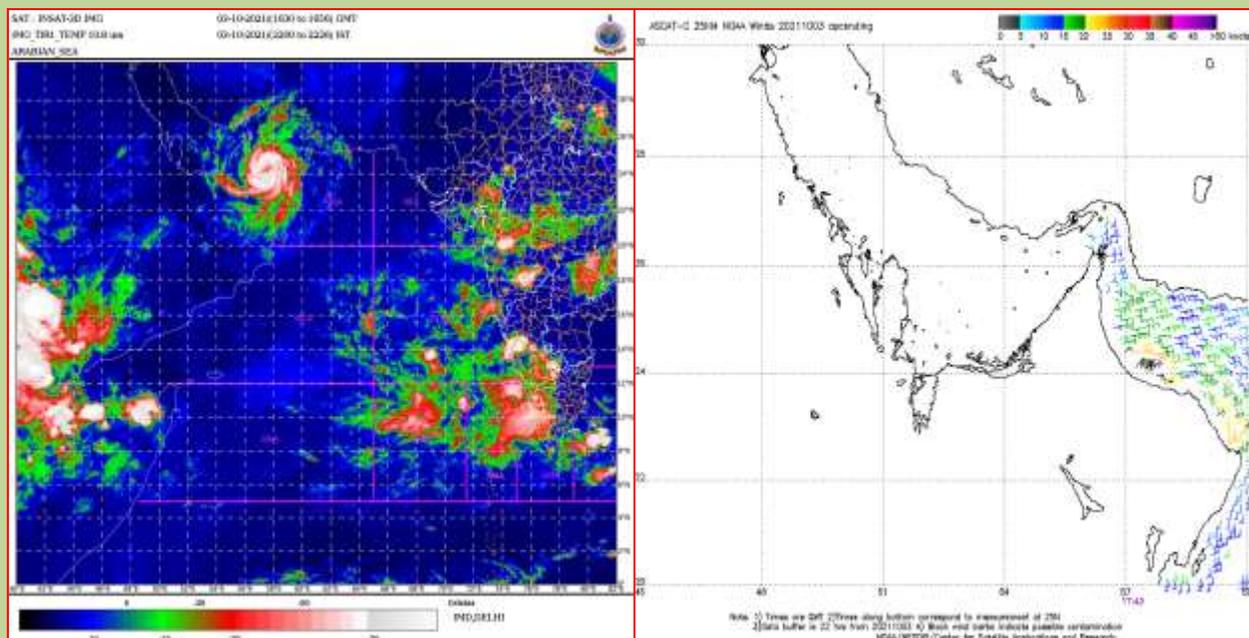# GOVERNMENT OF INDIA

MINISTRY OF EARTH SCIENCES

INDIA METEOROLOGICAL DEPARTMENT

Severe Cyclonic Storm Shaheen over northeast Arabian Sea adjoining Kutch (30th September – 4th October 2021)

Typical imagery of severe cyclonic storm Shaheen at (a) 1630 UTC from INSAT 3D and (b) 1743 UTC from ASCAT C of 3rd October

Cyclone Warning Division

India Meteorological Department

New Delhi

October 2021

Severe Cyclonic Storm Shaheen over northeast Arabian Sea adjoining Kutch

1. **Life History:**

➢ The remnant of cyclonic storm Gulab emerged as a well marked low pressure area into south Gujarat region & adjoining Gulf of Khambhat in the morning (0830 hours IST) of 29th September.

➢ Under favourable environmental and sea conditions, it concentrated into a depression over northeast Arabian Sea (AS) & adjoining Kutch, in the morning (0530 hours IST) of 30th September.

➢ Moving west-northwestwards, it further intensified into a deep depression over the same region in the midnight (2330 hours IST) of 30th September.

➢ Thereafter it moved westwards and intensified into cyclonic storm "Shaheen" over the northeast AS off Gujarat coast in the morning (0530 hours IST) of 1st October, 2021.

➢ Moving westwards for some time, it moved west-northwestwards and intensified into a severe cyclonic storm in the evening (1730 hours IST) of 1st October over northwest & adjoining northeast Arabian Sea.

➢ Continuing to move further west-northwards till evening (1730 hours IST) of 2nd October, it recurved west-southwestwards and crossed Oman coast during 0030-0130 IST of 4th Oct. with wind speed of 95-105 gusting to 115 kmph.

➢ Thereafter moving west-southwestwards, it weakened into a cyclonic storm over North Oman and adjoining United Arab Emirates in the morning (0530 hours IST), into deep depression in the forenoon (0830 hours IST), into a depression around noon (1130 hours IST) and into a well marked low pressure area in the evening (1730 hours IST) of 4th October over the same region.

➢ Observed track of the system during 30th September -4th October is presented in Fig.1.

Fig.1: Observed track of cyclonic storm Gulab (24th Sep - 28th Sep), it's remnant (28th Sep-30th Sep.) and severe cyclonic storm, Shaheen (30th Sep.-4th Oct.)

Table 1: Best track positions and other parameters of the Severe Cyclonic Storm SHAHEEN over Arabian Sea during 30 Sept- 4 Oct, 2021

Date	Time (UTC)	Centre lat.^{0} N/ long. ^{0} E		C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimated Pressure drop at the Centre (hPa)	Grade
30.09.2021	0000	22.7	69.5	1.5	998	25	4	D
	0300	22.7	68.6	1.5	998	25	4	D
	0600	22.8	68.2	1.5	998	25	4	D
	1200	23.1	67.4	1.5	998	25	4	D
	1800	23.1	66.8	2.0	996	30	6	DD
01.10.2021	0000	23.2	65.5	2.5	995	35	7	CS
	0300	23.2	64.9	2.5	994	40	8	CS
	0600	23.2	64.5	3.0	992	45	10	CS
	0900	23.3	64.1	3.0	991	45	11	CS
	1200	23.4	63.7	3.5	987	55	15	SCS
	1500	23.6	63.4	3.5	986	55	16	SCS
	1800	23.6	63.2	3.5	984	60	18	SCS
	2100	23.8	62.8	3.5	984	60	18	SCS
02.10.2021	0000	23.8	62.4	3.5	984	60	18	SCS
	0300	23.9	62.1	3.5	984	60	18	SCS
	0600	24.1	61.8	3.5	984	60	18	SCS
	0900	24.3	61.3	3.5	984	60	18	SCS
	1200	24.5	60.7	3.5	984	60	18	SCS
	1500	24.5	60.4	3.5	984	60	18	SCS
	1800	24.4	60.0	3.5	984	60	18	SCS
	2100	24.4	59.7	3.5	984	60	18	SCS
03.10.2021	0000	24.3	59.5	3.5	984	60	18	SCS
	0300	24.2	59.0	3.5	984	60	18	SCS
	0600	24.1	58.6	3.5	984	60	18	SCS
	0900	24.1	58.3	3.5	984	60	18	SCS
	1200	24.0	58.0	3.5	984	60	18	SCS
	1500	24.0	57.7	3.5	984	60	18	SCS
	1800	23.9	57.3	3.5	986	55	16	SCS
		Crossed Oman coast during 1900 to 2000 UTC of 3rd October, near latitude 23.9°N and longitude 57.3°E, about 120 km west-northwest of Muscat as a severe cyclonic storm with a maximum sustained wind speed of 95-105 kmph gusting to 115 kmph.						
	2100	23.8	57.2	-	988	55	14	SCS
04.10.2021	0000	23.7	56.8	-	994	40	08	CS
	0300	23.5	56.4	-	998	30	05	DD
	0600	23.3	56	-	1000	20	03	D
	1200	23.3	Weakened into a well-marked low pressure area over north Oman and adjoining United Arab Emirates						

2.   Monitoring:

India Meteorological Department (IMD) maintained round the clock watch over the north Indian Ocean and the system was continuously tracked after the landfall of cyclone Gulab over north Andhra Pradesh on 26th (Fig.2). Gulab weakened into a well marked low pressure area over western parts of Vidarbha in the afternoon (0600 UTC) of 28th Sep. However, the system was monitored even after that. On 29th September forenoon (0830 hours IST) the media and general public were informed about the likely emergence of remnant of Gulab into northeast Arabian Sea. The extended range outlook issued on 30th September indicated high probability of cyclogenesis over north Arabian Sea. 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. Various numerical weather prediction models run by Ministry of Earth Sciences (MoES) institutions, global models and dynamical-statistical models were utilized to predict the genesis, track, landfall and intensity of the system. A digitized forecasting system of IMD was utilized for analysis and comparison of various models' guidance, decision making process and warning products generation. Detailed satellite imageries from INSAT-3D, ASCAT, Total Perceptible Water and Microwave imageries utilized for monitoring SCS SHAHEEN are presented in Fig. 2 (a-f). IMD GFS analysis charts based on 0000 UTC during 30[th]Sep - 4th Oct are presented in Fig. 2 (h-l).
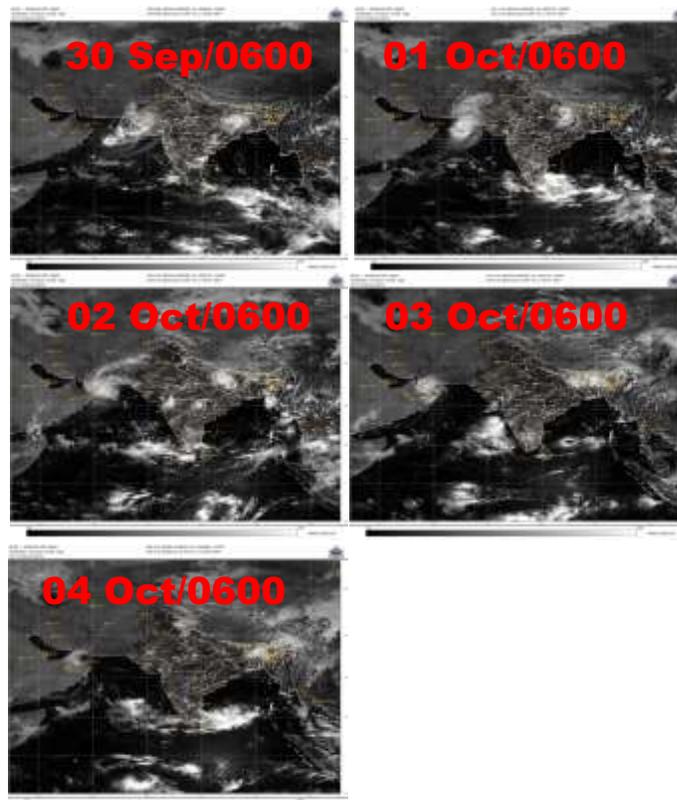

Fig. 2(a): INSAT-3D Visible imageries during life cycle of SCS SHAHEEN during 30 Sept- 4 Oct, 2021

30 Sep/0000 **30 Sep/1200** **01 Oct/0000**

01 Oct/1200 **02 Oct/0000** **02 Oct/1200**

02 Oct/1630 **03 Oct/0000** **03 Oct/1200**

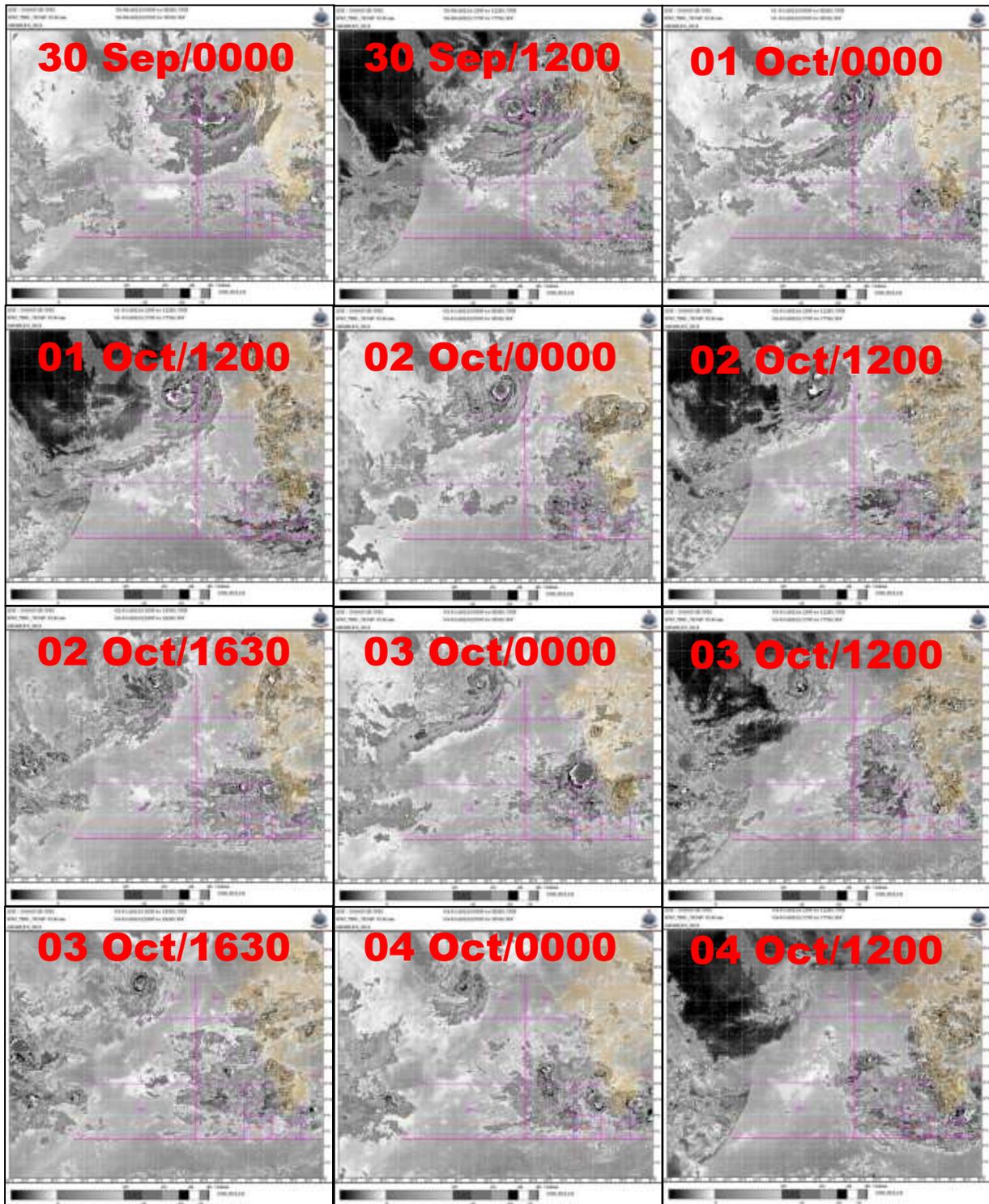**03 Oct/1630** **04 Oct/0000** **04 Oct/1200**

Fig. 2(b): INSAT-3D BD imageries during life cycle of SCS SHAHEEN during 30 Sept- 4 Oct, 2021

Fig. 2(c): INSAT-3D IR imageries during life cycle of SCS SHAHEEN during 30 Sept- 4 Oct, 2021
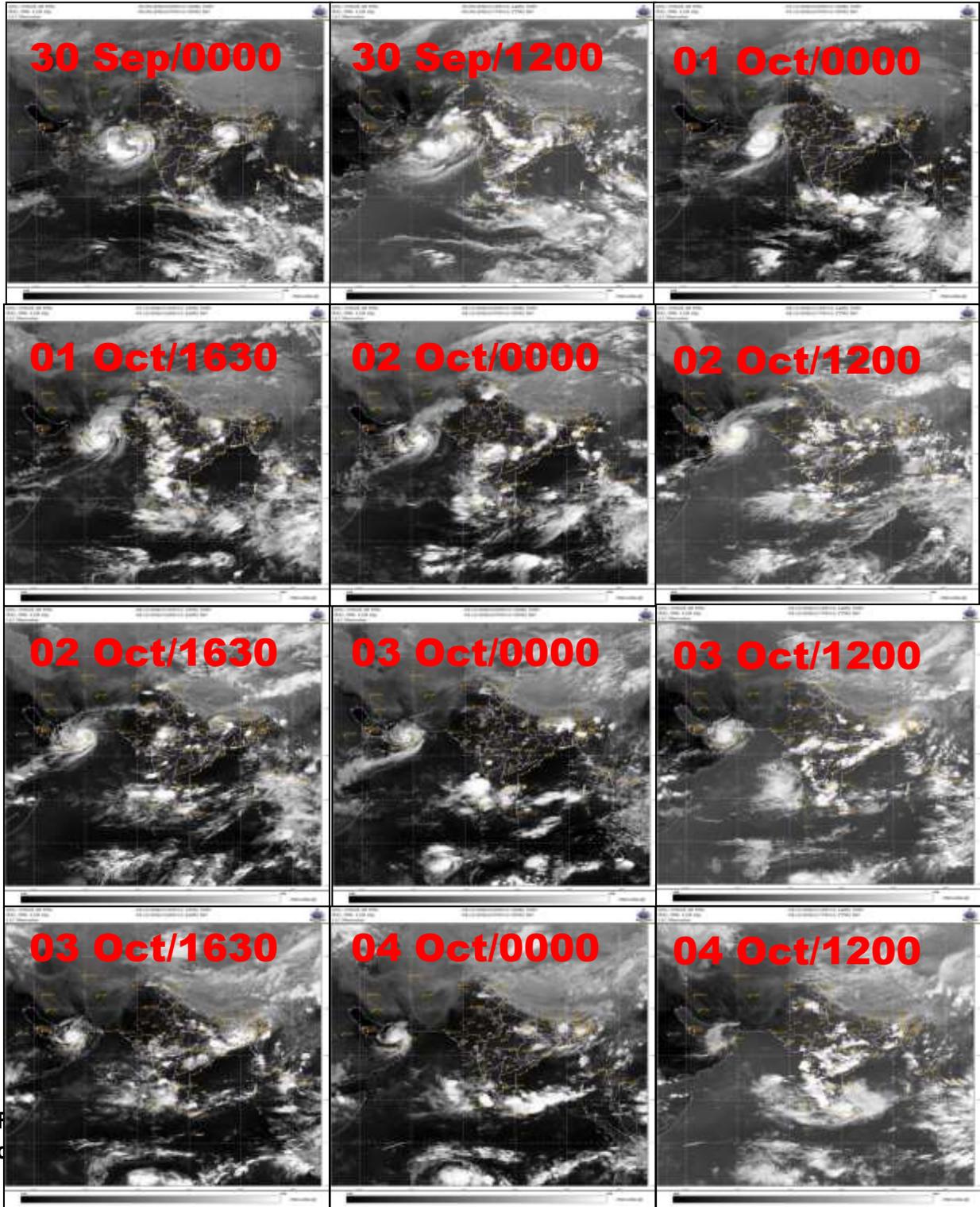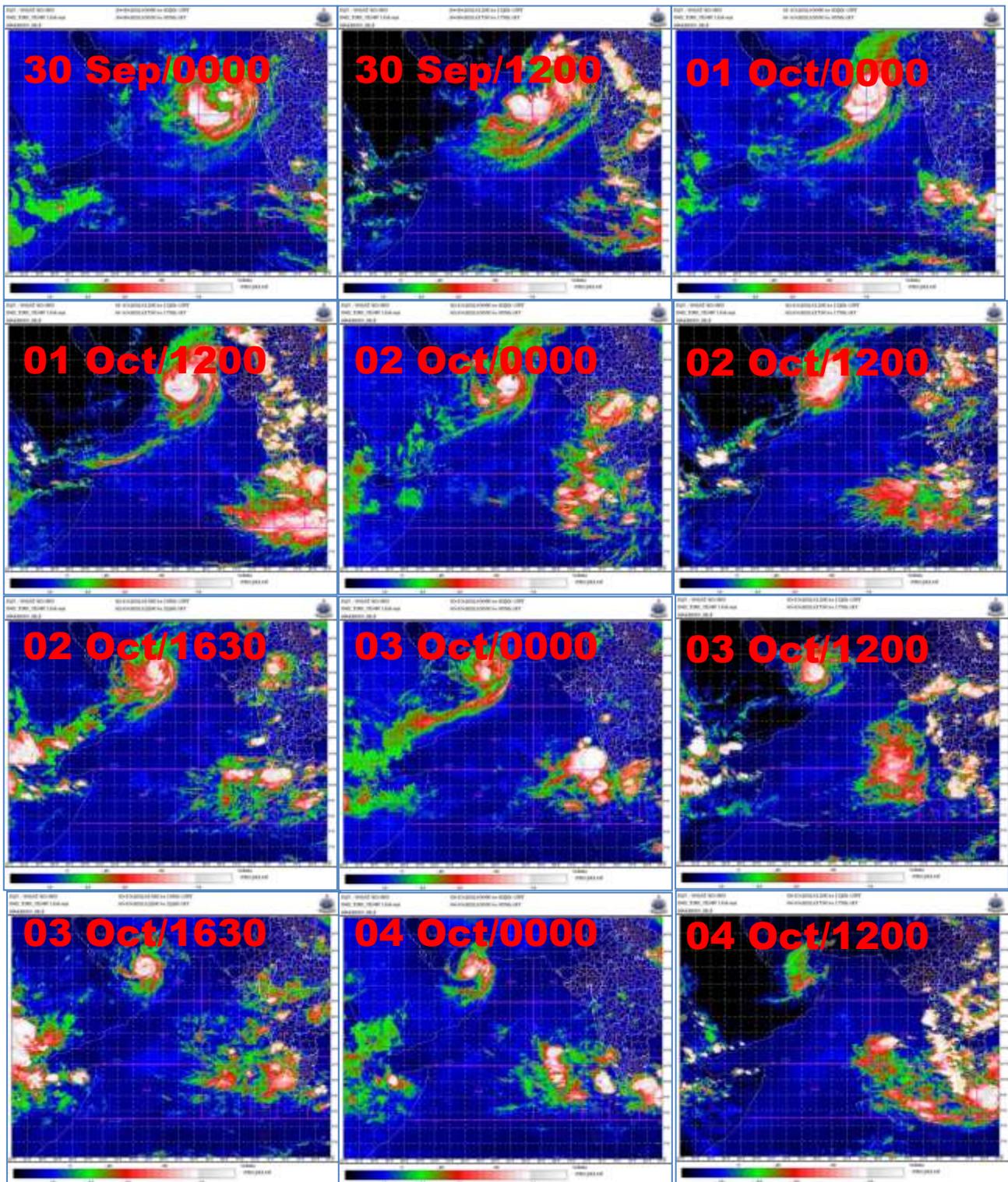
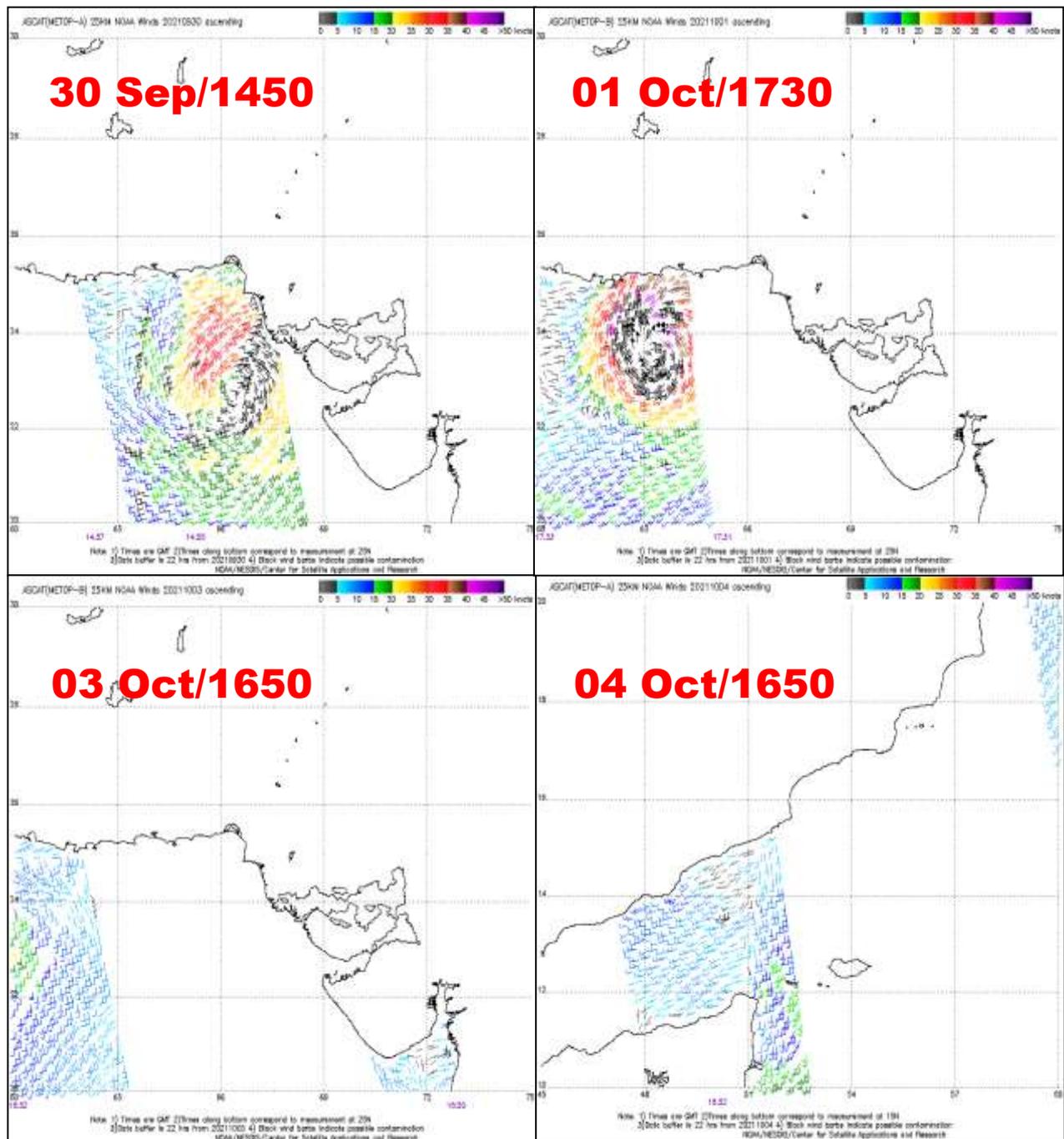**Fig. 2(d): INSAT-3D NHC imageries during life cycle of SCS SHAHEEN during 30 Sept- 4 Oct, 2021**

Fig. 2(e): ASCAT imageries during life cycle SCS SHAHEEN during 30 Sept- 4 Oct, 2021
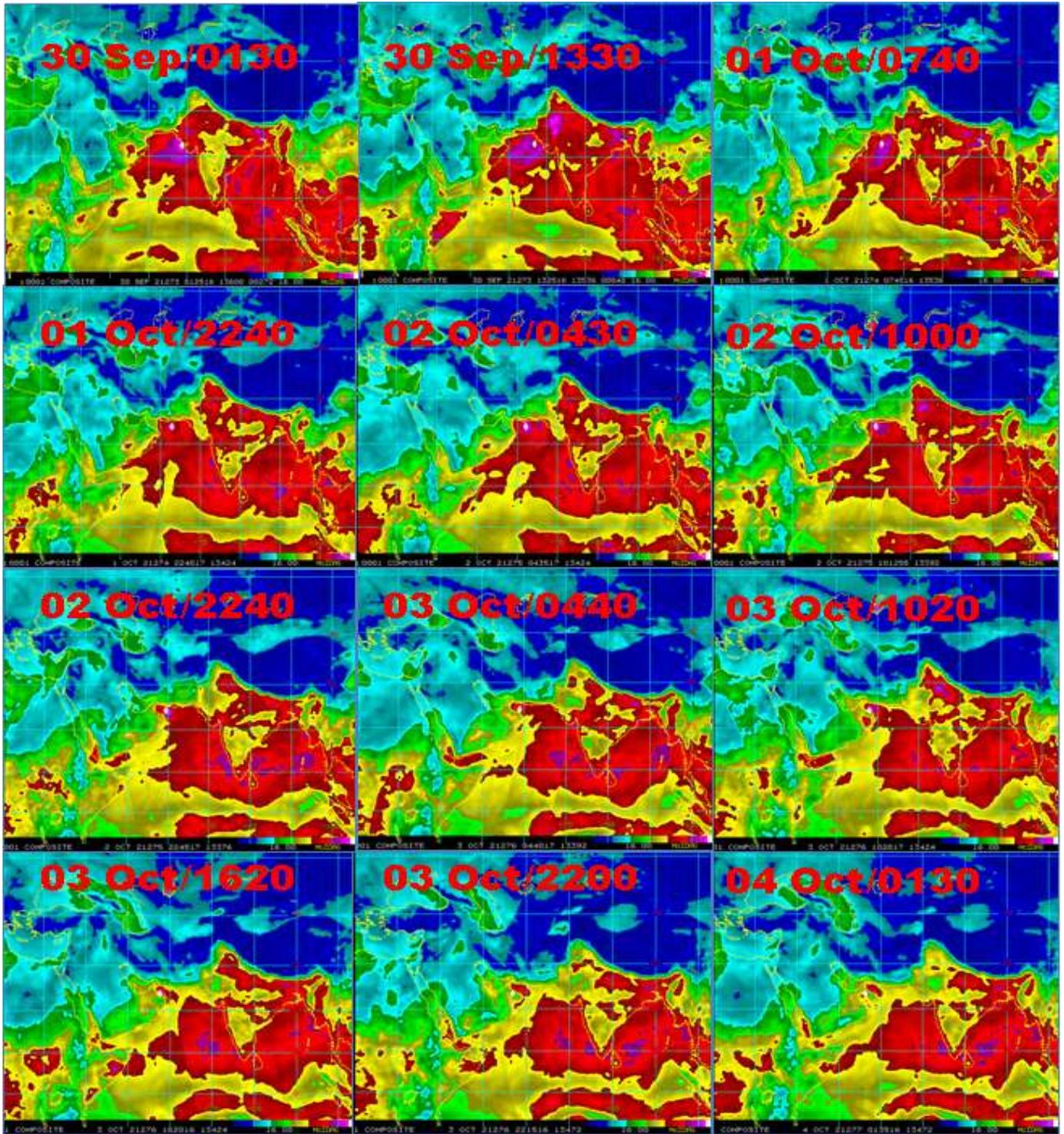
Fig. 2(f): Typical total precipitable water vapour imageries during life cycle of SCS SHAHEEN during 30 Sept- 4 Oct, 2021
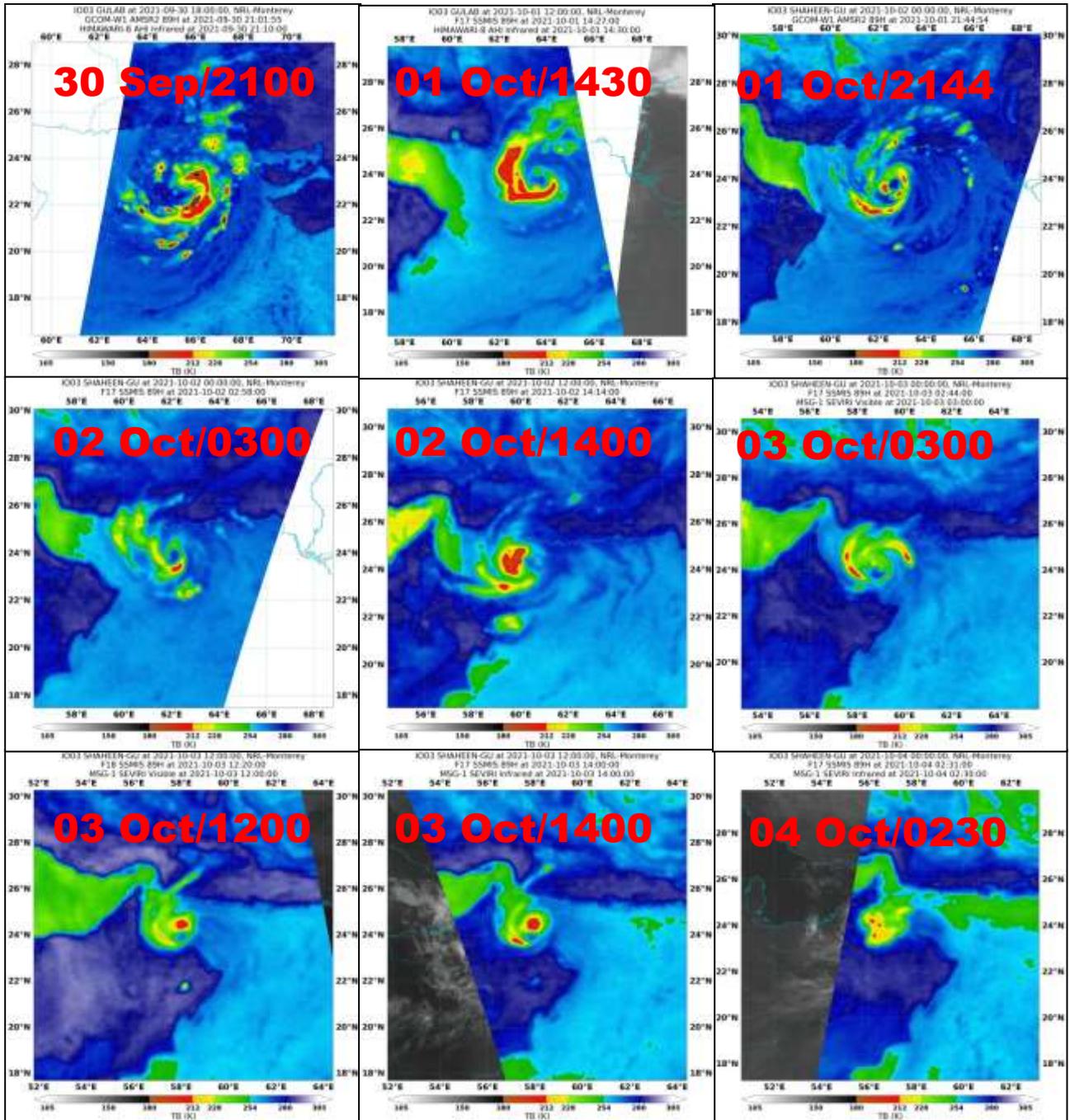
Fig.2 (g):): Microwave imageries during life cycle of SCS SHAHEEN during 30 Sept- 4 Oct, 2021
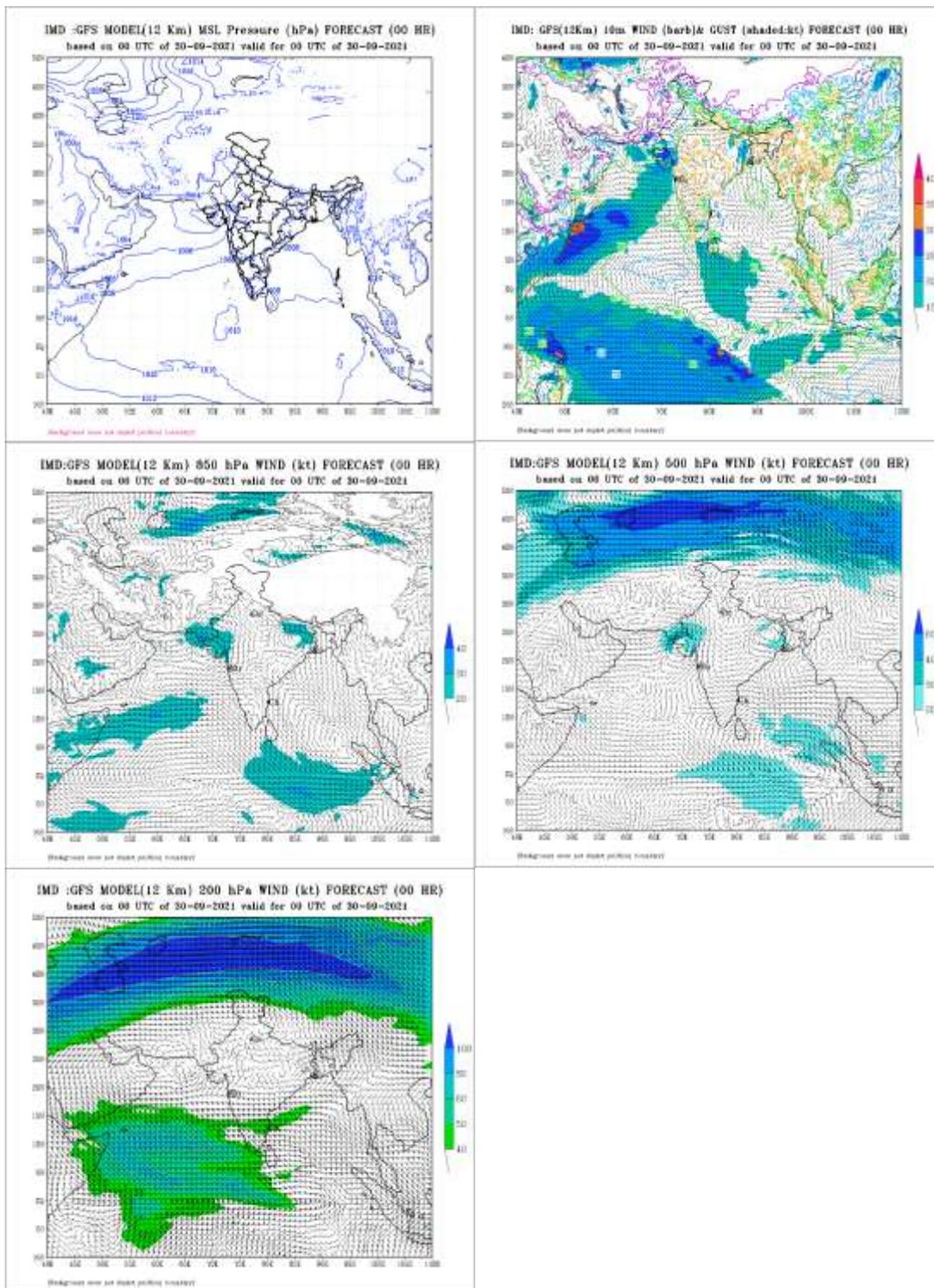
Fig.2 (h): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 30th September 2021

Fig.2 (i): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 1st October 2021

Fig.2 (j): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 2nd October 2021

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Fig.2 (k): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 3rd October 2021
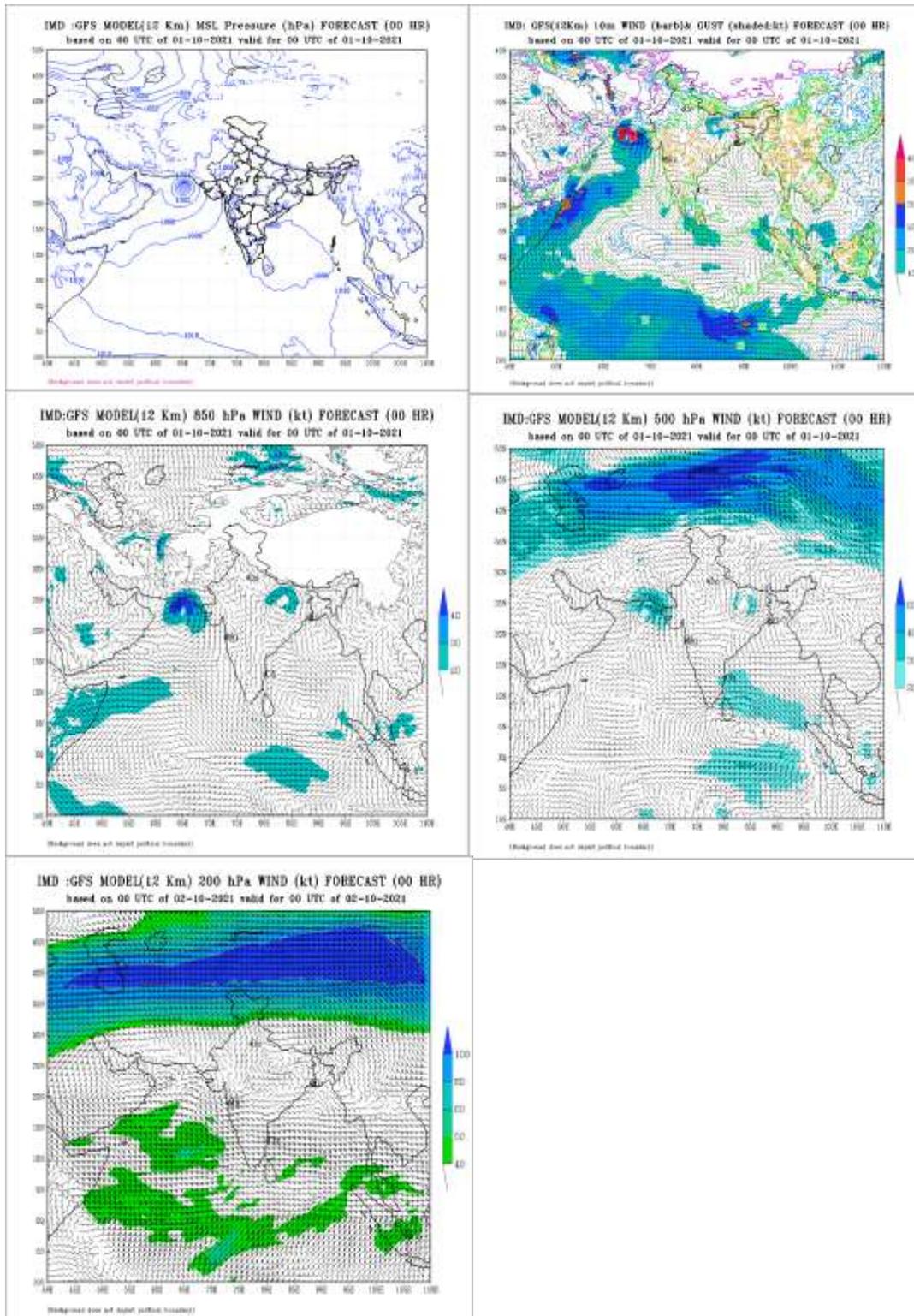
Fig.2 (I): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 4th October 2021
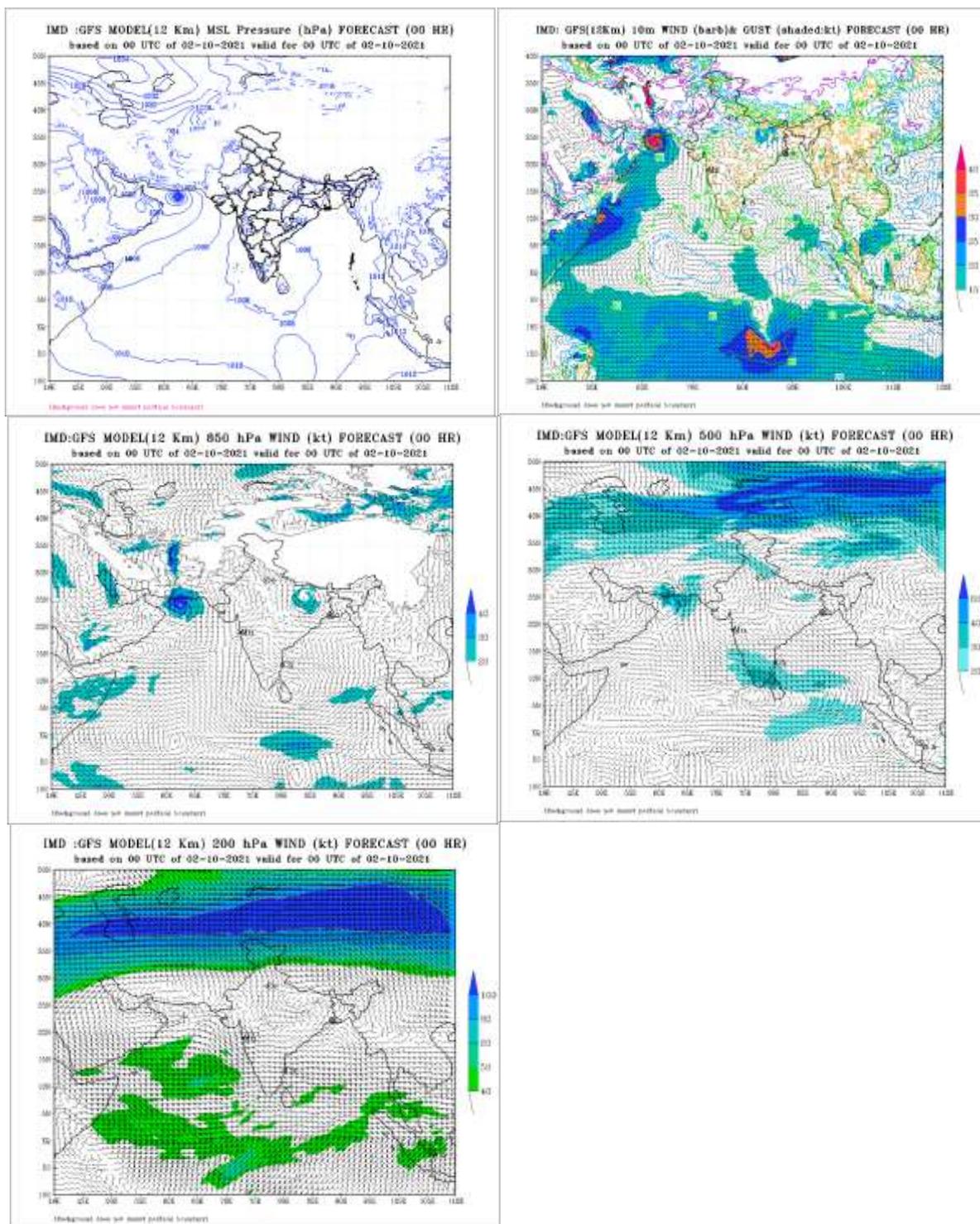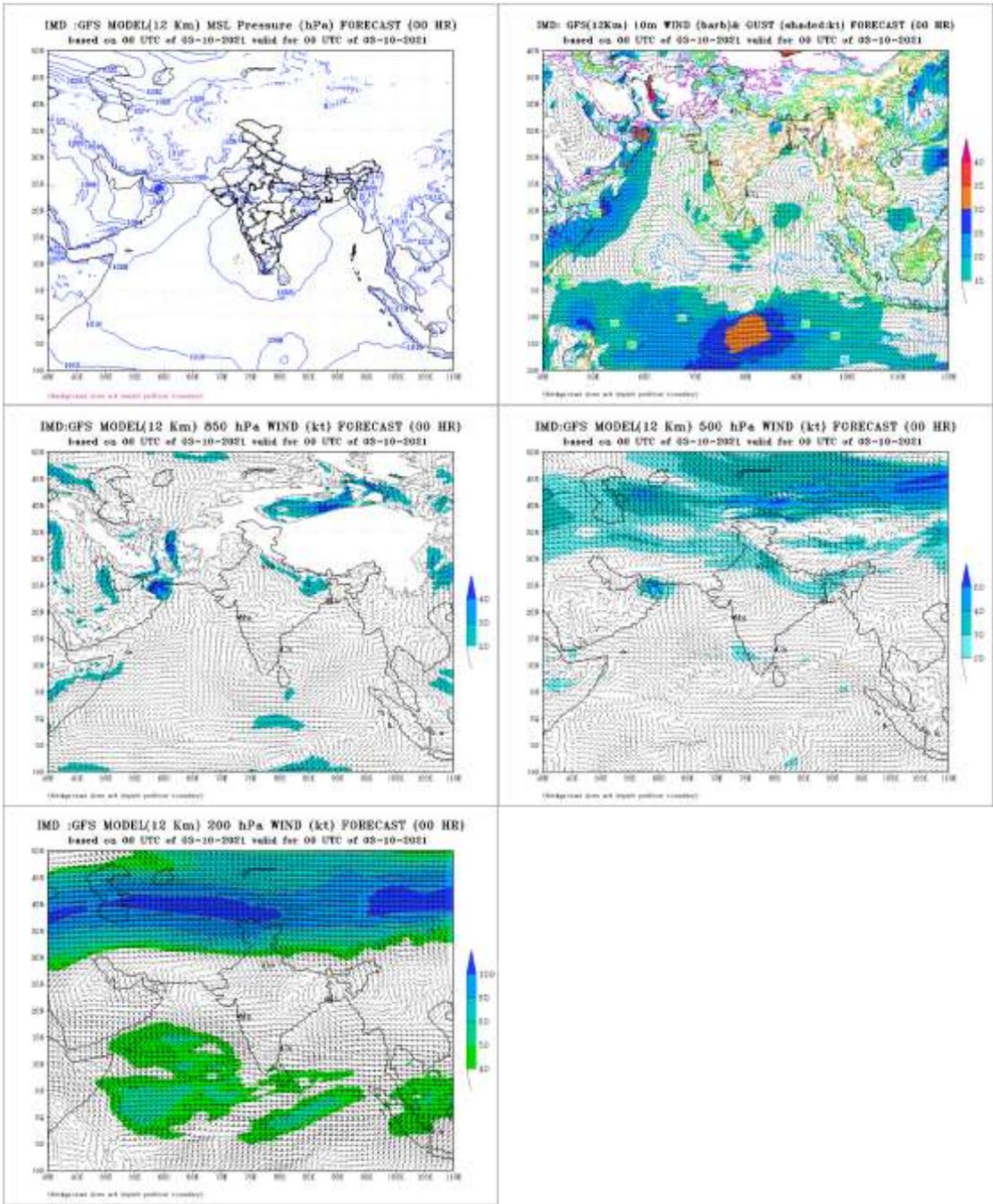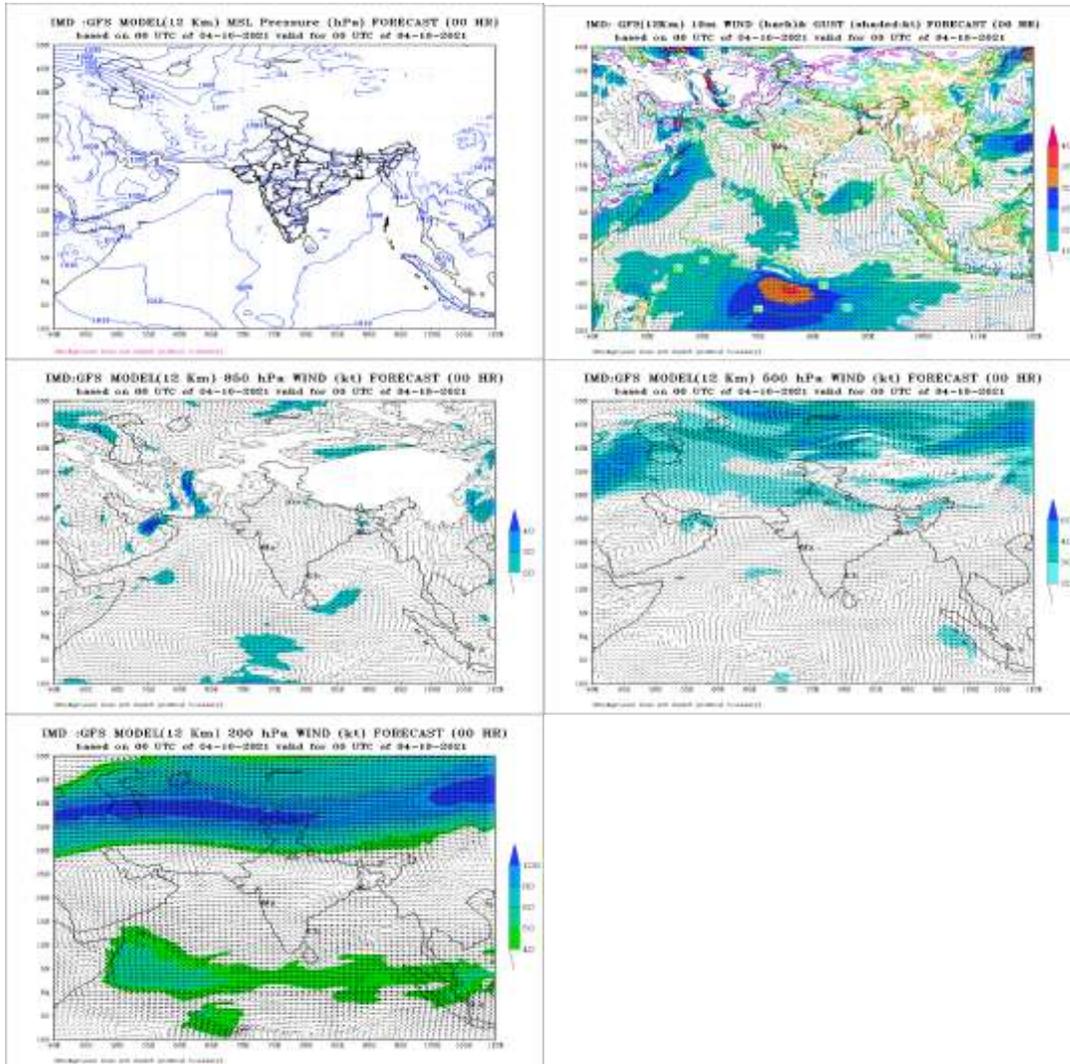
3. Realised Weather:

3.1. Realised rainfall

Rainfall associated with SCS Shaheen based on IMD-NCMRWF GPM merged gauge 24 hours cumulative rainfall ending at 0830 IST of date is depicted in Fig.3. The figure depicts that the system caused heavy to extremely heavy rainfall over Gujarat and Saurashtra region on 29th September. Thereafter, the rainfall belt shifted gradually from over northeast AS to northwest AS during 30th Sep. and 1st Oct. On 2nd Oct. heavy to extremely heavy rainfall was observed over northwest AS and adjoining Gulf of Oman. On 3rd, coastal Oman received heavy to extremely heavy rainfall.
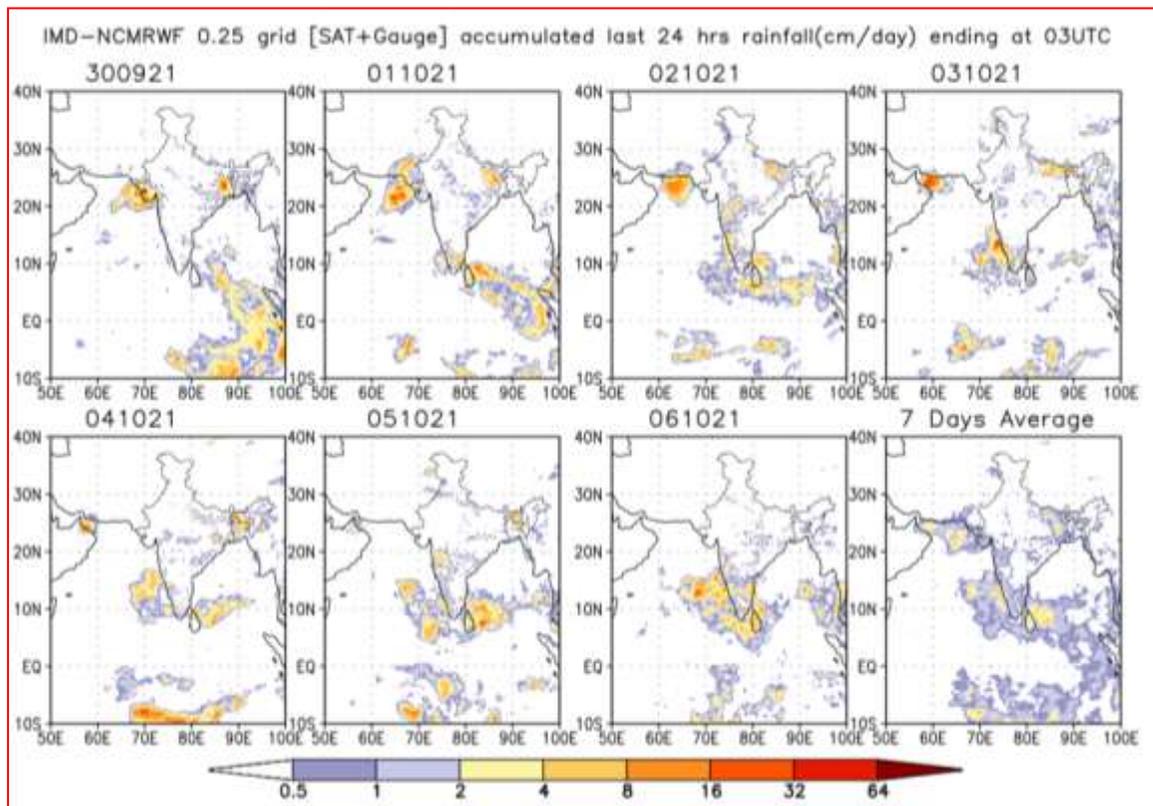
Fig.3: IMD-NCMRWF GPM merged gauge 24 hr cumulative rainfall (cm) ending at 0830 IST of date during 30th Sep. – 6th October and 7 days average rainfall (cm/day)

30 September 2021
India
24 hours accumulated rainfall ending at 0830 hours IST of 30th Sep (cm)
Gujarat Region:- Vagra-10, Hansot-9, Ankleshwer-9, Khambhat-7,
Saurashtra & Kutch:- Visavadar-29, Lilia-14, Khambhalia-14, Kalyanpur-13, Amreli-13, Mangrol(J)-13, Jafrabad-13, Bagasra-13, Jesar-12, Jamnagar-12, Amrelikvkaws-12, Keshod-11, Lalpur-11, Veraval-11, Kalavad-11, Rajula-11, Kutiana-10, Talala-9, Malia-9, Gariadhar-9, Dwarka-9, Palitana-9, Anjar-8, Mendarda-8, Lodhika-8, Talaja-7, Mundra-7, Okha-7, Rajkot-7, Bhesan-7, Upleta-7, Manavadar-7, Savarkundla-7, Bhavnagar-7
Pakistan : As per media reports, the cyclone caused light rain and gusty winds in parts of Karachi on September 30. The city's Millennium Mall on Rashid Minhas Road also saw heavy traffic due to three electric poles falling on the area.
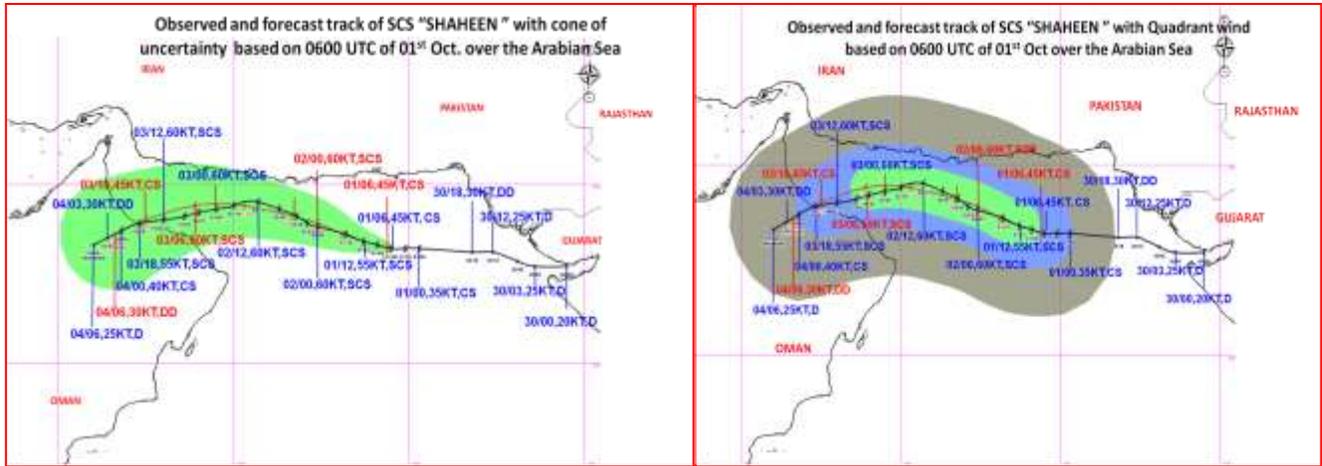
16

4th October

Oman

As per media reports 369 mm of rainfall was reported in the Wilayat of Al-Khaboura, the highest in association with the storm on 4th October. 290.8 mm of downpour was recorded in Suwaiq and Al-Khaboura at 167.9 mm.

4. Operational Forecast Performance

4.1. Genesis, track, landfall and intensity forecast performance:

- ➢ First information about likely emergence of remnant of cyclonic storm Gulab into northeast Arabian Sea was indicated in the All India Weather Inference issued at 1230 hours IST of 28th September. From 28th onwards, the fishermen were advised not to venture into north & adjoining central Arabian Sea and along & off Gujarat & north Maharashtra coasts during 30th September-2nd November.

- ➢ The extended range outlook issued at 30th September indicated high probability of cyclogenesis over north Arabian Sea.

- ➢ The special Message issued at 1250 IST of 29th September indicated that the well marked low pressure area over south Gujarat & adjoining Khambat region would emerge into northeast Arabian Sea by 30th and intensify gradually into a cyclonic storm. It was also indicated that the system would move away from Indian coast and would not cause damage over Indian mainland. Since first bulletin issued at 0830 hours IST of 30th it was indicated that the system would move away from Indian mainland. Typical observed and forecast track issued at 0830 hours IST (0300 UTC) of 30th September alongwith cone of uncertainty and wind warnings is presented in Fig.4. Typical observed and forecast track of cyclone Shaheen based on 1130 hours IST (0600 UTC) of 1st October (60 hours prior to landfall) demonstrating accuracy in track, landfall and intensity prediction are presented in Fig.5.

Fig.4: Typical observed and forecast track of severe cyclonic storm Shaheen at 0830 hours IST (0300 UTC) of 30th Sep. demonstrating movement of system away from Indian coast

Fig.5: Typical **observed and forecast track severe cyclonic storm Shaheen at 1130 hours IST of 1st October (about 60 hours prior to landfall) demonstrating accuracy in track, landfall and intensity prediction**

4.2. Operational landfall forecast error

The landfall point and time Forecast errors (Forecast – Actual) compared to long period average (LPA) errors during 2016-20 are presented in Fig.6 (a-b) and Table 2. The landfall point forecast errors for 12, 24, and 48 hrs lead period were 2.2, 14.3 and 5.5 km respectively against the LPA errors (2016-20) of 25.4, 44.7 and 69.4 km during 2016-20 respectively. The landfall time forecast errors for 12, 24, and 48 hrs lead period were 0.0, 0.50, and 0.0 hours respectively against the LPA errors (2016-20) of 2.0, 3.0 and 5.4 hours during 2016-20 respectively. For all lead periods, the landfall point errors were exceptionally less than the LPA errors during 2016-20. There was almost zero landfall point error for 12, 48 & 60 hours lead period. Landfall time error was also significantly less for all lead periods from 24 to 48 hours. It was almost zero for 12 and 48 hours lead period.
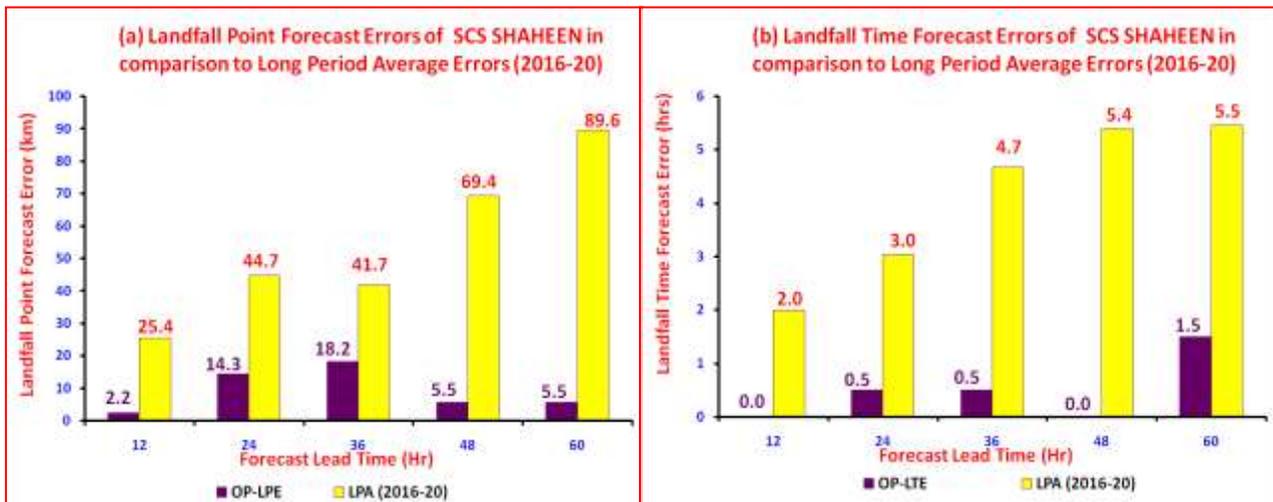

Fig.6: **Operational Landfall (a) point and (b) time forecast errors of SCS 'Shaheen" as compared to long period average (2016-20)**

Table 2: Operational Landfall point and time forecast errors of SCS 'Shaheen" as compared to long period average (2016-20)

Lead Period (hrs)	Base date/Time (UTC)	Forecast Latitude (Deg)	Forecast Longitude (Deg)	Actual latitude (Deg)	Actual Longitude (Deg)	OP-LPE (km)	Forecast Time (UTC)	Actual Time (UTC)	OP-LTE (hrs)
12	03/06	23.9	57.28	23.9	57.3	2.2	03/1800	03/1930	0.0
24	02/18	23.95	57.18	23.9	57.3	14.3	03/2300	03/1930	0.5
36	02/06	23.97	57.15	23.9	57.3	18.2	03/2300	03/1930	0.5
48	01/18	23.9	57.25	23.9	57.3	5.5	03/2030	03/1930	0.0
60	01/06	23.9	57.25	23.9	57.3	5.5	03/2000	03/1930	1.5

OP-LPE: Operational Landfall Point Error, OP-LTE: Operational Landfall Time Error,

'+': Delay, '-': Early

5.3. Track forecast error and skill

The track forecast errors (Forecast position – Actual position of Cyclone centre) and skill as compared to Climatological and Persistence forecast are presented in Fig.7(a-b) and Table 3. The track forecast errors for 24, 48 and 72 hrs lead period were 58.1, 107.2, and 120.1 km respectively against the LPA errors (2016-20) of 77.5, 116.8, and 158.8 km respectively (Fig.7 a). The track forecast skill was about 85%, 88%, and 88% against the LPA skill of 64%, 76%, and 78% for 24, 48 and 72 hrs lead period respectively (Fig.7b). The track forecast error for all lead periods were significantly less than the LPA errors. Skill in track forecasting was better than LPA skill for all lead periods.
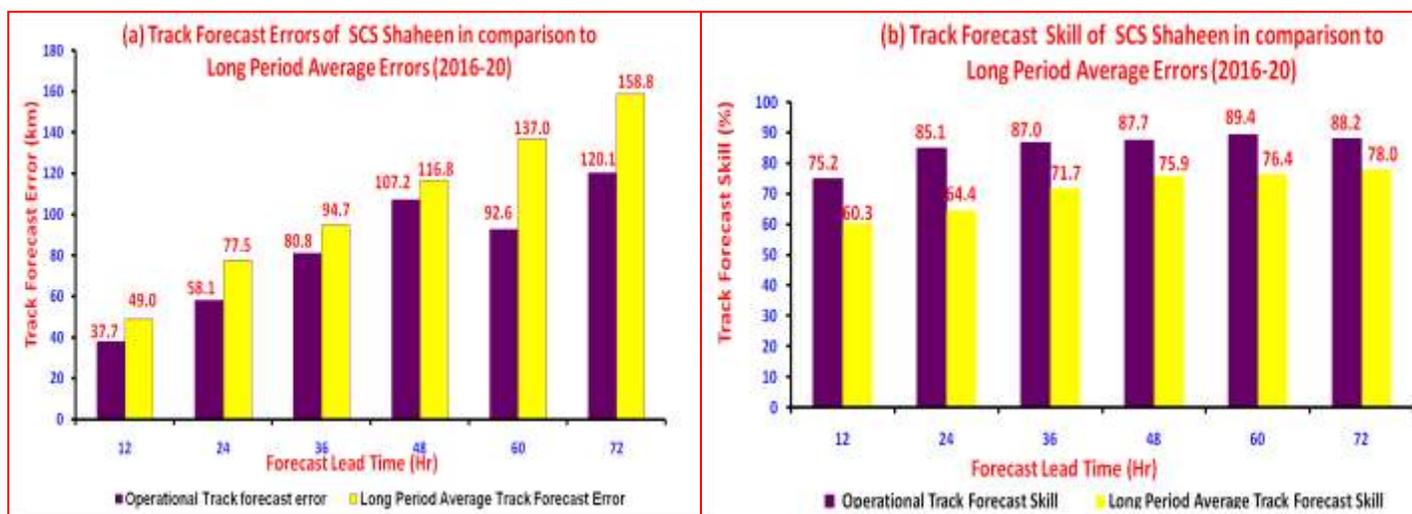

Fig.7: Operational Track forecast (a) errors and (b) skill of SCS 'Shaheen" as compared to long period average (2016-20)

Table 3: Operational Track forecast errors and skill of SCS 'Shaheen" as compared to long period average (2016-20)

Lead Period (hrs)	N	Operational Track forecast error (km)	Operational Track Forecast Skill (%)	Long Period Average (2016-20)	
				Track Forecast Error (km)	Track Forecast Skill (%)
12	16	37.7	75.2	49.0	60.3
24	14	58.1	85.1	77.5	64.4
36	12	80.8	87.0	94.7	71.7
48	10	107.2	87.7	116.8	75.9
60	7	92.6	89.4	137.0	76.4
72	2	120.1	88.2	158.8	78.0

N: no. of observations verified

5.4. Intensity forecast error and skill

The intensity forecast errors (Forecast wind – Actual wind) and skill based on absolute errors and root mean square errors are presented in Fig.8 & and Table 4   respectively. The absolute error (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 5.0, 9.0 and 2.4 knots against the LPA errors of 7.9, 11.4, and 14.1 knots during 2016-20 respectively (Fig. 9 a). The root mean square error (RMSE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 6.8, 9.53 and 3.3 knots against the LPA errors of 9.9, 13.8, and 16.7 knots respectively (Fig. 8b). The skill (%) in intensity forecast as compared to persistence forecast based on AE for 24, 48 and 72 hrs lead period was 55%, 70% and 98% against the LPA of 52%, 72% and 75% respectively (Fig.9a). The skill(%) in intensity forecast based on RMSE for 24, 48 and 72 hrs lead period was 58%, 75% & 98% against the LPA of 60%, 69% and 78% respectively (Fig.9b).
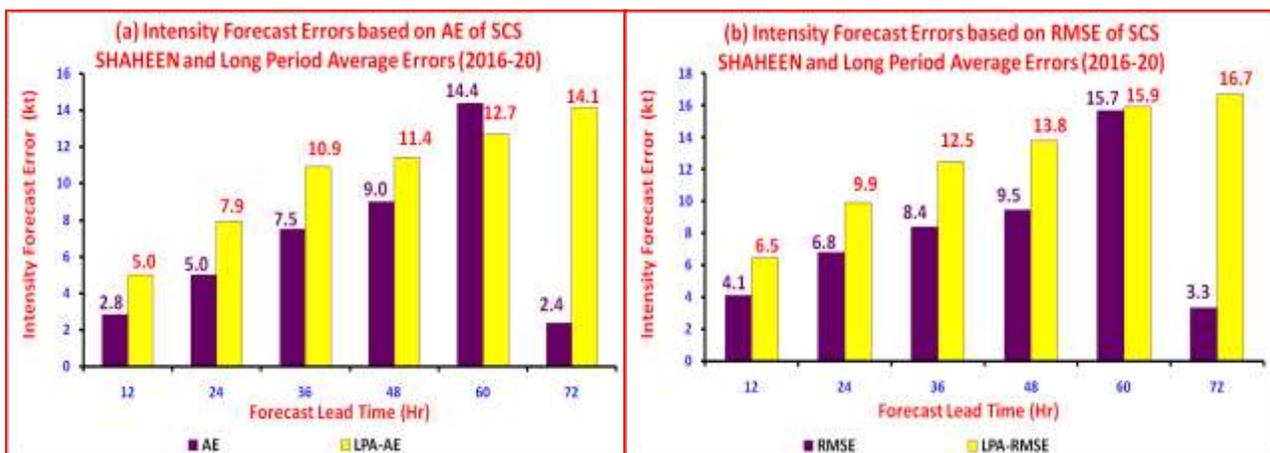

Fig. 8: (a) Absolute errors (AE) and (b) Root Mean Square errors (RMSE) in intensity forecast (winds in knots) of SCS "SHAHEEN" as compared to long period average (2016-20)
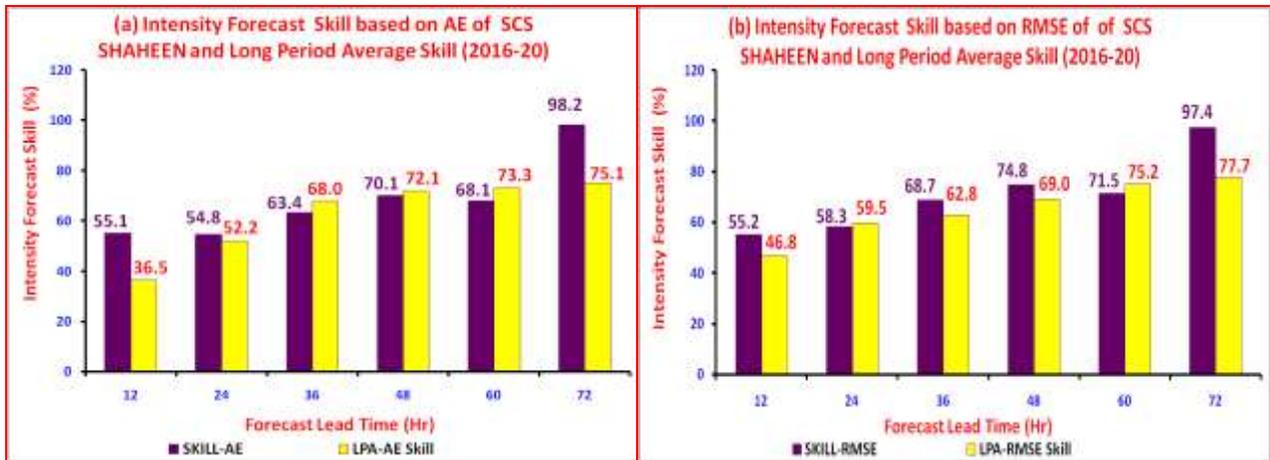
Fig.9: Skill **(%) in intensity forecast based on (a) Absolute errors (AE) and (b) Root Mean Square errors (RMSE) of SCS "SHAHEEN" as compared to long period average (2016-20)**

Table 4: Operational Absolute errors (AE) and Root Mean Square errors (RMSE) and corresponding skill in intensity forecast of SCS "Shaheen" as compared to long period average (2016-20)

Lead Period	N	AE	RMSE	Skill-AE	Skill-RMSE	Long Period Average (2016-20)			
						AE	RMSE	Skill-AE	Skill-RMSE
12	16	2.8	4.1	55.1	55.2	5.0	6.5	36.5	46.8
24	14	5.0	6.8	54.8	58.3	7.9	9.9	52.2	59.5
36	12	7.5	8.4	63.4	68.7	10.9	12.5	68.0	62.8
48	10	9.0	9.5	70.1	74.8	11.4	13.8	72.1	69.0
60	7	14.4	15.7	68.1	71.5	12.7	15.9	73.3	75.2
72	2	2.4	3.3	98.2	97.4	14.1	16.7	75.1	77.7

N: No. of observations verified, AE: Absolute error, RMSE: Root Mean Square Error, LPA: Long Period Average

6. Warning Services:

> **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… +72 hrs lead period commencing from 30th September till the system weakened into a low pressure area on 4th October. The above forecasts were issued from the stage of depression onwards along with the cone of uncertainty in the track forecast five times a day 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 and ≥50 knots wind in four quadrants of cyclone was issued every six hourly, commencing from 30th September giving forecast for +06, +12, +18, +24, +36 and +72 hrs lead period.

➢ **Adverse weather warning bulletins:**

The tropical cyclone forecasts alongwith expected adverse weather like heavy rain, gale wind and storm surge was issued with every three hourly update to central, state and district level disaster management agencies including MHA NDRF, NDMA for all concerned states along the west coast of India for 30th September. Fishermen warnings were issued since 28th September onwards for the sea area covering north and eastcentral AS. From first bulletin onwards, the disaster managers, media and general public were informed that the system would move away from Indian coast and would not cause any damage over the Indian mainland.

➢ **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 gale/squally wind & storm surge were presented in graphics on the website.

➢ **Warning and advisory 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 emergence of remnant of Gulab into the Arabian Sea.

➢ **Press release and Media briefing**:

Press and electronic media were given daily updates since inception of system through press release, e-mail, website.

➢ **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 Centres at Ahmedabad and maharashtra to ports, fishermen, coastal and high sea shipping community.

➢ **Fishermen Warning**:

Regular warnings for fishermen for deep sea of AS and the states of Gujarat, Maharashtra, Goa, Karnataka, Kerala and Lakshadweep were issued since 28th September onwards.

➢ **Advisory for international Civil Aviation:**

The Tropical Cyclone Advisory Centre (TCAC) bulletin for International Civil Aviation were issued every six hourly to all meteorological watch offices in Asia Pacific region for issue of significant meteorological information (SIGMET). It was also sent to Aviation Disaster Risk Reduction (ADRR) centre of WMO at Hong Kong.

➢ **Diagnostic and prognostic features of cyclone**:

The prognostics and diagnostics of the systems were described in the RSMC bulletins.

The statistics of bulletins issued by RSMC New Delhi for India as well as for Pakistan, Iran, Oman, UAE and Yemen are presented in Table 5.

Table 5: Bulletins issued by RSMC New Delhi

S. No.	Bulletin type	No. Of Bulletins	Issued to
1	National Bulletin	34	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 Gujarat, Daman & Diu, Maharashtra, Goa, Karnataka & Kerala.
2	RSMC Bulletin	30	1. IMD's website 2. WMO/ESCAP member countries through GTS and E-mail.
3	GMDSS Bulletins	22	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	15	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	15	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.
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	6	Disaster Managers, Media persons by email and uploaded on website
9	Press Briefings	Daily	Regular briefing daily

7. Damage due to Severe cyclonic storm, Shaheen

As per media reports about 14 deaths have been attributed to Shaheen. The damage photographs are presented **in Fig.10**

Fig.10 (a-f): (a) Flooded streets in Muscat, Oman (Source: https://www.aljazeera.com/ dated: 3rd Oct.), (b) Damaged tractor in the Wilayat of Barka (Source: https://timesofoman.com/ dated: 4th Oct.) (c) Flooded streets in Al Musanah (source:S dated: 4 Oct.) (d) A vehicle is seen crushed by a tree amid Cyclone Shaheen in Oman's capital Muscat on October 3. (source: https://www.dawn.com/ dated:4 Oct.) (e) Flooded street of the Al Khaburah district (Source: https://www.dawn.com/ dated:4 Oct.) (f) Shattered roads and vehicles in Muscat (Source: omanobserver.om/article/1107650 dated: 4 Oct)

Acknowledgement: