 hours was issued in the daily weather bulletins issued on 1st June.
- ❖ On 5th June, on formation of cyclonic circulation over southeast AS, it was indicated that the low pressure area would form over southeast AS around 6th and depression around 7th.
- ❖ Further, considering the rapid development of cyclonic circulation into a low pressure area and favourable environment, the warnings were further updated and the bulletin issued at 2030 hours IST of 5th June indicated likely intensification of the low pressure area into a depression by 6th morning.
- ❖ Actually, cyclonic circulation formed over southeast AS at 0830 hours IST (0300 UTC) of 5th June, low pressure area formed over southeast AS at 1730 hours IST (0300 UTC) of 5th June and depression at 0530 hours IST (0000 UTC) of 6th June.

ii) Operational track, intensity and landfall forecast performance

- ❖ The first advisory issued by IMD based on 0530 hours IST observations of 6th June, on formation of depression, indicated movement of the system towards central Arabian Sea. It was also indicated that the system would intensify further upto very severe cyclonic storm stage. However, no landfall was indicated in this forecast as it was beyond five day forecast period. Subsequently, from 11th June (1130 hours IST) onwards landfall over Saurashtra & Kutch coast close to Jakhau airport was indicated. Typical track and intensity forecast issued on 11th June (about 110 hours prior to landfall) demonstrating the accuracy in track, intensity and landfall prediction is presented in **Fig. 8**.
- ❖ Typical track & intensity forecast with cone of uncertainty and wind distribution based on 1730 hours IST of 9th June (about 6 days and 6 hours prior to landfall) and 0530 hours 12th June (3 days and 18 hours prior to landfall) are presented in **Fig. 9**.
- ❖ The track forecast errors for 24, 48, 72, 96 and 120 hrs lead period were 69, 104, 152, 194, 238 km respectively against the long period average (LPA) errors (2018-22) of 74, 112, 153, 208 and 316 km respectively (**Fig. 10 a**). **For all lead periods upto 120 hours, the operational track forecast errors were less than LPA errors.**
- ❖ The track forecast skill for 24, 48 and 72 hrs lead period were 75, 82, 83, 83 and 83 % respectively against the LPA skill (2018-22) of 65, 77, 78, 80 and 79 % respectively (**Fig. 10 b**). **For all lead periods upto 120 hours, the operational track forecast skill was more than the LPA skill.**
- ❖ The landfall point forecast errors for 24, 48, 72 and 96 hrs lead period were 16.8, 23.2, 15.3 and 11.7 km respectively against the LPA errors (2018-22) of 26.2, 39.9, 75.7 and 59.9 km during 2018-22 respectively (**Fig.11a**). **For 24 to 96 hours lead period, the landfall point forecast errors varied between 10-23 km.**
- ❖ The landfall time forecast errors for 24, 48, 72 and 96 hrs lead period were 0.5, 6.0, 7.5 and 11.5 hours respectively against the LPA errors (2018-22) of 2.8, 4.5, 8.0 and 8.5 hours during 2018-22 respectively (**Fig.11b**).
- ❖ The absolute errors (AE) of intensity (wind) forecast for 24, 48, 72, 96 and 120 hrs lead period were 7.0, 8.4, 10.4, 13.2 and 16.9 knots against the LPA errors of 7.4, 10.5, 14.0, 17.4 and 18.7 knots during 2018-22 respectively (**Fig.12 a**). **For all lead periods upto 120 hours, the errors in prediction of intensity were less than the LPA errors.** The skill in intensity forecast based on AE for 24, 48, 72, 96 and 120 hrs lead period was 25.3, 62.7, 72.3, 75.2 and 77.5 % against the LPA skill of 55.4, 74.6, 77.2, 77.4 and 80.9 % during 2018-22 respectively (**Fig.12 b**).
- ❖ The root mean square error (RMSE) of intensity (wind) forecast for 24, 48, 72, 96 and 120 hrs lead period were 8.9, 10.5, 11.9, 14.6 and 17.4 knots against the LPA errors of 9.3, 13.1, 16.8, 20.1 and 22.0 knots during 2018-22 respectively (**Fig.13 a**). **For all lead periods upto 120 hours, the errors in prediction of intensity were less than the LPA errors.** The skill in intensity forecast based on RMSE for 24, 48, 72, 96 and 120 hrs lead period was 31.3, 64.9, 74.7, 77.7 and 81.1 % against the LPA skill of 52.8, 71.8, 78.6, 78.6 and 84.0 % during 2018-22 respectively (**Fig.13 b**).

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 6th June 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 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 geographical quadrants of cyclone was issued alongwith graphics, commencing from 6th June five times a day during depression and every three hours during the cyclone period.
- **Adverse weather warning bulletins:** The tropical cyclone forecasts alongwith expected adverse weather like heavy rainfall for Saurashtra & Kutch, Gujarat region, Rajasthan & Madhya Pradesh, gale & squally wind, storm surge and state of sea 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 west coast of India including Gujarat, Daman & Diu, Maharashtra, Goa, Karnataka & Kerala and Rajasthan, Madhya Pradesh & Uttar Pradesh. The bulletins also contained the suggested actions for disaster managers and general public in particular for fishermen, ports and offshore & onshore activities. These bulletins were also issued to Defence including Indian Army, 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 capsules 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 and Cyclone Warning Centre at Ahmedabad & Thiruvananthapuram to ports, fishermen, coastal and high sea shipping community.
- **Fishermen Warning:** Regular warnings (4 to 8 times a day) for fishermen for coastal and deep Sea areas of Arabian Sea were issued since 1st June valid for subsequent 5 days.
- **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 cyclone were described in the RSMC bulletins.

- **High level briefing meetings attended by the Director General of Meteorology, India Meteorological Department:**
 - (i) National Emergency Response Committee (NERC) headed by Home Secretary, Govt. Of India was organised on 11th June
 - (ii) National Crisis Management Committee Meeting on impending Cyclone Scenario in Arabian Sea under the Chairmanship of Home Secretary, on 12th June.
 - (iii) Hon'ble Prime Minister reviewed the preparedness in a high level meeting on 12th June.
 - (iv) Hon'ble Home Minister reviewed the preparedness in a high level meeting on 13th June.
 - (v) **Director General of Meteorology** presented the current status, forecast and warning issued for the cyclone, expected damage and suggested actions in all the above meetings. Similarly Head, Cyclone Warning Centre, Ahmedabad provided briefing to state level authorities in Gujarat.
- **Director General of Meteorology** addressed media through press conference every day in connection with this cyclone since 13th June. The press briefings were conducted in hybrid mode. On the day of landfall, DG IMD briefed Press every three hourly, till landfall and these briefings were recorded and shared through whatsapp, facebook, twitter and Instagram.

Statistics of bulletins issued by Cyclone Warning Division, RSMC New Delhi, Cyclone Warning Centre Ahmedabad and Meteorological Centre Jaipur in association with the "ESCS Biparjoy" are given in **Table 2-3**.

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

S.N.	Bulletin type	No. of Bulletins	Issued to
1.	Bulletin from DG IMD	9: daily once from 12 th June to 19 th June	To senior level Govt. Officials including Cabinet Secretary, Principal Secretary to Prime Minister, Secretary Ministry of Home Affairs, Ministry of Agriculture, Defence, Information & Broadcasting, Ministry of Earth Sciences, Deptt. of Science & Technology, Shipping & Surface Transport, Ministry of Home Affairs, Director Punctuality, Indian Railways, Director All India Radio, Doordarshan, Secretary NDMA, Director General NDRF, Chief Secretaries of Gujarat, Daman & Diu, Dadra & Nagar Haveli, Rajasthan, Madhya Pradesh, Uttar Pradesh, Maharashtra, Goa, Karnataka and Kerala.
2.	National Bulletin	98 (including 40 four stage warning bulletins)	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 Gujarat, Daman & Diu, Dadra & Nagar Haveli, Rajasthan, Madhya Pradesh, Uttar Pradesh, Maharashtra, Goa, Karnataka and Kerala.
3.	Hourly bulletins	16	1. IMD's website, RSMC New Delhi website 2. FAX and e-mail to Control Room Ministry of Home Affairs

	on the day of landfall		& 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 Gujarat, Daman & Diu, Dadra & Nagar Haveli, Rajasthan, Madhya Pradesh, Uttar Pradesh, Maharashtra, Goa, Karnataka and Kerala. 3. WMO/ESCAP Panel member countries including Pakistan
4.	RSMC Bulletin	98 + 6 tropical weather outlooks since 1 st June	1. IMD's website 2. WMO/ESCAP member countries including Pakistan through GTS and E-mail.
5.	GMDSS Bulletin	49	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	43	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	45	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	15 (5 th to 19 th June)	Disaster Managers, Media persons by email and uploaded on website
10.	Press Briefings	Frequently	Regular briefing daily. Regular Press Conference from 13 th June. 3 hourly media briefing by DG IMD on the day of landfall
11.	Bulletins for offshore industries	56	6 hourly during depression and 3 hourly during cyclonic storm by email to offshore industries, Directorate General of Hydrocarbons, Coast Guard
12.	SMS	Frequently	❖ 32.67 crores SMS through CAP Sachet to different users in the coastal districts of various states along the west coast, ❖ 5.63 crores SMS through CAP to fishermen through INCOIS, ❖ Frequent SMS to farmers through Ministry of Agriculture

			M Kisan & PM Kisan Portals, ❖ 2.7 lakhs SMS were sent to registered users mainly general public in coastal states and central & state level disaster managers by IMD
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.

Table 3: Bulletins issued by Area Cyclone Warning Centre (Mumbai), Cyclone Warning Centres (CWC) Ahmedabad, Meteorological Centre (MC) Jaipur

SN	Type of Bulletin	No. of Bulletins issued		
		ACWC Mumbai	CWC Ahmedabad	MC Jaipur
1.	Sea Area Bulletins	59	-	-
2.	Coastal Weather Bulletins	20	70	-
3.	Fishermen Warnings issued	39	70	-
4.	Port Warnings	38	35 (from 06 th to 17 th June 2023)	-
5.	Four Stage Warning Bulletins	Nil	40	-
8.	Information & Warning issued to State Government and other Agencies	23	23	14
9.	SMS	Around 40,000	Through Common Alert Protocol, SACHET	95,731,098 through CAP SACET
10.	No. of Press releases	6	23	

Personal briefings and meetings attended by CWC Ahmedabad with High Dignitaries of Government of Gujarat:

- (i) 05-06-23: Briefing to Relief Commissioner
- (ii) 09-06-23: Online meeting with Honorable Chief Minister
- (iii) 11-06-23: Meeting with Honorable Chief Minister
- (iv) 12-06-23: Meeting with Honorable Chief Minister and Chief Secretary.
- (v) 13-06-23: Meeting with Honorable Chief Minister (twice a day) and Chief Secretary
- (vi) 14-06-23: Meeting with Honorable Chief Minister (twice a day)
- (vii) 15-06-23: Meeting with Honorable Chief Minister (twice a day)
- (viii) 16-06-23: Meeting with Honorable Chief Minister (twice a day)
- (ix) 17-06-23: Meeting with Honorable Central Home Minister

Personal Meetings and Briefings attended by MC Jaipur with High Dignitaries of Government of Jaipur:

- (i) 14-06-2023: Briefing to Chief Minister, Rajasthan
- (ii) 14-06-2023: Meeting with Chief Secretary, Govt. of Rajasthan
- (iii) 16 to 19-06-2023: Briefing to Chief Secretary, Govt. of Rajasthan on telephone/mobile.
- (iv) 16-06-2023: Briefing to Hon'ble Minister Disaster Management
- (v) 20-06-2023: Meeting with Secretary, Disaster management & Relief Commissioner Govt. of Rajasthan

8. Realized Weather

8.1. Realised rainfall:

The system caused heavy to extremely heavy rainfall over Gujarat region and Saurashtra and Kutch on 13th and during 15th to 18th June, over Rajasthan during 16th to 20th June and heavy to very heavy rainfall over Madhya Pradesh during on 19th to 21st June. IMD NCMRWF satellite gauge merged rainfall maps are presented in **Fig. 14**. Station level realised rainfall is presented in **Fig. 15**. Districtwise rainfall realised over Gujarat, Rajasthan and Madhya Pradesh are presented in **Fig. 16**.

24 hours cumulative heavy rainfall (≥ 7 cm) in cm ending at 0830 hours IST of date the 16th June in association with cyclone "BIPARJOY"

13th June:

Saurashtra & Kutch:

Sutrapada (dist Gir Somnath) 21, Veraval (dist Gir Somnath) 20, Keshod (dist Junagadh) 20, Mendarda (dist Junagadh) 19, Malia (dist Junagadh) 18, Mangrol(j) (dist Junagadh) 14, Talala (dist Gir Somnath) 13, Vanthali (dist Junagadh) 12, Manavadar (dist Junagadh) 11, Junagarh_aws (dist Junagadh) 10, Junagadh (dist Junagadh) 8, Porbandar (dist Porbandar) 8, Upleta (dist Rajkot) 8, Visavadar (dist Junagadh) 7, Bhanvad (dist Devbhoomi Dwarka) 7, Kutiana (dist Porbandar) 7.

14th June:

Saurashtra & Kutch

Khambhalia (dist Devbhoomi Dwarka) 12, Okha (dist Devbhoomi Dwarka) 11, Kalyanpur (dist Devbhoomi Dwarka) 7, Dwarka (dist Devbhoomi Dwarka) 7, Upleta (dist Rajkot) 7, Jamjodhpur (dist Jamnagar) 7.

15th June: Nil

16th June:

Gujarat Region: Wav (dist Banaskantha) 8,

Saurashtra & Kutch:

Gandhidham (dist Kutch) 20, Kandla Airport (dist Kutch) 16, Dwarka (dist Devbhoomi Dwarka) 15, Anjar (dist Kutch), Bhuj (dist Kutch) & Mundra (dist Kutch) 13 each, Okha (dist Devbhoomi Dwarka) 11, Kandla New (dist Kutch) & Khambhalia (dist Devbhoomi Dwarka) 10 each, Jamjodhpur (dist Jamnagar) 9, Kalyanpur (dist Devbhoomi Dwarka) 8, Jamnagar (dist Jamnagar), Naliya (dist Kutch) & Kalavad (dist Jamnagar) 7 each.

17th June:**Saurashtra & Kutch:**

Okha (dist Devbhoomi Dwarka)-23, Anjar (dist Kutch)-22, Mandvi(k) (dist Kutch)- 22, Bhachau (dist Kutch)-21, Mundra (dist Kutch)-19, Rapar (dist Kutch)-19, Nakhatrana (dist Kutch)-17, Kandla New (dist Kutch)-17, Jamnagar (dist Jamnagar)-16, Gandhidham (dist Kutch)-15, Khambhalia (dist Devbhoomi Dwarka)-13, Bhuj (dist Kutch)-13, Kandla Airport (dist Kutch)-12, Lodhika (dist Rajkot)-11, Lakhpat (dist Kutch)- 10, Kalavad (dist Jamnagar)-10, Chuda (dist Surendranagar)-10, Wankaner (dist Morbi)- 9, Jodia (dist Jamnagar)-9, Rajkot (dist Rajkot)-9, Tankara (dist Morbi)-8, Morbi (dist Morbi)-8, Dhrol (dist Jamnagar)-7, Abdasa (dist Kutch)-7, Targhadia (dist Rajkot)-7, Chotila (dist Surendranagar)-7, Halvad (dist Morbi)-7, Jamnagar (dist Jamnagar)- 7.

Gujarat Region:

Vadgam-11, Dhanera-11, Dantiwada-10, Deodar-9, Radhanpur-9, Vadali-9, Harij-9, Santalpur-8, Poshina-8, Bhabhar-8, Visnagar-8, Deesa-8, Suigam-8, Khedbrahma-8, Sami-7, Satlasana-7, Dantewadaaws-7, Dharoi Colony-7, Palanpur-7,

West Rajasthan:

Mt. Abu (Sirohi)- 21, Sedwa (Barmer) 14, Mounntabu Tehsil (Sirohi) 13, Raniwada (Jalore) 11, Bidasra (Churu) 8 and Reodar (Sirohi) 7

East Rajasthan:

Mounntabu Tehsil -13, Reodar -7,

18th June:**Gujarat Region:**

Amirgadh (dist Banaskantha) 21, Danta (dist Banaskantha) 17, Dhanera (dist Banaskantha) 16, Dantiwada (dist Banaskantha) 15, Poshina (dist Sabarkantha) 15, Palanpur (dist Banaskantha) 14, Santalpur (dist Patan) 13, Deesa (dist Banaskantha) 13

Rajasthan:

Mounntabu (Sirohi) 36, Chitalwana (Jalore) 34, Raniwada (Jalore) 32, Jalore (Jalore) 32, Sheoganj (Sirohi) 31, Sanchole (Jalore) 30, Jaswantpur (Jalore), 29, Sumerpur (Pali) 27, Chotan (Barmer) 27, Dhorimanna (Barmer) 26, Rani (Pali) 25, Reodar (Sirohi) 24, Bali (Pali) 24, Siwana (Barmer) 24, Bagoda (Jalore) 23, Jawai Dam (Pali) 23, Abu Road (Sirohi) 20, Pali (Pali) 20, Samdari (Barmer) 20, Sedwa (Barmer) 19, Dhanau (Barmer) 18, Balotra (Barmer) 18, Desuri (Pali) 18, Pindwara (Sirohi) 18, Bhinmal (Jalore) 17, Deogarh (Rajsamand) 15, Guddamalan (Barmer) 14, Marwar (Pali) 13, Junction Pachbhadra (Barmer) 13, Sirohi (Sirohi) 13, Kubhalgarh (Rajsamand) 12, Gadhbora (Rajsamand) 12, Gogunda (Udaipur) 12, Bhadrarajun (Jalore) 11, Ahore (Jalore) 10, Kotda (Udaipur) 10, Nokda (Barmer) 9, Jodhpur (Jodhpur) 9, Luni (Jodhpur) 9, Kalyanpur (Barmer) 9, Sindhari (Barmer) 9, Jodhpur (Jodhpur) 9, Rohat (Pali) 9, Baitu (Barmer) 8, Sayla (Jalore) 8, Sojat (Pali) 8, Amet (Rajsamand) 7, Ramsar (Barmer) 7, Todgarh (Ajmer) 7

19th June:**Gujarat Region:**

Danta (dist Banaskantha) 13, Amirgadh (dist Banaskantha) 9, Khedbrahma (dist Sabarkantha) 8, Vijaynagar (dist Sabarkantha) 7,

East Rajasthan:

Sheoganj (dist Sirohi) 35, Nagrarfort (dist Tonk) 31, Deogarh (dist Rajsamand) 27, Kumbhalgarh (dist Rajsamand) 25, Amet (dist Rajsamand) 24, Rajsamand (dist Rajsamand) 22, Ajmer Tehsil (dist Ajmer) 16, Reodar (dist Sirohi) 15, Srinagar (dist Ajmer) 15, Pushkar (dist Ajmer) 15, Deoli (dist Tonk) 15, Nainwa (dist Bundi) 14, Mandal (dist Bhilwara) 13, Ajmer (dist Ajmer) 13, Tonk Tehsil (dist Tonk) 13, Piplu (dist Tonk) 13, Kekri (dist Ajmer) 12, Nasirabad (dist Ajmer) 11, Railmagra (dist Rajsamand) 11, Pindwara (dist Sirohi) 11, Abu Road (dist Sirohi) 11, Gegal (dist Ajmer) 11, Jawaja (dist Ajmer) 11, Tatgarh (dist Ajmer) 10, Bhinay (dist Ajmer) 9, Bhim (dist Rajsamand) 9, Kishangarh (dist Ajmer) 9, Niwai (dist Tonk) 9, Jahazpur (dist Bhilwara) 9, Nathdwara (dist Rajsamand) 9, Sahada (dist Bhilwara) 9, Raipur (dist Bhilwara) 9, Uniara / Aligarh (dist Tonk) 8, Asind (dist Bhilwara) 8, Gogunda (dist Udaipur) 8, Arai (dist Ajmer) 8, Todaraisingh (dist Tonk) 8, Sirohi (dist Sirohi) 8, Geola (dist Ajmer) 8, Sarwar (dist Ajmer) 8, Mangliawas (dist Ajmer) 7, Rashmi (dist Chittorgarh) 7, Pisagan (dist Ajmer) 7, Hurda (dist Bhilwara) 7, Kotda (dist Udaipur) 7, Tonk Vanasthali (dist Tonk) 7, Malpura (dist Tonk) 7, Hindoli (dist Bundi) 7, Vijaynagar (dist Ajmer) 7.

West Rajasthan:

Desuri (dist Pali) 38, Sumerpur (dist Pali) 28, Erinpura/jawai Dam (dist Pali) 24, Bali (dist Pali) 19, Ahore Sr (dist Jalore) 17, Marwar Junction (dist Pali) 14, Jalore (dist Jalore) 9, Jaswantpura (dist Jalore) 8, Merta City (dist Nagaur) 8, Bilara (dist Jodhpur) 7, Pali (dist Pali) 7.

West Madhya Pradesh:

Ratlam-7

20th June:**East Rajasthan:**

Dholpur Tehsil (dist Dholpur) 19, Ajmer (dist Ajmer) 15, Banera (dist Bhilwara) 12, Kishangarh (dist Ajmer) 11, Ajmer Tehsil (dist Ajmer) 11, Nasirabad (dist Ajmer) 11

West Madhya Pradesh:

Ater (dist Bhind) 14, Morena- (dist Morena) 13, Gormi (dist Bhind) 12, Ambah (dist Morena) 12, Badoda (dist Sheopur) 10,

West Uttar Pradesh:-

Khairagar-13,

(dist: District)

8.2. Realised wind:

Realised wind at different stations of Saurashtra and Kutch during landfall is presented in **Table 4**. Dwarka reported 130 kmph, Kandla 115 kmph, Sikka 111 kmph and Mundra Port 102 kmph. **IMD had predicted MSW during landfall as 125-135 kmph gusting to 150 kmph since 0945 hours IST of 11th June (about 4 days and 15 hours prior to landfall) and 115-125 kmph gusting to 140 kmph along & off Saurashtra & Kutch districts since 0900 hrs IST of 15th June (about 15 hours prior to landfall)**. Estimated maximum sustained wind in association with the system is presented in **Fig. 17**.

Table 4: Realised wind at different stations of Saurashtra and Kutch during landfall

Place	Maximum wind during landfall (kmph)
Dwarka	130
Kandla	115
Sikka	111
Mundra port	102
Navlakhi	95
Okha	93
Jakhau port	93
Dahej	83
Bhavnagar	83
Jafrabad	78
Sartanpur	78
Porbandar	74
Hazira	74

8.3. Realised storm surge:

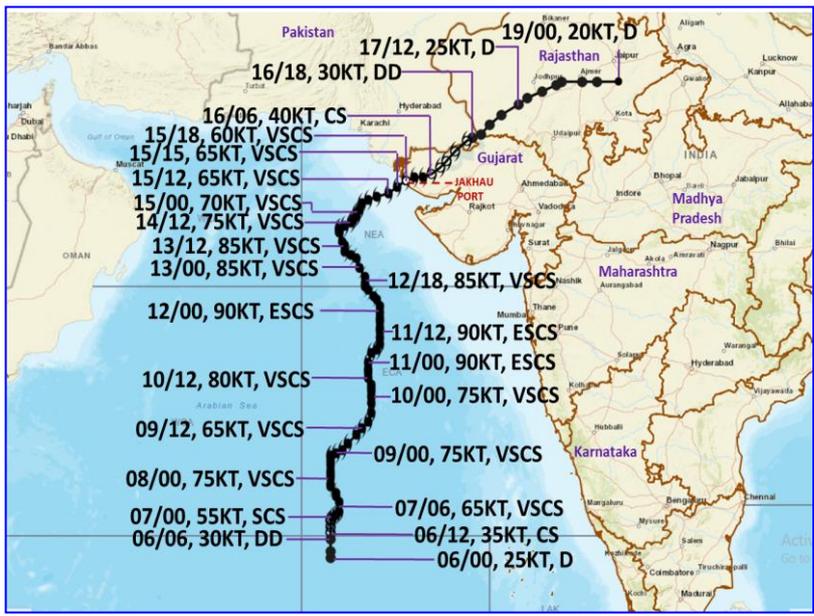
Estimated storm surge of height 2-2.5 m above astronomical tide inundated the low lying areas Kutch and Morbi districts. Peak surge of height 2.1 m was observed at the south of Naliya and 2.2 m near Navlakhi. Realised storm surge map is presented in Fig. 18.

9. Damage report

As per available reports, no death was reported from Gujarat, 7 deaths were reported from Rajasthan due to heavy rain related incidents associated with Biparjoy cyclone. Typical damage photographs from Gujarat and Rajasthan are presented in Fig. 19 and Fig. 20 respectively.

10. Acknowledgements:

India Meteorological Department (IMD) and RSMC New Delhi duly acknowledge contribution from WMO and WMO/ESCAP member countries. IMD and RSMC New Delhi also acknowledge the contribution from all the stakeholders and disaster management agencies who contributed to the successful monitoring, prediction and early warning service of “ESCS BIPARJOY”. 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) Mumbai, Cyclone Warning Centre Ahmedabad & Meteorological Centre, Goa, Jaipur and Bhopal. The contribution from Numerical Weather Prediction Division, Satellite and Radar Divisions, Surface & Upper air instruments Divisions, New Delhi and Information System and Services Division at IMD and all the coastal observatories of Gujarat is also duly acknowledged.



- : LESS THAN 34 KT
- : 34-47 KT
- ⦿ : ≥ 48 KT
- D: Depression
- DD: Deep Depression
- CS: Cyclonic Storm
- SCS: Severe Cyclonic Storm
- VSCS: Very SCS
- ESCS: Extremely SCS
- █ : Observed Track

Fig. 1: Observed track of extremely severe cyclonic storm ‘BIPARJOY’ over the AS during 6th-19th June, 2023

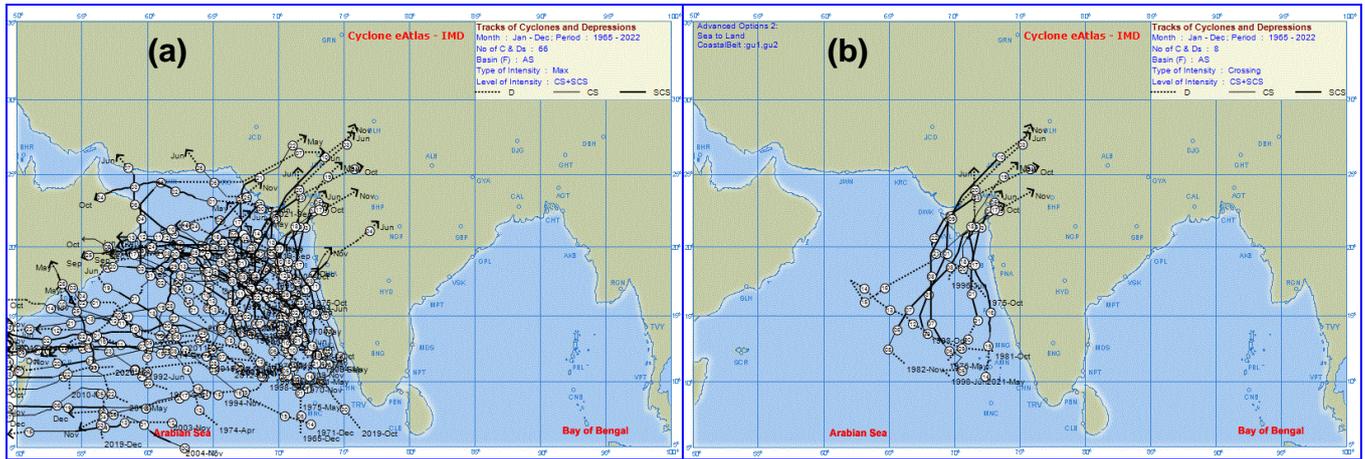


Fig. 2: Tracks of (a) cyclones (MSW ≥ 62 kmph) developing over the Arabian Sea and (b) crossing Gujarat coast during 1965-2022

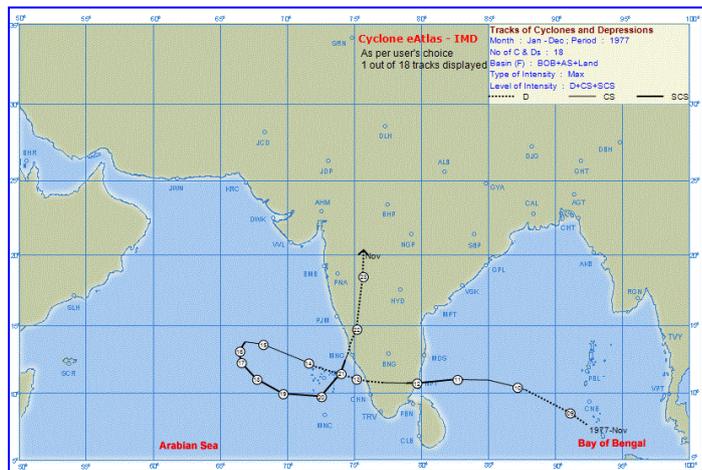


Fig. 3: Track of the cyclone with longest life period during 8 Nov-23 Nov, 1977, about 14 days and 6 hours

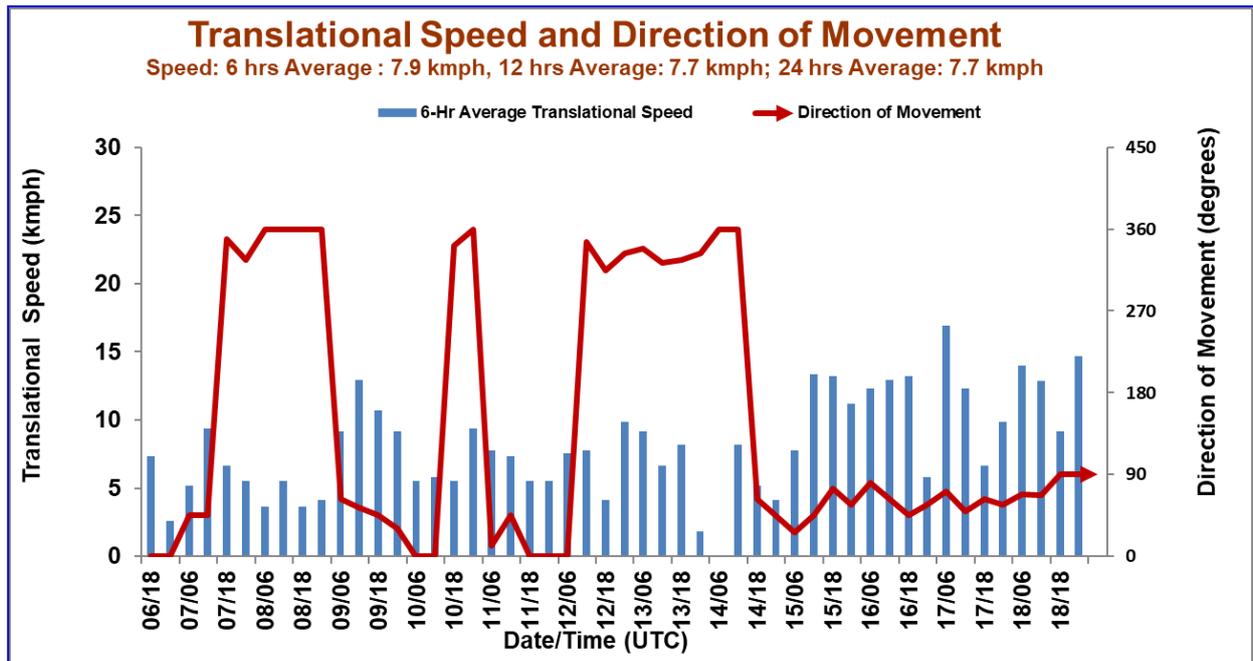


Fig. 4: Translation speed and direction during life cycle of “Biparjoy”

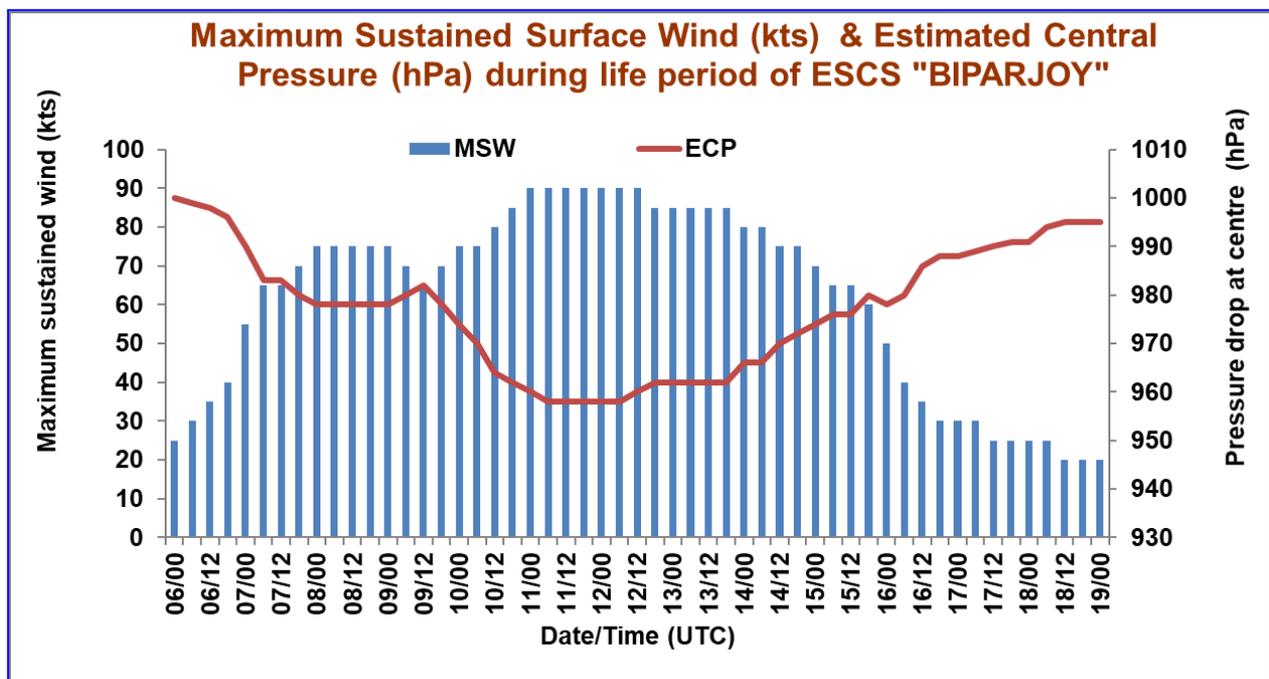


Fig.5: Maximum sustained surface wind speed (kt) and estimated central pressure (hPa) during life period of “ESCS BIPARJOY”

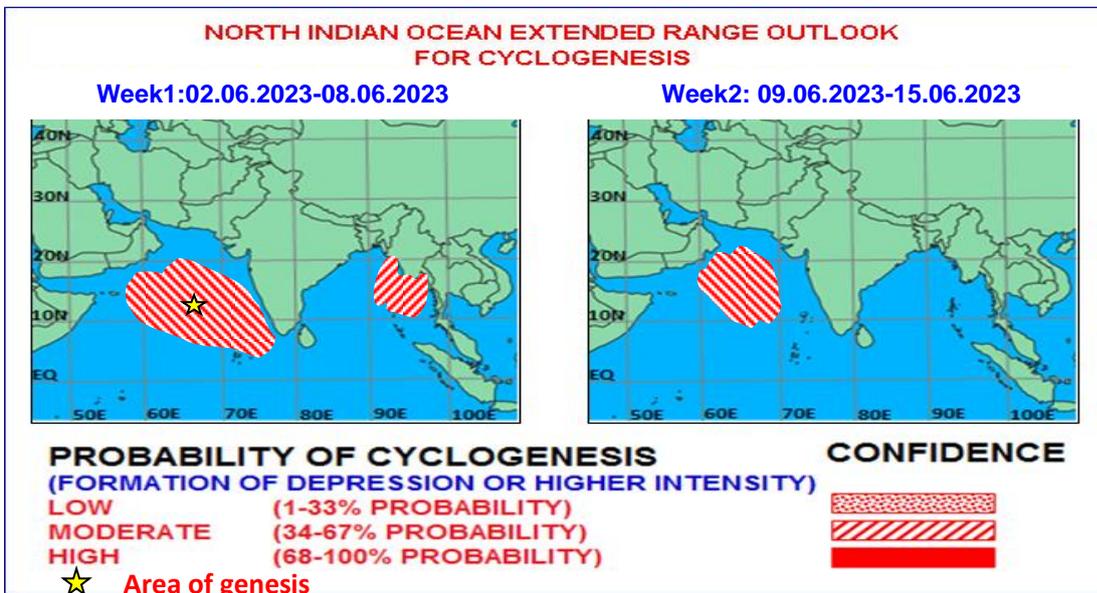


Fig.6: Extended range outlook issued on 1st June (5 days prior to formation of depression)

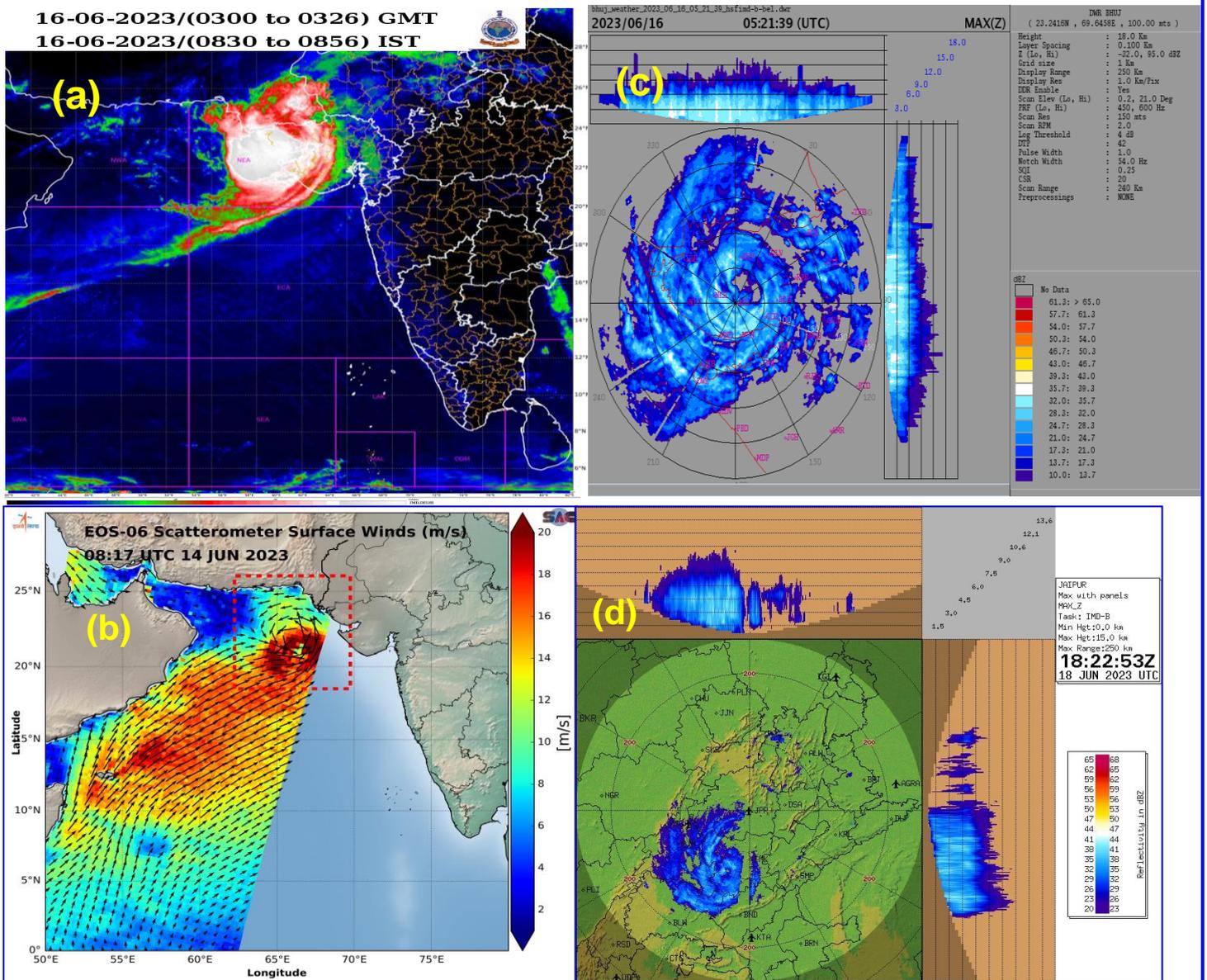


Fig.7: (a) Typical INSAT 3D (R), (b) SCAT SAT, (c) Doppler Weather Radar Bhuj and (d) Doppler Weather Radar Jaipur imagery

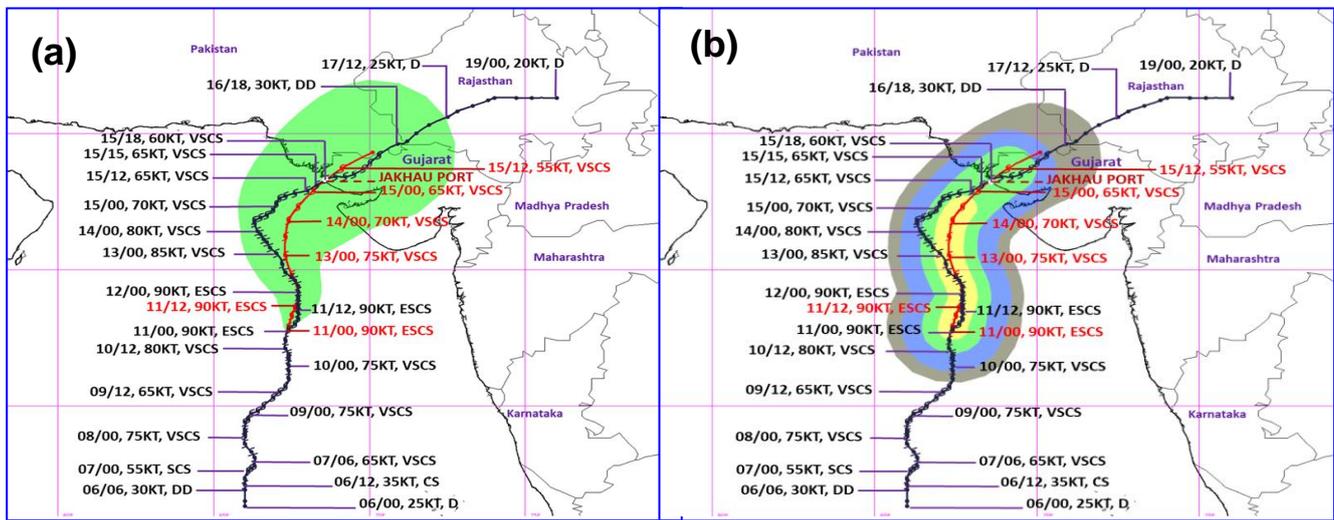


Fig.8: Observed track and forecast track alongwith (a) cone of uncertainty in track forecast and (b) wind distribution issued on 11th June based on 0000 UTC (0530 IST) observations demonstrating accuracy in track, landfall point and intensity prediction (about 4 days 18 hrs prior to landfall)

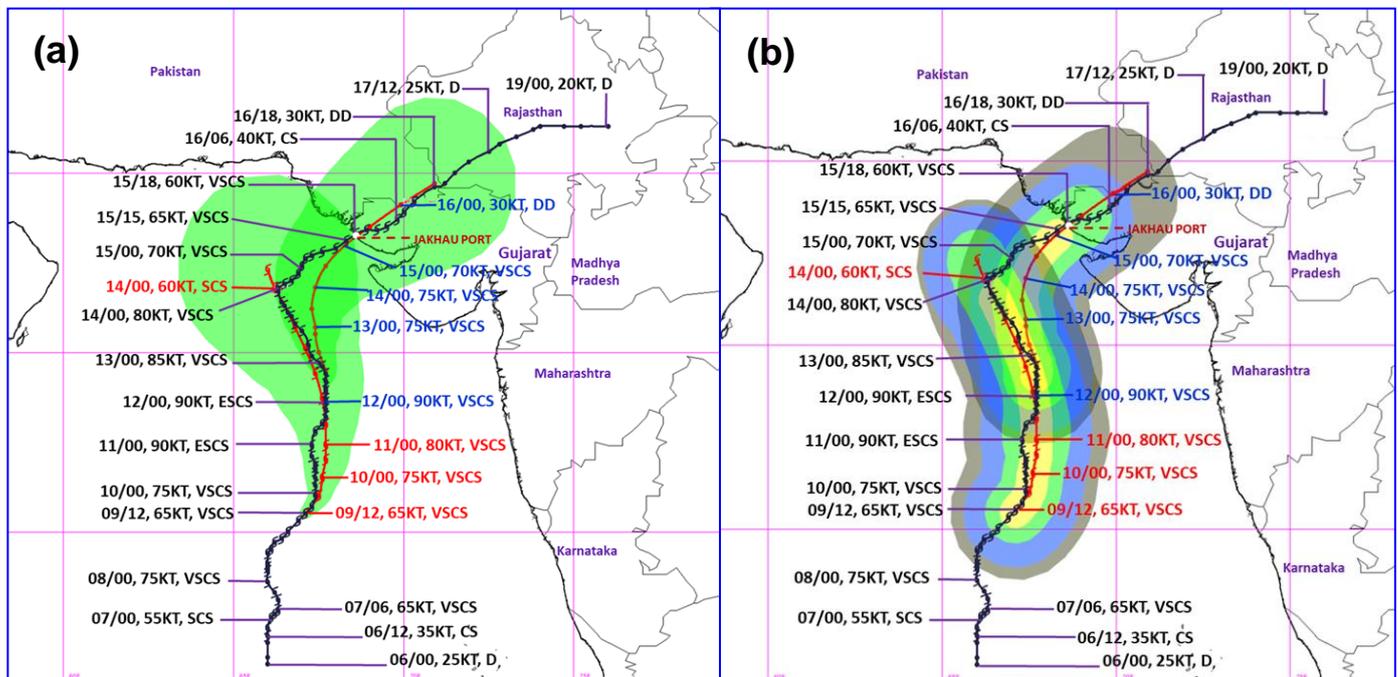


Fig.9: Typical track and intensity forecast alongwith (a) cone of uncertainty and (b) wind distribution issued on 9th June evening (1730 hrs IST/1200 UTC) about 6 days and 6 hours prior to landfall and 12th June morning (0000 UTC/ 0530 hours IST) about 4 days and 18 hours prior to landfall demonstrating accuracy in track, intensity and landfall prediction

Legends:

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
- : ≥ 48 KT

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

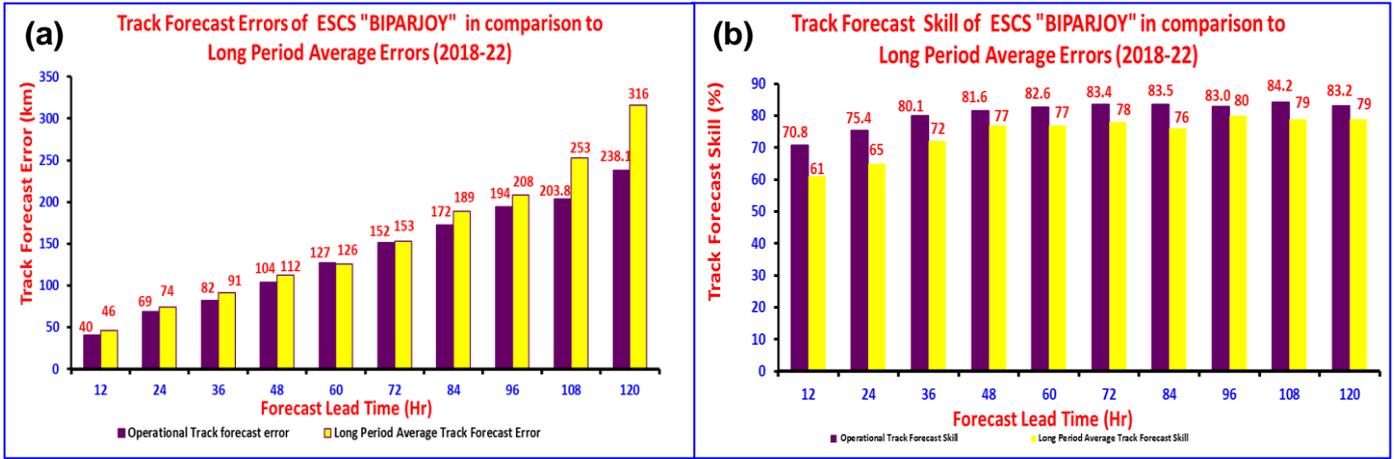


Fig.10: Operational (a) track forecast accuracy and (b) track forecast skill of cyclone Biparjoy compared to long period average (LPA) during 2018-22

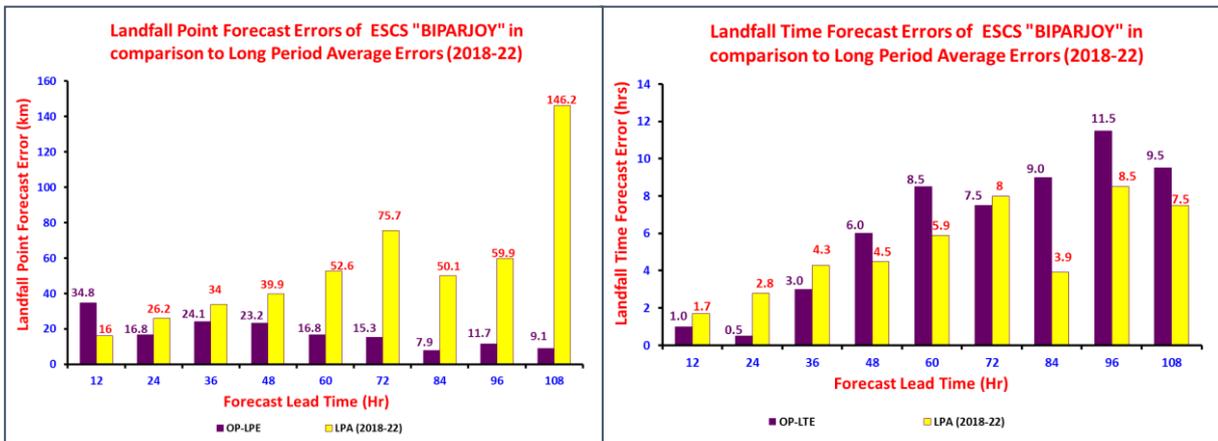


Fig.11: Operational landfall (a) point and (b) time forecast accuracy of cyclone Biparjoy compared to long period average (LPA) during 2018-22

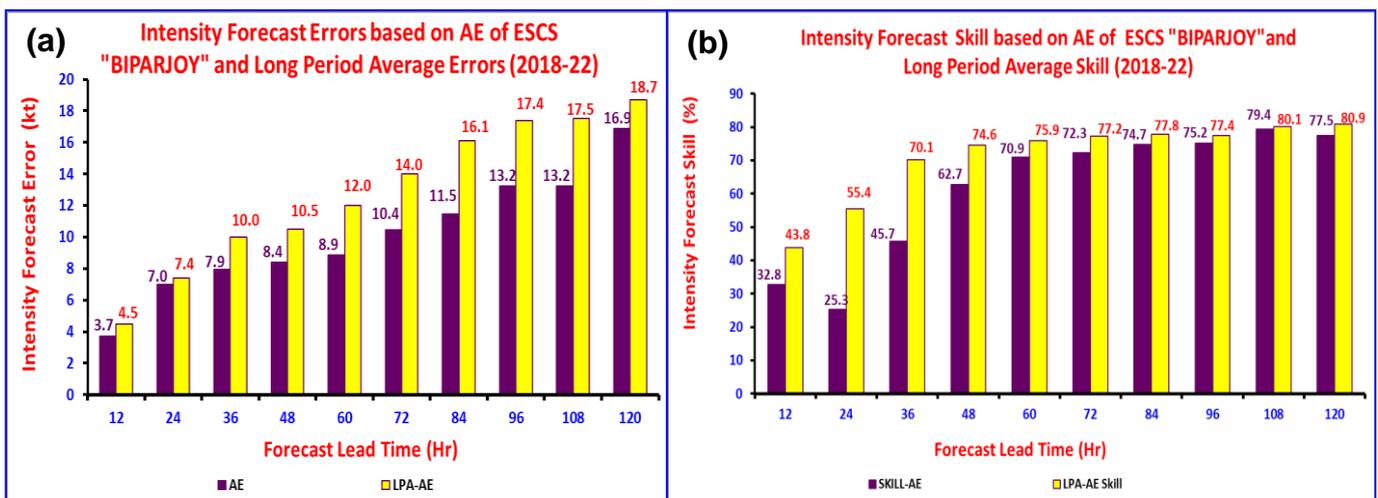


Fig.12: Operational (a) Absolute errors (AE) and (b) skill in intensity forecast of cyclone Biparjoy compared to long period average (LPA) during 2018-22

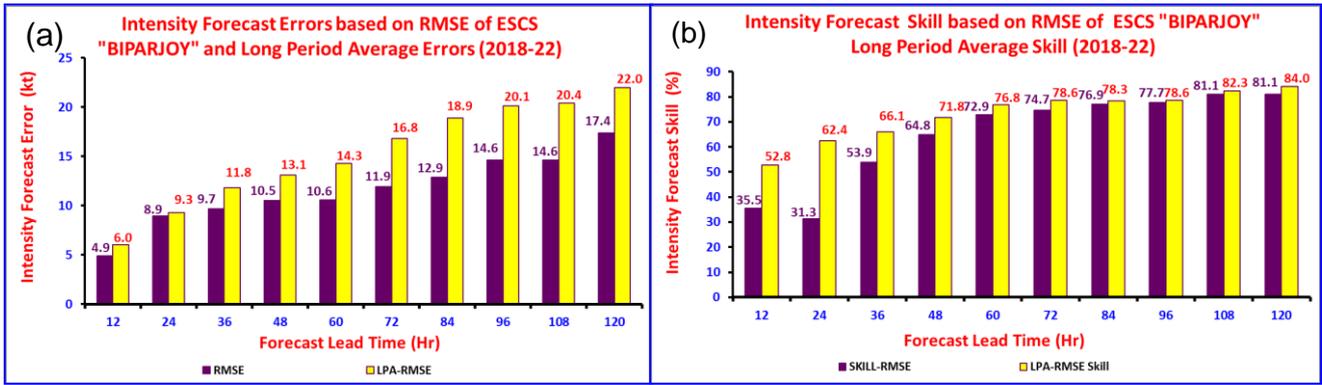


Fig.13: Operational (a) Root Mean Square Error (RMSE) and (b) skill in intensity forecast compared to long period average (LPA) during 2018-22

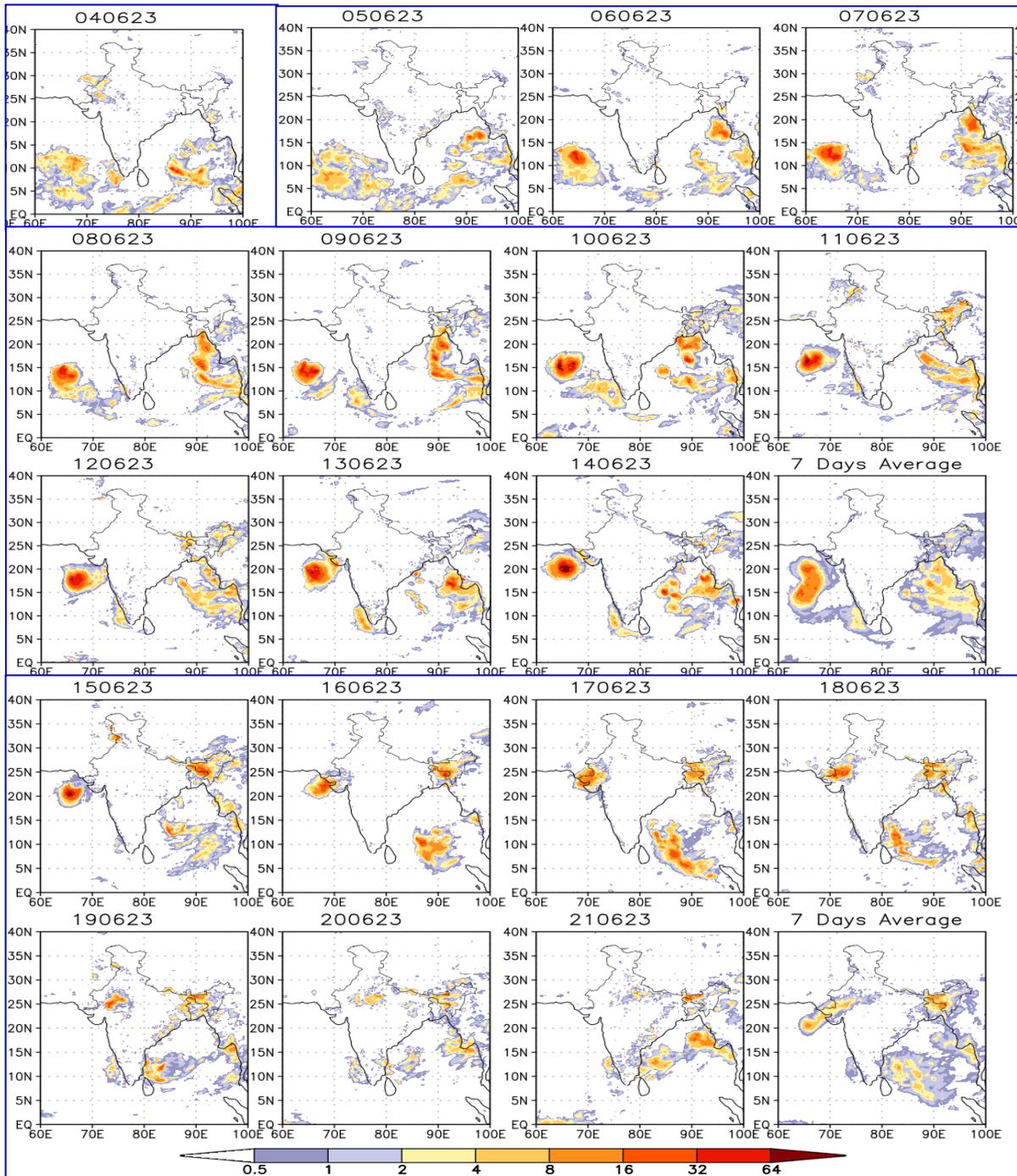


Fig.14: IMD NCMRWF satellite gauge merged rainfall during 6th-19th June

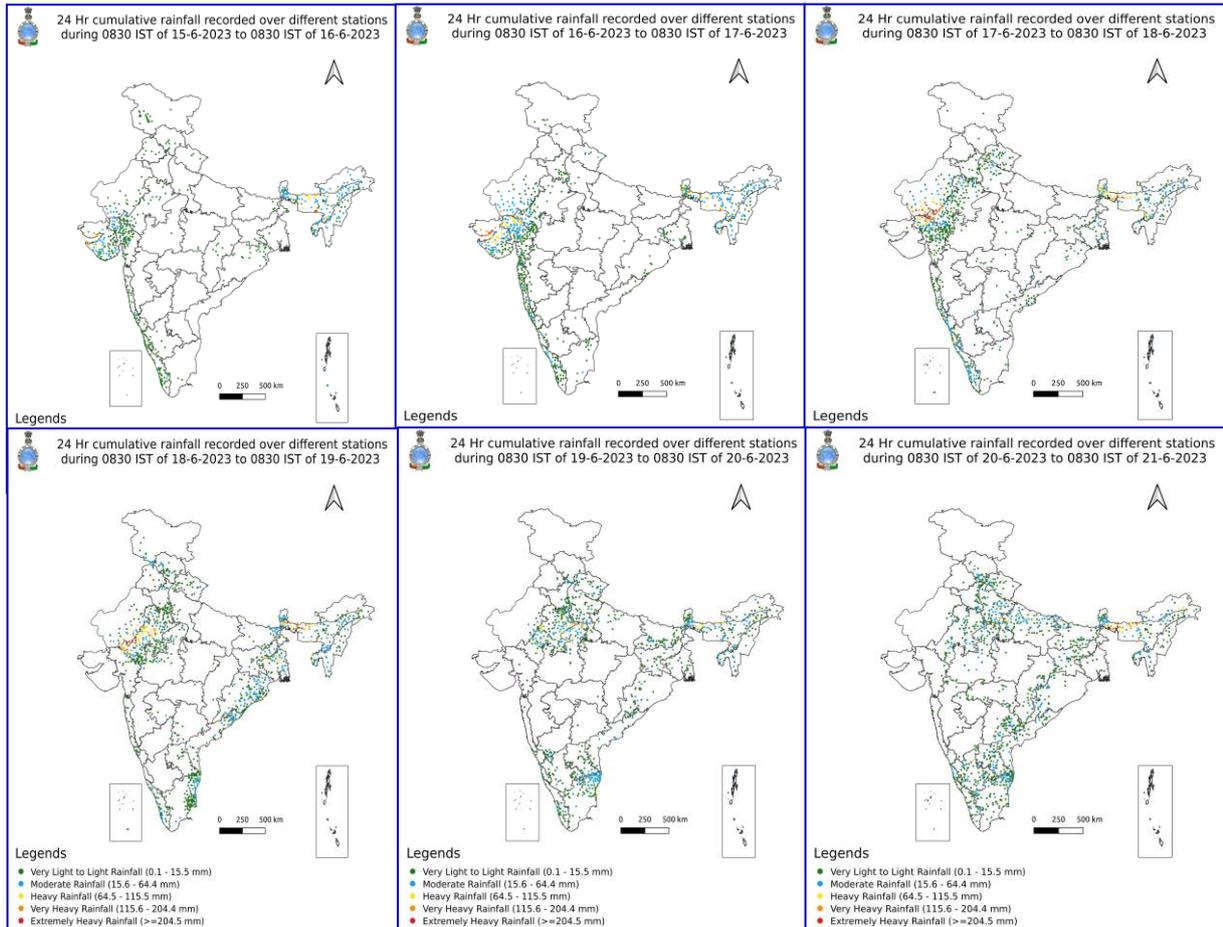


Fig.15: 24 hour cumulative rainfall recorded over different stations during 15th to 20th June

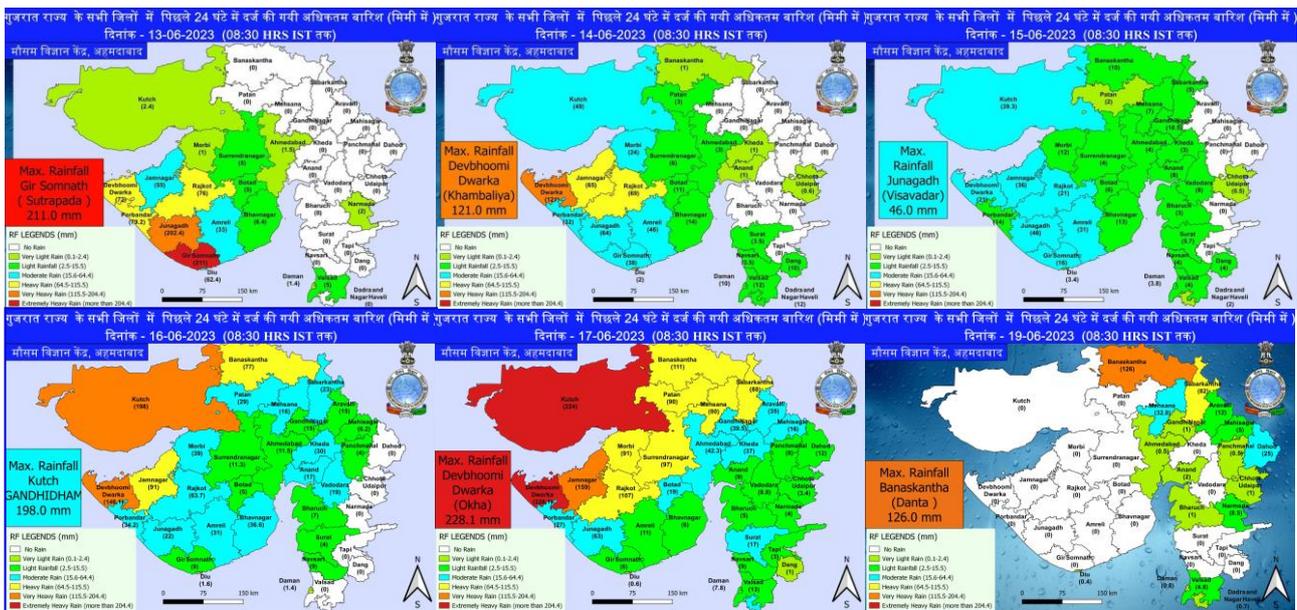


Fig.16: District-wise realised rainfall over Gujarat during 13th-19th June

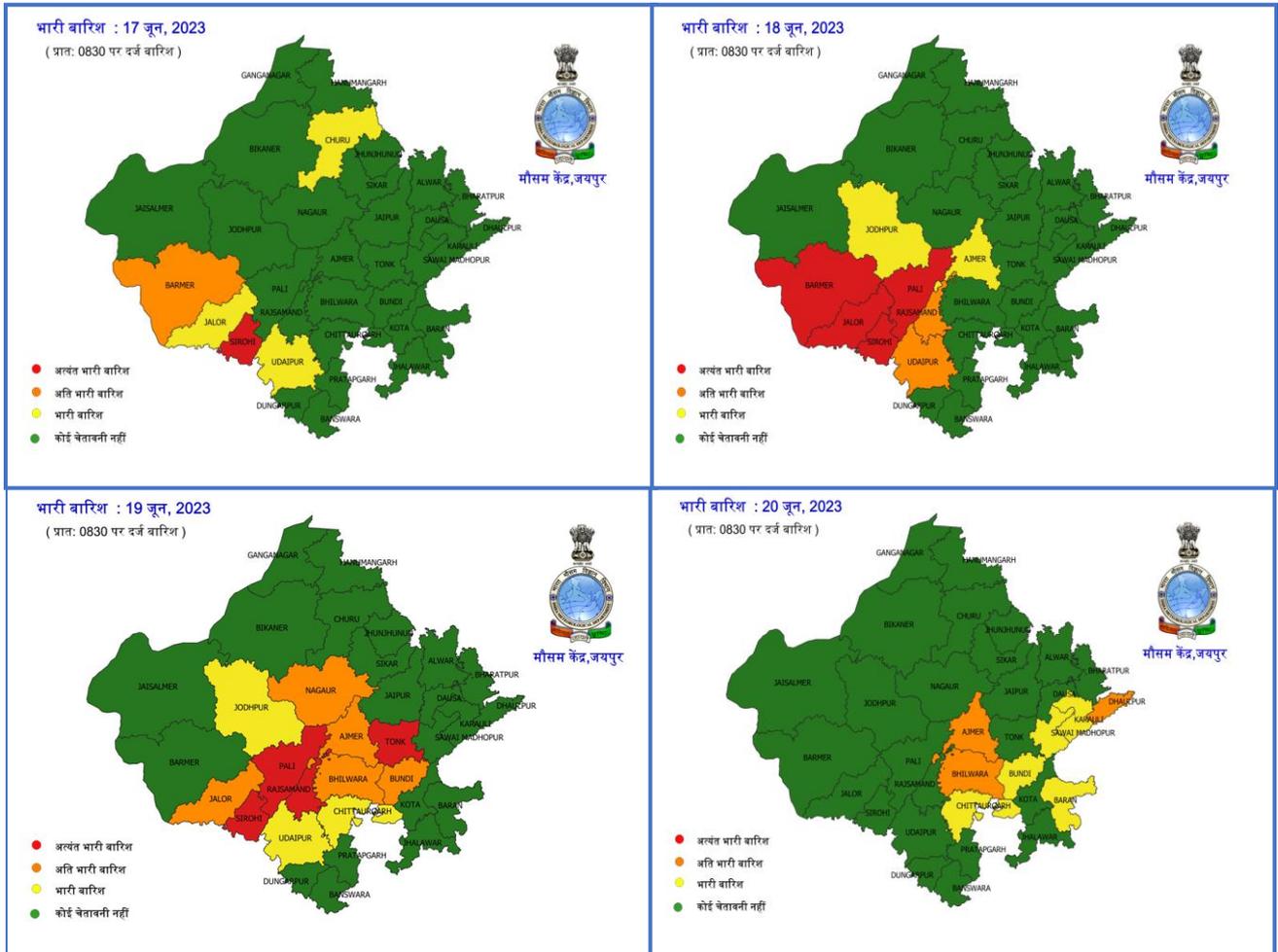


Fig.16 contd: District-wise realised rainfall over Rajasthan during 16th-20th June

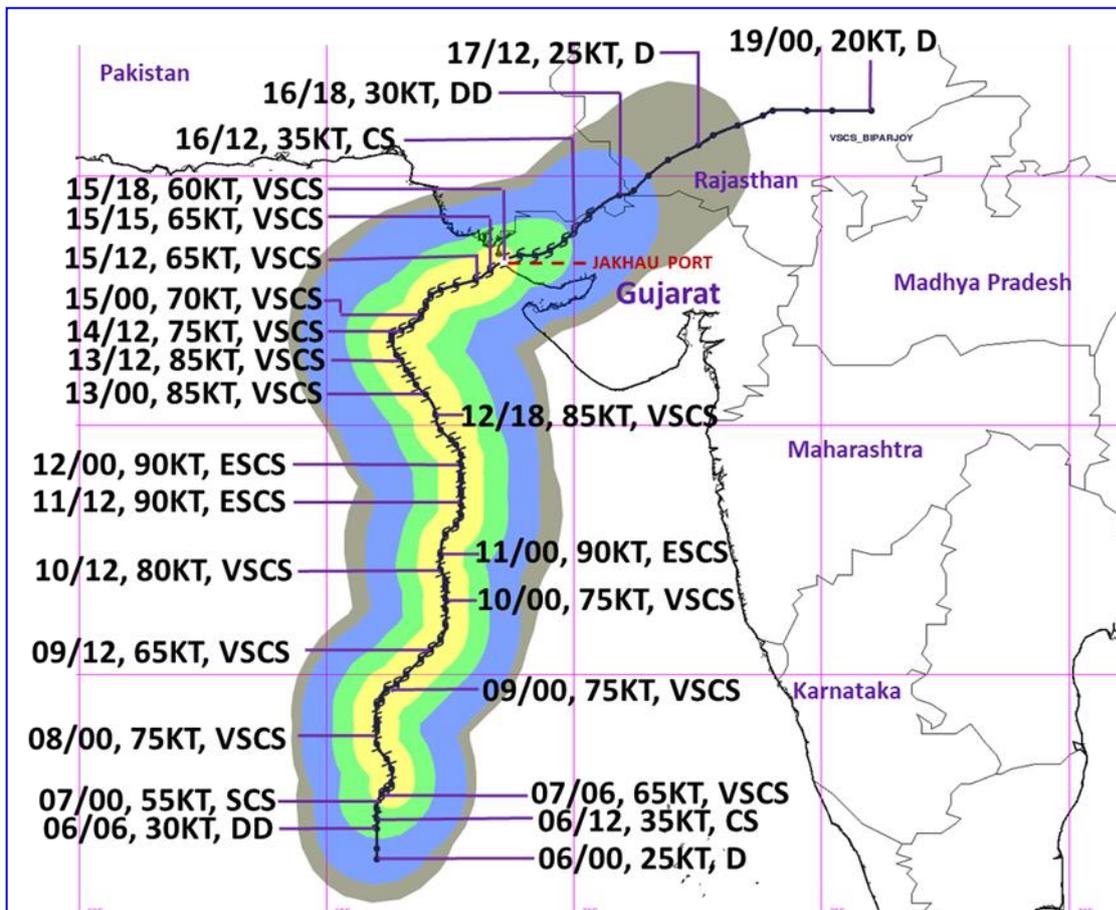


Fig.17: The estimated maximum sustained wind speed in association with ESCS Biparjoy during 6th-19th June.

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

● : LESS THAN 34 KT
 ○ : 34-47 KT
 ⊙ : ≥ 48 KT

█ OBSERVED TRACK

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

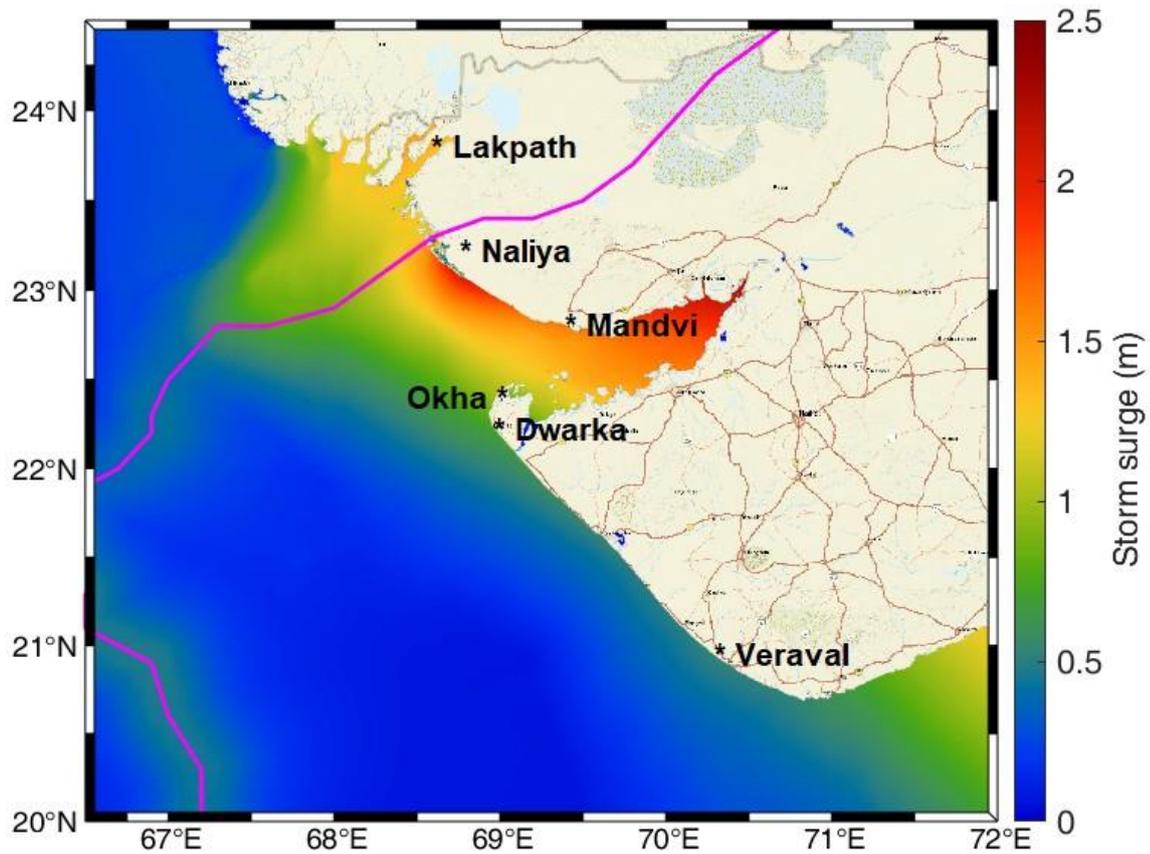


Fig.18: The estimated storm surge in association with ESCS Biparjoy during landfall

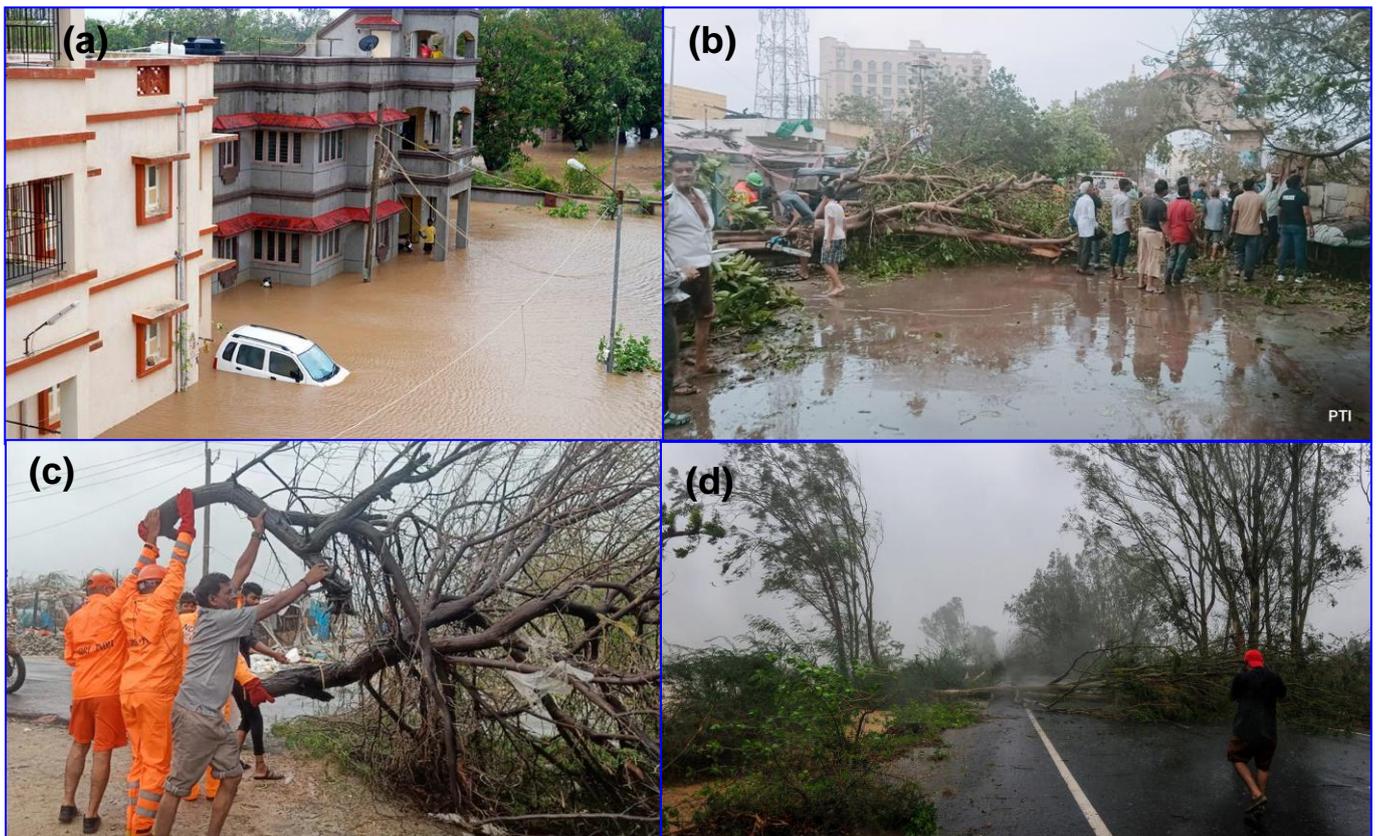


Fig. 19 (a) Car submerged in Mandvi, Gujarat (Reuters, 16th June), (b) Fallen trees in Saurashtra (PTI, 16th June), (c) NDRF team clearing fallen trees (NDTV, 16th June) and (d) Blocked road at Naliya near Jakhau (The Hindu, 17th June)



Fig. 19 (contd.): (e) Damaged electric poles in Kutch district (PTI, 17th June), (f) Damage at Jakhau Port (g) Damaged trees at Kandla Port and (h) Damaged buildings at Kandla Port (Source: Fig. f-g: Post Cyclone Survey team, IMD)



Fig. 20: (a) Flooded roads in Ajmer, Rajasthan and (b) Damaged vehicles in Rajasthan (ET, 17th June)