

Depression over eastcentral Arabian Sea during 07th Nov- 09th Nov, 2021

1. Introduction

- Under the influence of the cyclonic circulation over southeast and adjoining southwest Bay of Bengal (BoB), a low pressure area formed over central parts of south BoB at 0300 UTC (0830 hours IST) of 27th October, 2021.
- It moved westwards and emerged into Comorin Area at 0300 UTC (0830 hours IST) of 1st November. Continuing to move westwards, it emerged into southeast Arabian Sea (AS) at 0300 UTC (0830 hours IST) of 3rd November.
- It lay as a well marked low pressure area over eastcentral AS at 0300 UTC (0830 hours IST) of 6th November.
- It concentrated into a depression over eastcentral AS at 0300 UTC (0830 hours IST) of 7th November.
- It moved west-northwestwards till 0300 UTC (0830 hours IST) of 8th. It thereafter gradually recurved south-southwestwards and weakened into a well marked low pressure area over eastcentral AS at 0000 UTC (0530 hours IST) of 9th November.
- The observed track of the system during 07th Nov- 09th Nov is presented in Fig.1. Best Track parameters associated with the system are presented in Table1.

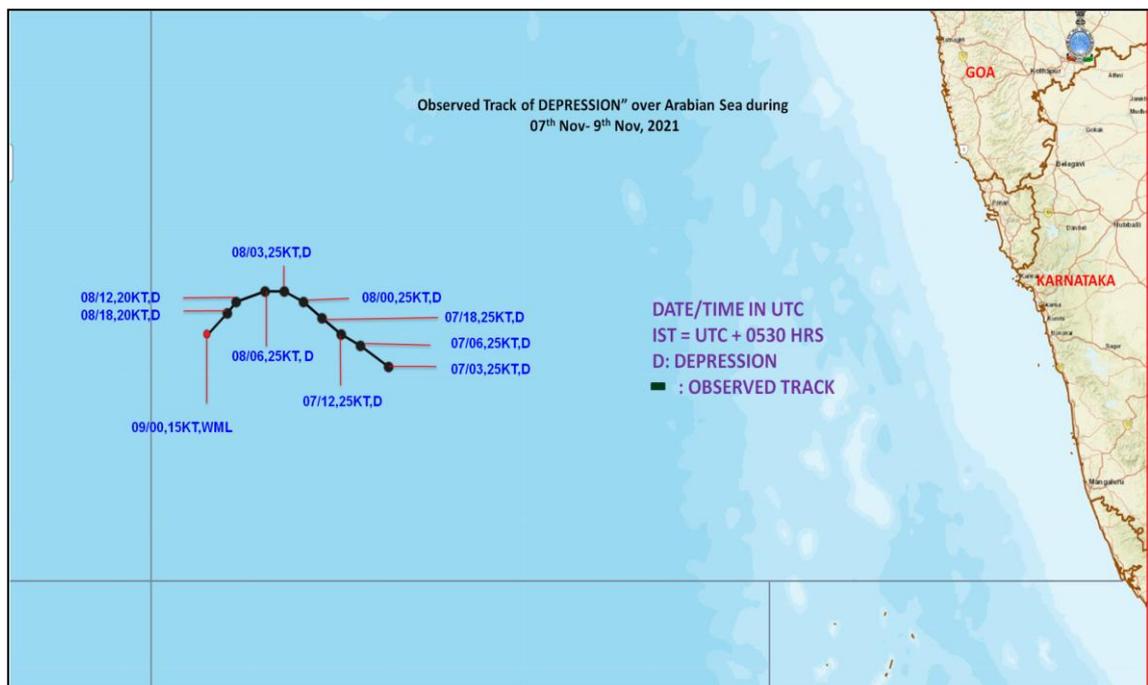


Fig.1: Observed track of depression over North Andaman Sea and neighbourhood (07th - 09th Nov, 2021)

KT: Knots(nautical mile per hour), 1 KT=1.85 kmph

Table 1 : Best track positions and other parameters of the Depression over Arabian Sea during 07th Nov- 09th Nov, 2021

Date	Time (UTC)	Centre lat. ^o N/ long. ^o E	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (knot)	Estimated Pressure drop at the Centre (hPa)	Grade
07.11.2021	0300	14.0 67.5	1.5	1002	25	4	D
	0600	14.2 67.2	1.5	1002	25	4	D
	1200	14.3 67.0	1.5	1002	25	4	D
	1800	14.5 66.8	1.5	1002	25	4	D
08.11.2021	0000	14.6 66.6	1.5	1002	25	4	D
	0300	14.7 66.4	1.5	1002	25	4	D
	0600	14.7 66.2	1.5	1002	25	4	D
	1200	14.6 65.9	1.5	1003	20	3	D
	1800	14.5 65.8	1.5	1003	20	3	D
09.11.2021	0000	Weakened into a Well Marked Low Pressure Area over central parts of Arabian Sea					

2. Brief life history

2.1 Genesis Intensification and movement

Under the influence of a cyclonic circulation over southeast and adjoining southwest Bay of Bengal (BoB), a low pressure area formed over central parts of south BoB at 0300 UTC of 27th October, 2021. Moving westwards, it emerged into Comorin Area at 0300 UTC of 1st November and into southeast AS at 0300 UTC of 3rd November.

At 0300 UTC of 3rd November, the Madden Julian Oscillation (MJO) index was in Phase 2, with amplitude less than 1. It was expected to propagate further eastwards & move across phase 3 and reach phase 4 on 5th November with amplitude remaining less than 1. It was expected to continue in same phase till 8th November. Hence, MJO was supporting enhancement of convective activity over the North Indian Ocean (NIO) during next 5 days. The sea surface temperature (28- 29°C) and ocean thermal energy (OTE) over southeast & eastcentral AS were favourable to support convection. Vertical wind shear was low to moderate over southeast & adjoining eastcentral AS. There were 2 distinct regions of vertically coupled low level convergence & upper level divergence maxima, one located over Maldives – Comorin area and the other over southeast AS to the northwest of Lakshadweep area. The upper tropospheric ridge lay along latitude 15^oN over the AS.

The system moved north-northwestwards and lay as a well marked low pressure area over eastcentral AS at 0300 UTC of 6th November. At 0300 UTC of 6th November, the convectively active phase of MJO lay in phase 3 with amplitude less than 1. It was likely to enter into phase 4 around 9th November and further propagate eastwards with amplitude less than 1 till 9th November. Favourable sea conditions prevailed over southeast & east-central. Vertical wind shear was low (5-10 knots) over the region and the shear tendency was neutral. However, it was high to the north of the system centre. The low level convergence was $5-10 \times 10^{-5} \text{ s}^{-1}$ over southeast AS. The upper level divergence was also $5-10 \times 10^{-5} \text{ s}^{-1}$ over southeast and adjoining

eastcentral AS. The low level cyclonic vorticity was around $(50-60 \times 10^{-6} \text{ s}^{-1})$ and it extended upto mid-tropospheric levels over east-central AS. The upper tropospheric ridge roughly lay along lat. 15°N over the AS. A moist environment, as indicated by the total precipitable water vapour imageries prevailed over the southeast and adjoining east-central AS. Under these conditions, the system moved west-northwestwards and lay as a well marked low pressure area over eastcentral AS.

At 0300 UTC of 07th November, the SST was about $28-29^{\circ}\text{C}$ over northeast and eastcentral AS with decreasing trend towards west. The TCHP was about $80-90 \text{ KJ/cm}^2$ over northeast AS with decreasing trend towards the northwest & westcentral AS. Positive vorticity increased and was about $100 \times 10^{-6} \text{ s}^{-1}$ around system centre at 850 hPa with vertical extension upto 500 hPa level. Positive lower level convergence increased and was about $10 \times 10^{-5} \text{ s}^{-1}$ to the east of system center. Positive upper level divergence also increased and was about $20 \times 10^{-5} \text{ s}^{-1}$ to the east of system center. Moderate vertical wind shear about (20-25 knots) prevailed around the system center. Under these favourable environmental conditions, it concentrated into a depression over eastcentral AS at 0300 UTC of 7th November and moved northwestwards under the influence of southeasterlies prevailing in middle and upper tropospheric levels.

At 0300 UTC of 8th November, similar sea and environmental conditions prevailed. The system lay to the south of ridge near 15.5°N . Under these conditions, the system moved west-northwestwards maintaining its intensity of depression.

Thereafter, the system was steered by easterly to northeasterly winds in the mid & upper tropospheric levels. Thus, it moved nearly westwards for some time and gradually recurved southwestwards from 1200 UTC of 8th November. At 1200 UTC of 08th November, similar sea conditions prevailed. However, slight weakening trend was seen in all the thermodynamic parameters and wind shear also increased over the system area. Under these conditions, the system recurved southwestwards and weakened gradually into a well marked low pressure area over central parts of AS at 0000 UTC of 9th November.

3. Monitoring of depression over Arabian Sea

India Meteorological Department (IMD) maintained round the clock watch over the north Indian Ocean and the system was monitored since 30th October (8 days prior to formation of depression over eastcentral AS on 7th November) when it was indicated that the low pressure area over southwest BoB would move westwards and emerge into southeast AS and intensify further. The cyclone was monitored with the help of available satellite observations from INSAT 3D and 3DR and polar orbiting satellites. Various numerical weather prediction models developed by Ministry of Earth Sciences (MoES) institutions and dynamical-statistical models were utilized to predict the genesis, track, landfall and intensity of the cyclone. A digitized forecasting system of IMD was utilized for analysis and comparison of various model guidance, decision making process and warning product generation.

4. Features observed through satellite

Satellite monitoring of the system was mainly done by using half hourly INSAT-3D and 3DR imageries. Satellite imageries of international geostationary satellites Meteosat-8 & MTSAT, high resolution polar orbiting satellites and scatterometer imageries from ASCAT were also considered for monitoring the system. Typical INSAT-3D visible/ IR imageries, enhanced colored imageries and ASCAT (Met-Op A) imageries are presented in **Fig.2**. The cloud mass was organized in shear pattern during its life cycle. The detailed sat features are discussed in this section.

At 0300 UTC of 7th November, INSAT 3D imagery indicated broken low and medium clouds with embedded intense to very intense convection lay over eastcentral AS between latitude 12.0^oN & 19.0^oN and longitude 67.0^oE & 71.5^oE. Minimum cloud top temperature (CTT) was -93^oC. Intensity of the system was categorized as T 1.5. Satellite derived total precipitable water vapour (TPW) imagery indicated moist environment around the system centre.

At 0300 UTC of 8th November, the cloud mass further shifted northwestwards. Minimum CTT was -93^oC. Intensity of the system was categorised as T 1.5. Associated broken low and medium clouds with embedded intense to very intense convection lay over eastcentral AS between latitude 13.0^oN & 17.0^oN and longitude 65.0^oE & 71.0^oE.

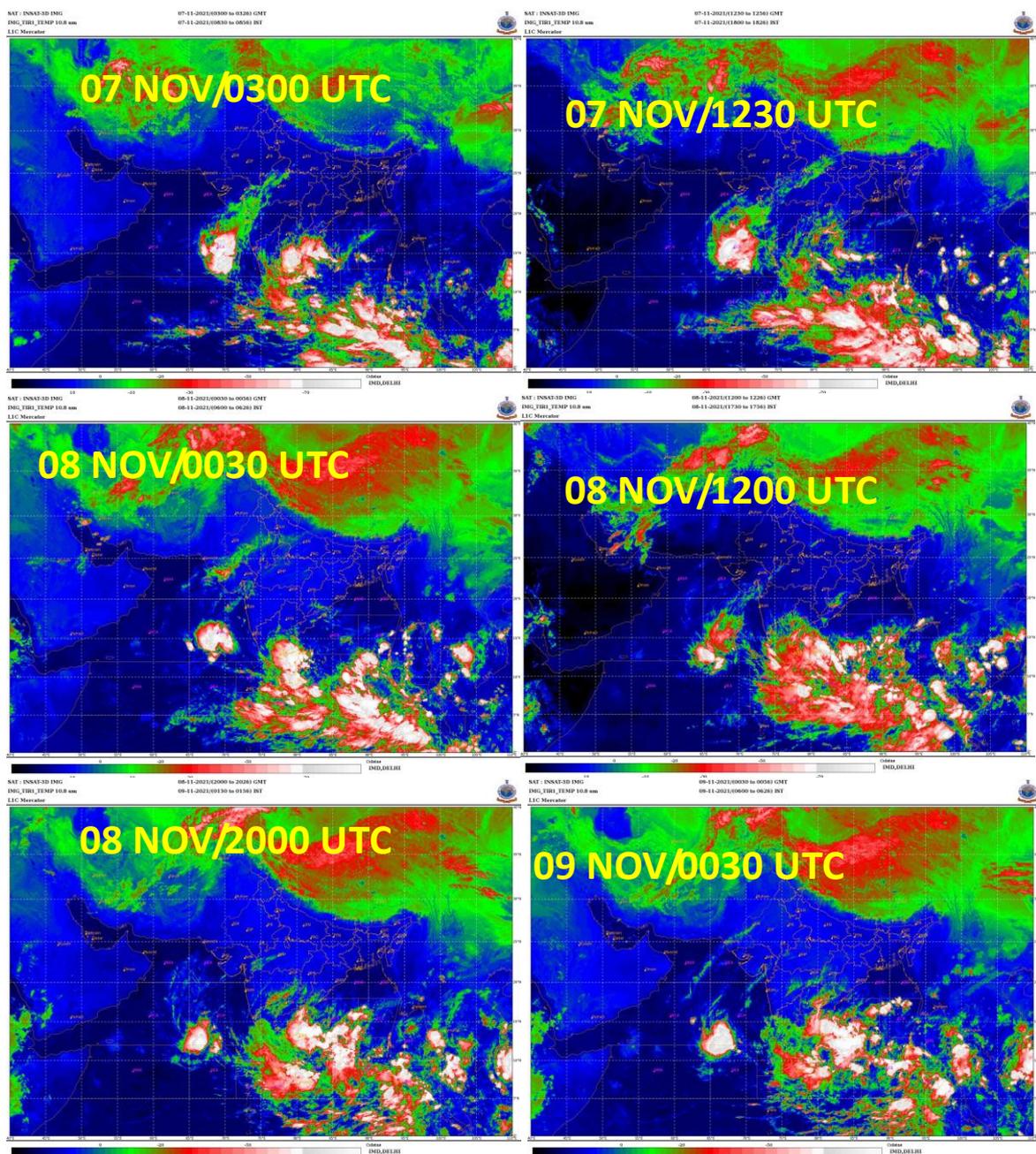


Fig. 2a: INSAT-3D enhanced colored imageries during life cycle of Depression over North Andaman Sea during 07th- Nov- 09th Nov, 2021

At 1200 UTC of 8th November, the cloud mass moved northwestwards. Associated minimum CTT was -93°C . Intensity of the system was categorised as T 1.0/C.I. 1.5. Associated broken low & medium clouds with embedded intense to very intense convection lay over eastcentral AS between latitude 12.0°N & 18.0°N and longitude 64.0°E & 70.5°E .

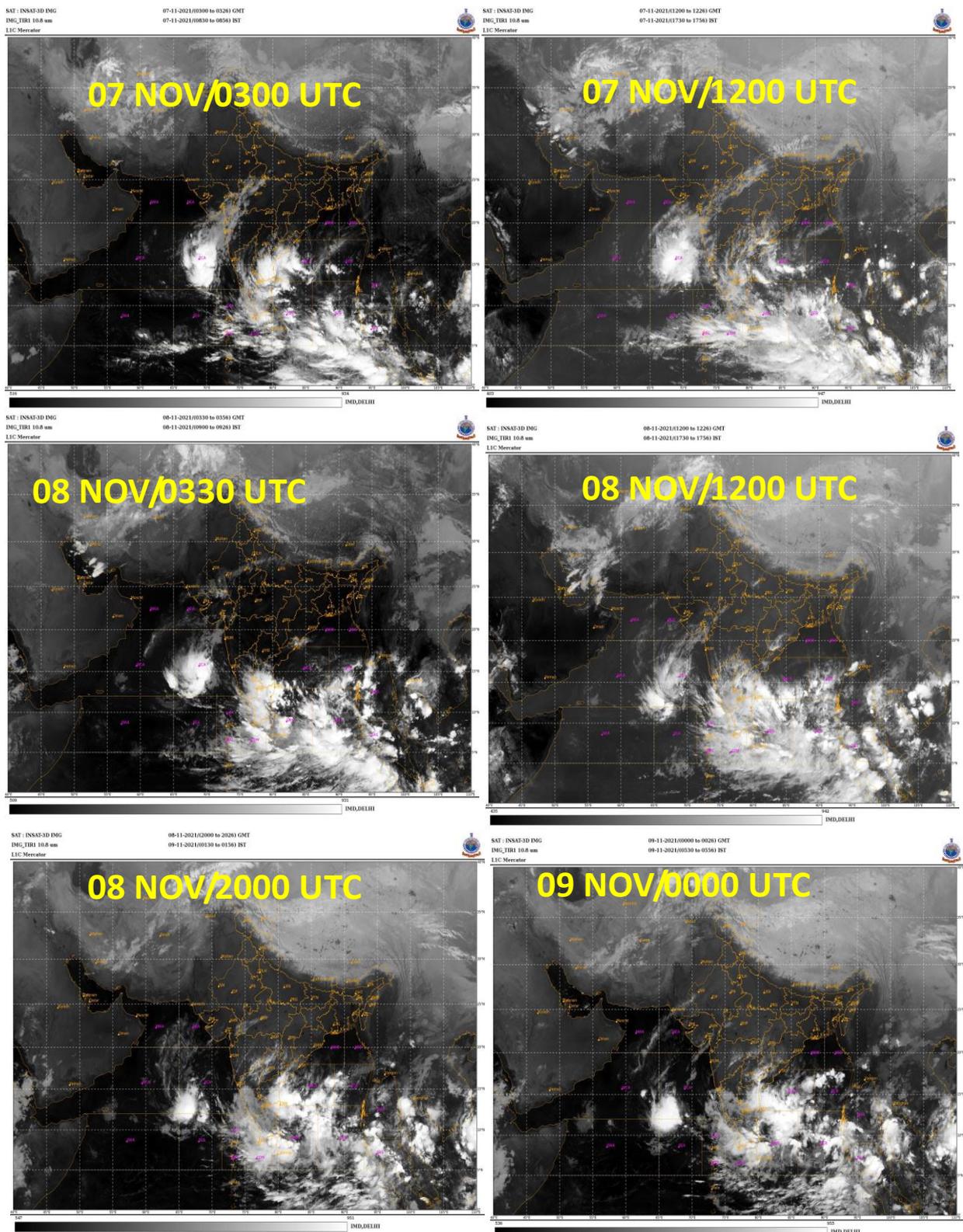


Fig. 2b: INSAT-3D IR imageries during life cycle of Depression over North Andaman Sea during 07th- Nov- 09th Nov, 2021

At 1800 UTC of 8th November, the system entered unfavourable environment. The cloud top temperature was -93°C . Intensity of the system was categorised as T 1.0/C.I. 1.5. Associated scattered to broken low & medium clouds with embedded intense to very intense convection lay over eastcentral AS between latitude 11.0°N & 17.0°N and longitude 64.0°E & 70.0°E .

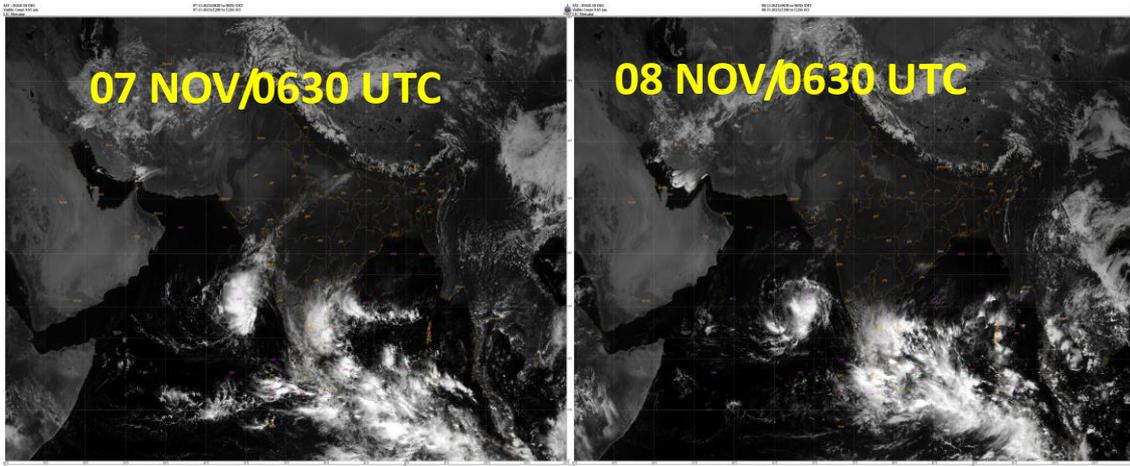


Fig. 2c: INSAT-3D Visible imageries during life cycle of Depression over North Andaman Sea during 07th- Nov- 09th Nov, 2021

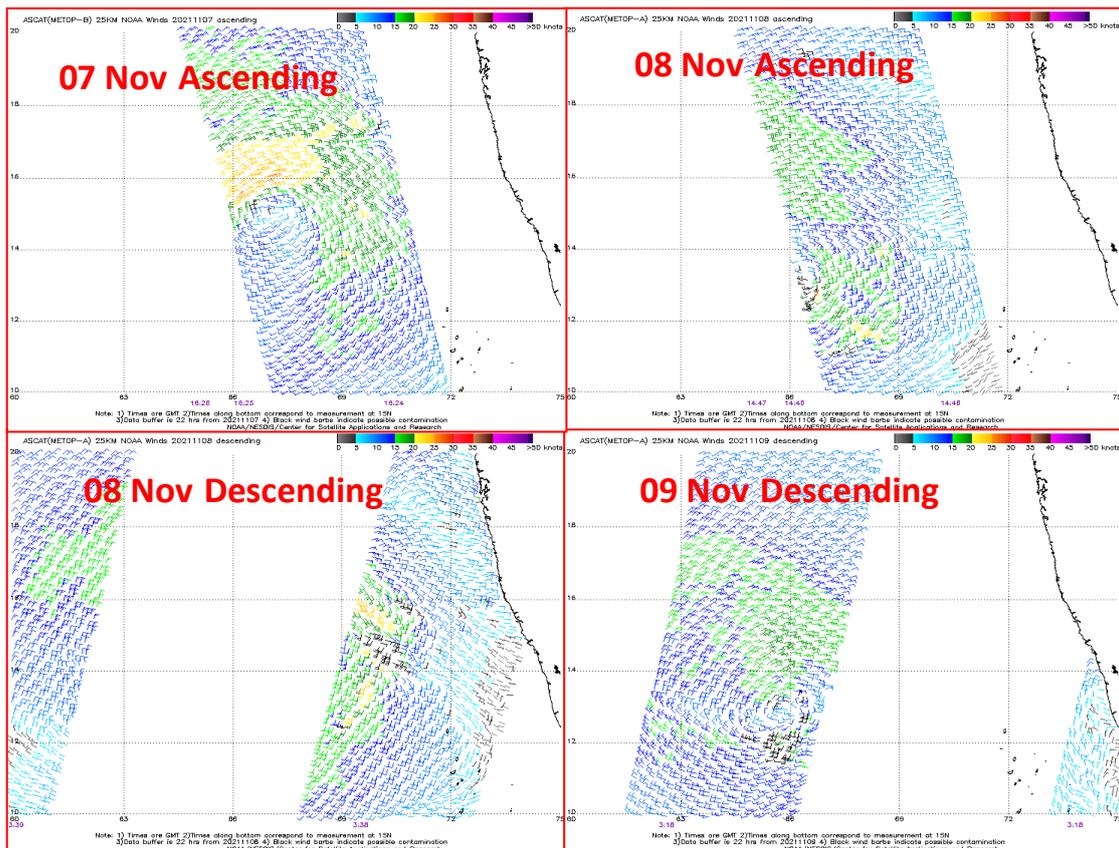


Fig. 2d: ASCAT imageries during life cycle of Depression during 07th - 09th November, 2021

According to scatterometer data, wind were stronger in the northern sector due to prevailing northeast monsoon condition.

5. Dynamical features

The IMD GFS analysis based on 0000 UTC during 7th to 9th November is presented in Fig. 3. The analysis based on 0000 UTC of 7th November indicated a depression over eastcentral AS. At upper level, the ridge was seen near 15^oN.

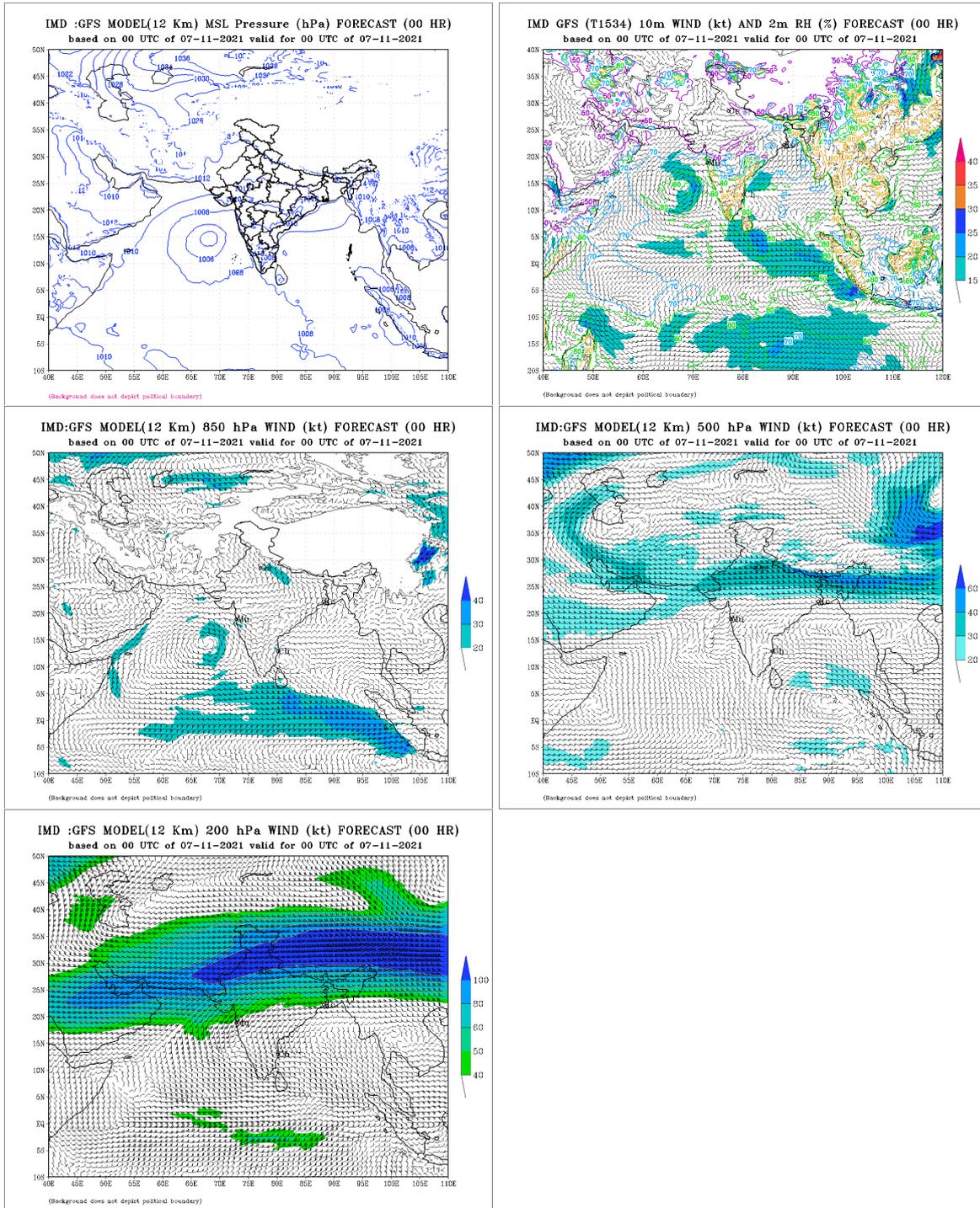


Fig.3 (a): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 7th November 2021

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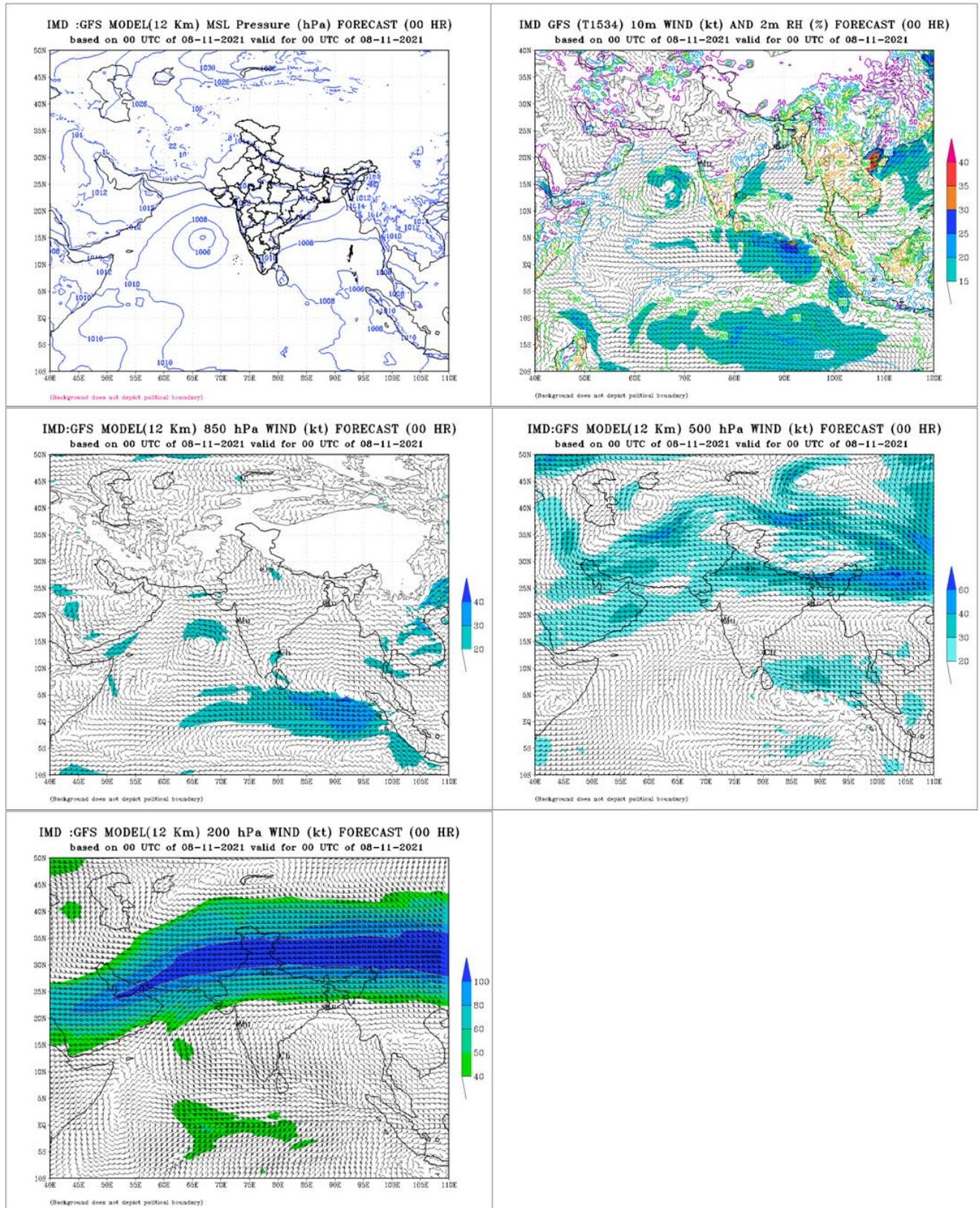


Fig.3 (b): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 8th November 2021

The analysis based on 0000 UTC of 9th November indicated a depression over eastcentral AS and also southwestwards movement of the system. Weakening of the system was also picked by the model. At upper level, the ridge was seen near 15^oN.

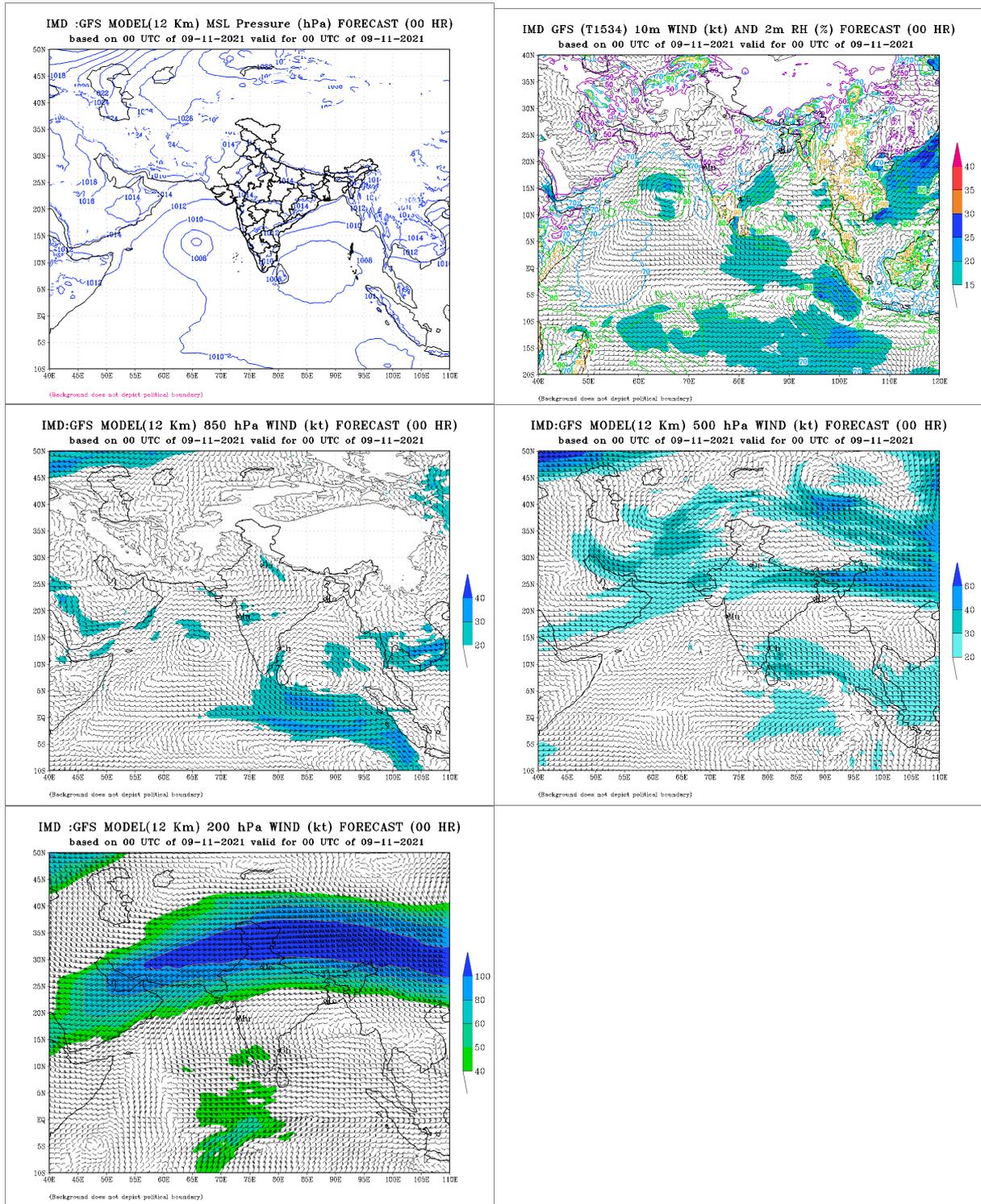


Fig.3 (c): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 9th November 2021

6. Realized Weather:

Rainfall associated with the depression over eastcentral AS based on IMD-NCMRWF GPM merged gauge rainfall data is depicted in **Fig 4**. It indicates higher rainfall activity in the northern sector.

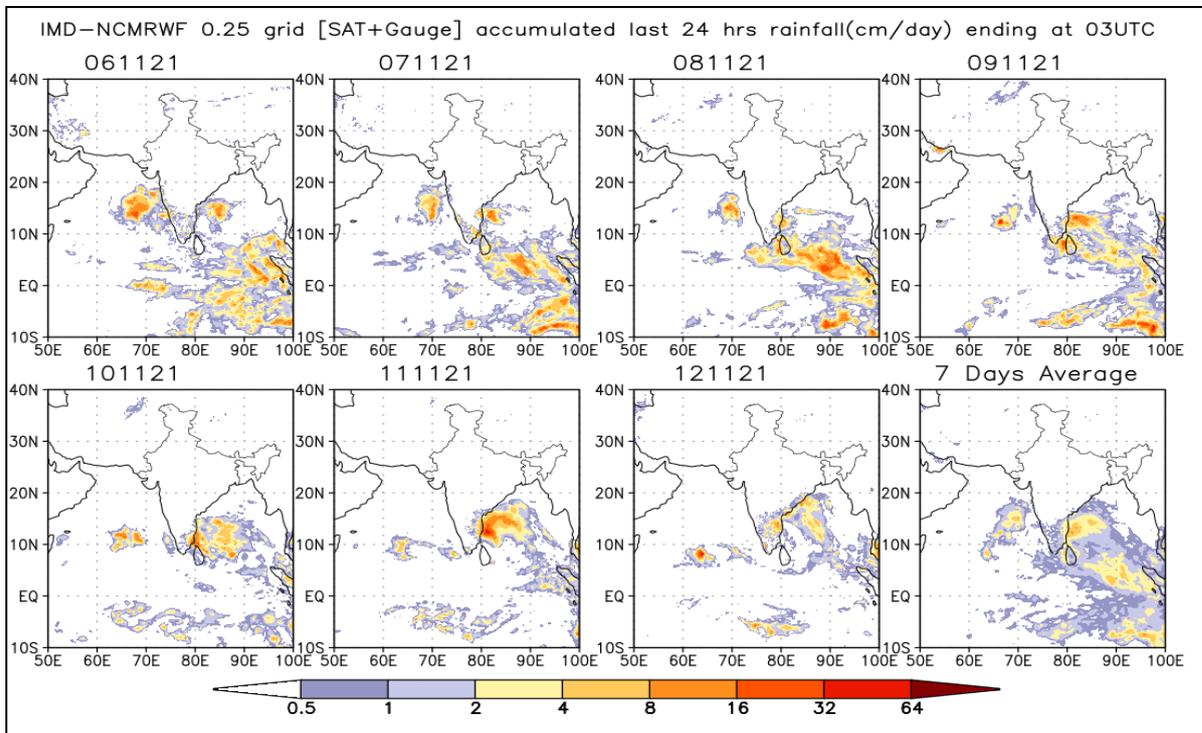


Fig.4: IMD-NCMRWF GPM merged gauge rainfall during 6th November - 12th November and 7 days average rainfall (cm/day)

7. Realised Weather

As the system was moving away from Indian coast, no adverse occurred over the west coast of India due to this system.

8. Damage due to the system

No damage was reported in association with this system.

9. Operational Forecast Performance

Genesis, Track and Intensity Forecast

- First information about likely formation of depression over eastcentral AS around 7th November was indicated in the National Operation Centre Report under Forecast Demonstration Project on 30th October (8 days prior to formation)
- In the subsequent Tropical Weather Outlooks issued during 1st November to 6th November likely cyclogenesis over eastcentral AS around 7th November was regularly predicted.

- In the first National bulletin issued at 1130 hours IST of 7th November, it was indicated that the system would move west-northwestwards, maintain the intensity of depression till 9th and weaken gradually thereafter.
- In the subsequent National bulletin issued at 2030 hours IST of 8th November, it was indicated that the system would recurve southwestwards and weaken thereafter.
- Actually, the system moved northwestwards till 0300 UTC of 8th and recurved gradually thereafter with initial westwards movement for some time followed by southwestwards movement from 1200 UTC of 8th and weakening at 0000 UTC of 9th November.

10. Warning Services

Bulletins issued by Cyclone Warning Division, New Delhi

- **Track & intensity forecast:** IMD continuously monitored, predicted and issued bulletins containing track & intensity forecast for +12, +24 and +36 hours lead period till the system weakened into a low pressure area. The above forecasts were issued from the stage of depression onwards along with the cone of uncertainty in the track forecast every six hours.
- **Cyclone structure forecast for shipping and coastal hazard management** The radius of maximum wind and radii of MSW ≥ 28 knots was issued every six hourly giving forecast for +12, +24 and +36 hrs lead period.
- **Adverse weather warning bulletins:** Since the first bulletin issued on 7th November, it was indicated that the system would not cause any adverse weather over the west coast of India.
- **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/squally wind were also presented in graphics alongwith colour codes in the website.
- **Warning and advisory through social media:** Daily updates (every six hourly or whenever there was any significant change in intensity/track) were uploaded on face book and tweeter regularly during the life period of the system from 7th evening onwards, updates were posted on facebook and tweeter.
- **Warning and advisory for marine community:** The three/six hourly bulletins under Global Maritime Distress Safety System (GMDSS) 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 Thiruvananthapuram and Ahmedabad to ports, fishermen, coastal and high sea shipping community.
- **Fishermen Warning:** Regular warnings for fishermen for deep sea of Comorin Area, Lakshadweep area and southeast & eastcentral AS were issued since 30th October, 2021 onwards.

- **Diagnostic and prognostic features of Depression:** The prognostics and diagnostics of the systems were described in the RSMC bulletins and tropical cyclone advisory bulletins.

Statistics of bulletins issued by RSMC New Delhi in association with this system are given in Table 3.

Table 3: Bulletins issued by RSMC New Delhi

S.N	Bulletin type	No. of Bulletins	Issued to
1	National Bulletin	10	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, Headquarter Integrated Defence Staff, Director General Doordarshan, All India Radio, National Disaster Response Force, Chief Secretary, Government of Maharashtra, Gujarat , Daman, Diu, Dadra & Nagar Haveli, Goa, Karnataka, Kerala, Lakshadweep
2	RSMC Bulletin	10	1. IMD's website 2. WMO/ESCAP member countries through GTS and E-mail.
3	GMDSS Bulletins	10	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	Warnings through SMS	Frequently	Nil
5	Warnings through Social Media	Daily	Cyclone Warnings were uploaded on Social networking sites (Face book and Tweeter) since inception to weakening of system (every six hourly).

11. Acknowledgement:

India Meteorological Department (IMD) and RSMC New Delhi duly acknowledge the contribution from all the stake holders and disaster management agencies who contributed to the successful monitoring, prediction and early warning service of the system. 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, research institutes including IIT Bhubaneswar, and Space Application Centre, Indian Space Research Organisation (SAC-ISRO) for their valuable support. The support from various Divisions/Sections of IMD including Area Cyclone Warning Centre (ACWC) Mumbai, Cyclone Warning Centre (CWC) Thiruvananthapuram & Ahmedabad, Meteorological Centre (MC) Bengaluru. The contribution from Numerical Weather Prediction Division, Satellite and Radar Division, Surface & Upper air instruments Divisions, New Delhi and Information System and Services Division at IMD is also duly acknowledged.