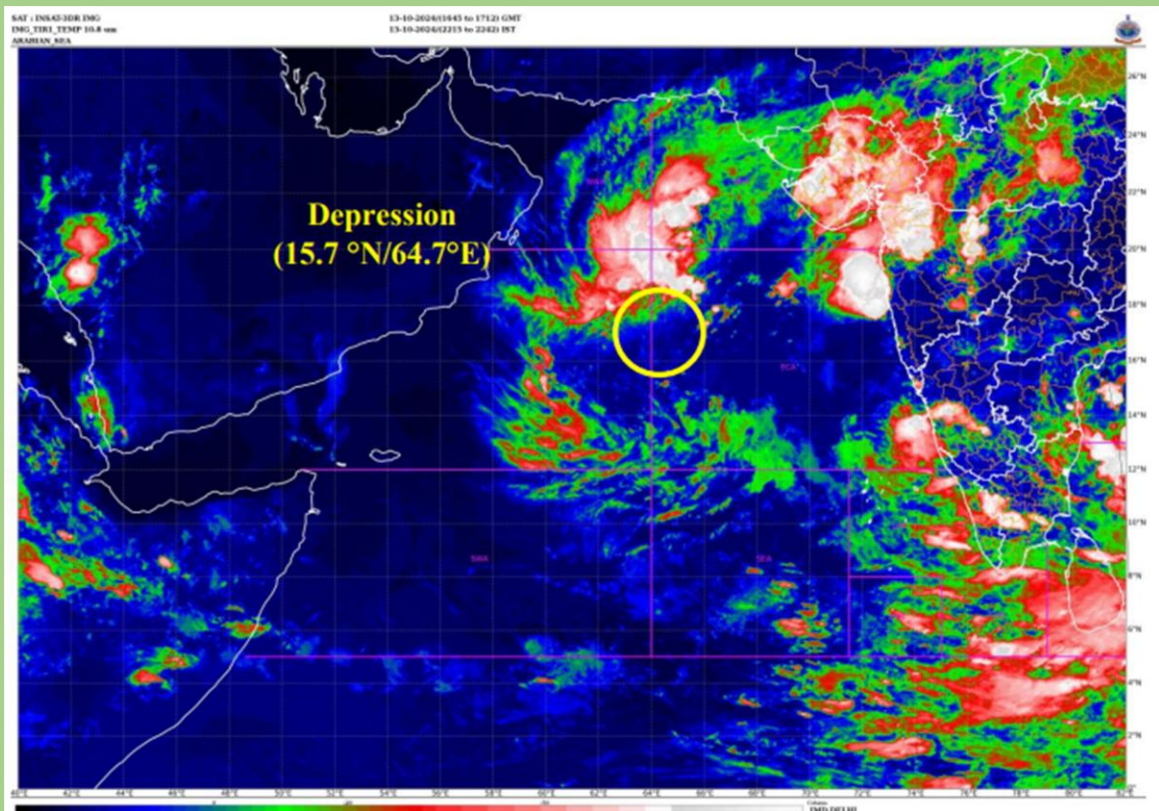




GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
INDIA METEOROLOGICAL DEPARTMENT

**Depression over central Arabian Sea during
13th October -15th October, 2024: A Report**

INSAT-3D Satellite imagery of Depression over central Arabian Sea
at 1700 UTC of 13th of Oct, 2024



Cyclone Warning Division
India Meteorological Department
New Delhi
October, 2024

Depression over central Arabian Sea during 13th October-15th October 2024

1. Introduction

- An upper air cyclonic circulation lay over South Kerala & neighbourhood in the morning (0300 UTC/0830 hours IST) of the 7th October, 2024.
- Under its influence, a Low Pressure Area formed over Lakshadweep and adjoining southeast & eastcentral Arabian Sea (AS) in the morning (0300 UTC/0830 hours IST) of the 9th October, 2024.
- It lay as a Well Marked Low Pressure Area over eastcentral AS off Karnataka-Goa coasts in the morning (0300 UTC/0830 hours IST) of the 10th October 2024.
- It intensified into a Depression in the evening (1200 UTC/1730 hours IST) of the 13th October, 2024 over central AS.
- It moved northwestwards and crossed Oman coast near latitude 19.35°N and longitude 57.7°E, close to Duqm (Oman) between 2230 and 2330 hours IST (1700 UTC and 1800 UTC).
- Continuing to move northwestwards, it weakened into a Well Marked Low Pressure Area over coastal Oman in the same midnight (1800 UTC/2330 hours IST) of the 15th October, 2024. Observed track of the depression is presented in Fig.1. Best Track parameters associated with the system are presented in Table1.

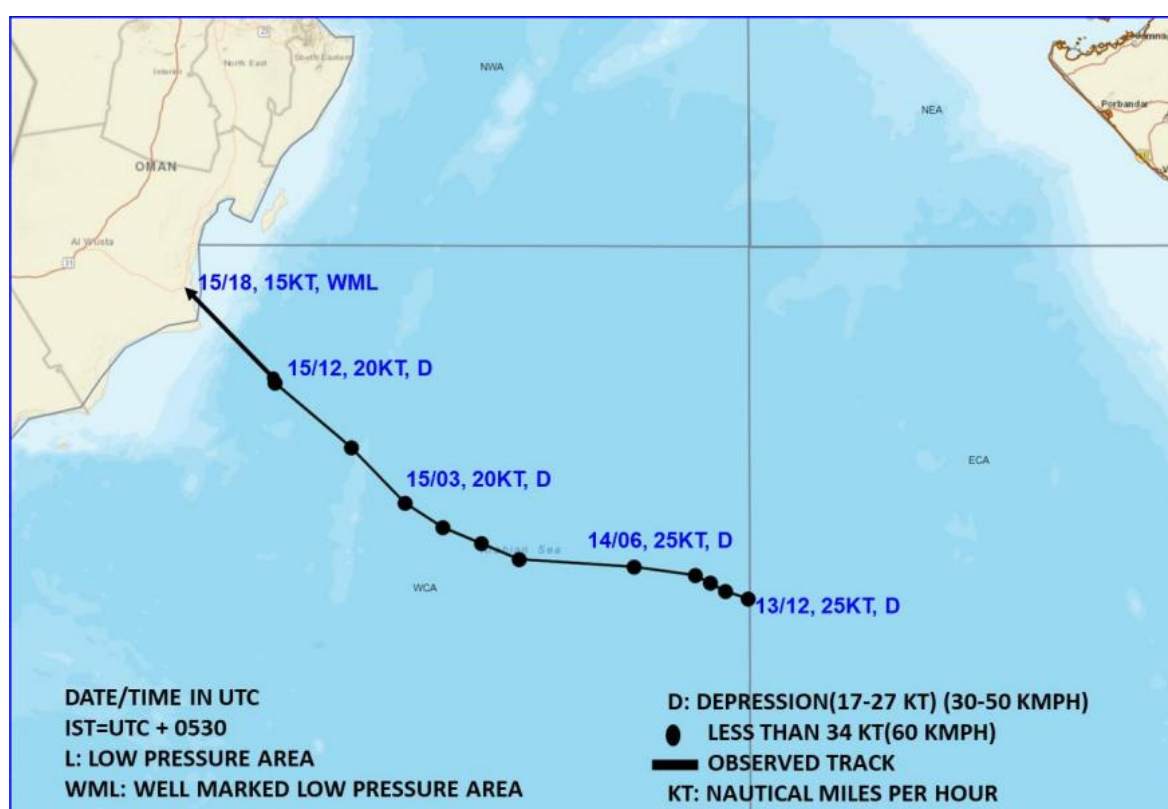


Fig. 1: Observed track of Depression over central AS during 13th Oct – 15th Oct, 2024.

Table 1: Best track positions and other parameters of the Depression over central AS during 13th Oct– 15th Oct, 2024

Date	Time (UTC)	Lat.	Long.	ECP	ΔP	MSW (kt)	Category
13.10.24	1200	15.6	65.0	1002	3	20	D
	1800	15.7	64.7	1002	3	20	D
14.10.24	0000	15.8	64.5	1002	3	20	D
	0300	15.8	64.3	1001	4	25	D
	0600	16.0	64.0	1001	4	25	D
	1200	16.1	62.0	1001	4	25	D
	1800	16.1	61.5	1001	4	25	D
15.10.24	0000	16.1	61.0	1002	3	20	D
	0300	16.8	60.5	1002	3	20	D
	0600	17.5	69.8	1002	3	20	D
	1200	18.3	58.8	1002	3	20	D
Crossed North Oman coast close to Duqm (41291, Oman) between 1700 to 1800 UTC of 15th October (2230 to 2330 hrs IST of 15 th October) as a depression with wind speed of 40-50 gusting to 60 kmph							
15.10.24	1800	Weakened into a well-marked low-pressure area over Oman coast					

KT: Knots (nautical mile per hour), 1 KT=1.85 kmph, D: Depression, DD: Deep Depression

2. Brief life history - Genesis Intensification and movement

2.1 Genesis

At 0300 UTC of 13thOctober, the Madden-Julian Oscillation (MJO) index was in phase 4, with amplitude more than 1 and was predicted to continue in same phase during next 4 days with further increasing amplitude. Thus, the MJO was not favourable for cyclogenesis over AS. The guidance from NCICS model predicted presence of strong westerly winds (7-9 mps) over south AS and strong easterly winds (7-9 mps) over central AS along with eastward moving Kelvin waves & MJO and westwards moving large equatorial Rossby wave extending from south Bay of Bengal to south AS during next 3 days. The sea surface temperature (SST) was 28-30°C over eastcentral AS and around 27°C over the westcentral and southwest parts of AS. The tropical cyclone heat potential (TCHP) was 60-70 KJ/cm² over eastcentral AS and it was less than 50 KJ/cm² over westcentral AS & off Oman coast. Total precipitable water imagery indicated continuous warm moist air incursion into the core. Low-level relative vorticity was around $50-60 \times 10^{-6}$ over the system area with vertical extension upto 500 hPa level. Low-level convergence was around $5 \times 10^{-6} s^{-1}$ over eastcentral AS. Positive

upper-level divergence was around $10 \times 10^{-6} \text{ s}^{-1}$ over system area. Deep layer vertical wind shear (VWS) was low to moderate (05-15 knots) over system area and along the expected path. Upper tropospheric ridge ran along 20°N .

Under these favourable features, the well marked low pressure area over eastcentral AS intensified into a depression over central AS in the evening (1200 UTC/1730 hours IST) of the 13th October, 2024.

Similar features prevailed till 14th evening (1200 UTC). At 1200 UTC of 14th October, low-level relative vorticity decreased and was around $50 \times 10^{-6} \text{ s}^{-1}$ over the system area with vertical extension upto 500 hPa level. Low-level convergence increased and was around $10 \times 10^{-6} \text{ s}^{-1}$ over system area. Positive upper-level divergence increased and was around $20 \times 10^{-6} \text{ s}^{-1}$ to the northwest of system area. Deep layer VWS remained moderate (15 knots) over system area and along the expected path. The system maintained its intensity of depression.

At 1200 UTC of 15th October, the low-level relative vorticity remained around $50 \times 10^{-6} \text{ s}^{-1}$ over the system area with vertical extension upto 500 hPa level. Low-level convergence was around $20 \times 10^{-6} \text{ s}^{-1}$ over system area. Positive upper-level divergence was around $05-10 \times 10^{-6} \text{ s}^{-1}$ to the northwest of system area. Deep layer VWS remained moderate (15 knots) over system area and along the expected path. Under these features, the system maintained its intensity and crossed North Oman coast close to Duqm (41291, Oman) between 1700 to 1800 UTC of 15th October (2230 to 2330 hrs IST of 15th October) as a depression.

Thereafter, due to land interactions and disruption of moisture supply, it weakened into a Well Marked Low Pressure Area over coastal Oman in the same midnight (1800 UTC/2330 hours IST) of the 15th October, 2024.

3. Monitoring

India Meteorological Department (IMD) maintained round the clock watch over the north Indian Ocean (NIO) and the system was monitored well in advance since 10th October. The system was monitored with the help of available satellite observations from INSAT 3D and 3DR, polar orbiting satellites, available ships & buoy observations in the region and coastal observations on the day of landfall. 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.

3.1 Features observed through satellite

Satellite monitoring of the system was mainly done by using half hourly INSAT-3D and 3DR imageries. Satellite imageries of other international geostationary satellites, high resolution polar orbiting satellites and scatterometer imageries from ASCAT were also considered for monitoring of the system. Typical INSAT-3D enhanced colored imageries, visible/ IR, brightness temperature and water vapour imageries

are presented in **Fig. 2 (a) to (d)**. The detailed features from the satellite pictures are discussed in this section.

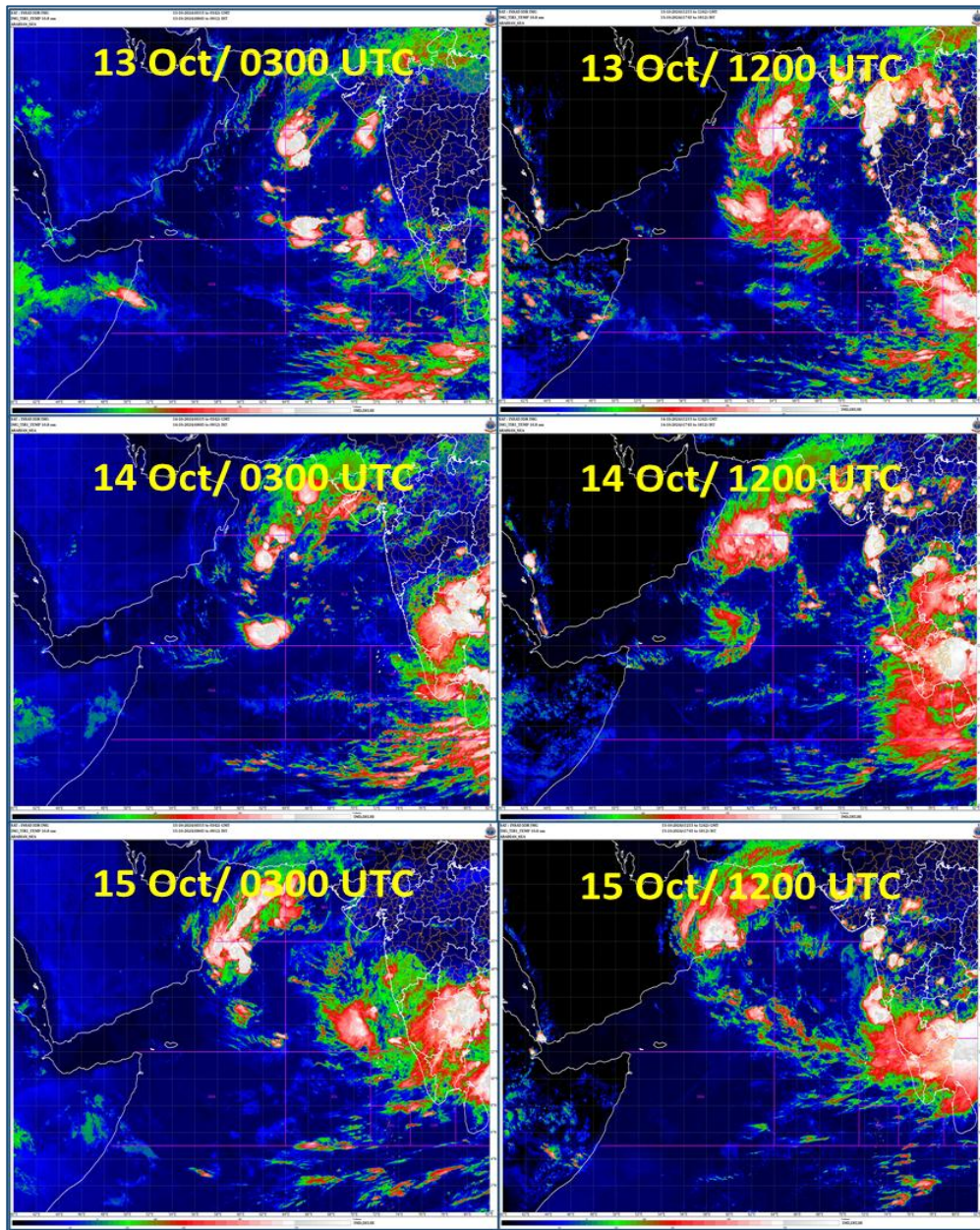


Fig.2 (a): INSAT-3D enhanced colored imageries during life cycle of Depression over central AS during 13th Oct-15th Oct 2024

At 0300 UTC of 13th October 2024, Intensity of the system was characterised as T 1.0. Associated scattered low/med clouds with embedded intense to very intense convection lay over central AS between latitude 13.0°N & 20.0°N and Longitude 60.0°E & 70.0°E. Minimum cloud top temperature (CTT) was minus 80-90°C. Multi-satellite based winds indicated stronger winds in the southwest and northwest sector. Moderate to intense convection lay over North AS. Scattered low and medium clouds with embedded intense to very intense convection lay over Gulf of Cambay, Central AS, Southeast AS & Lakshadweep Islands (Minimum CTT minus 70-85 °C). Scattered low and medium clouds with embedded moderate to intense convection lay over North

AS, Maldives & Comorin area and isolated weak to moderate convection lay over Gulf of Kutch & Southwest AS.

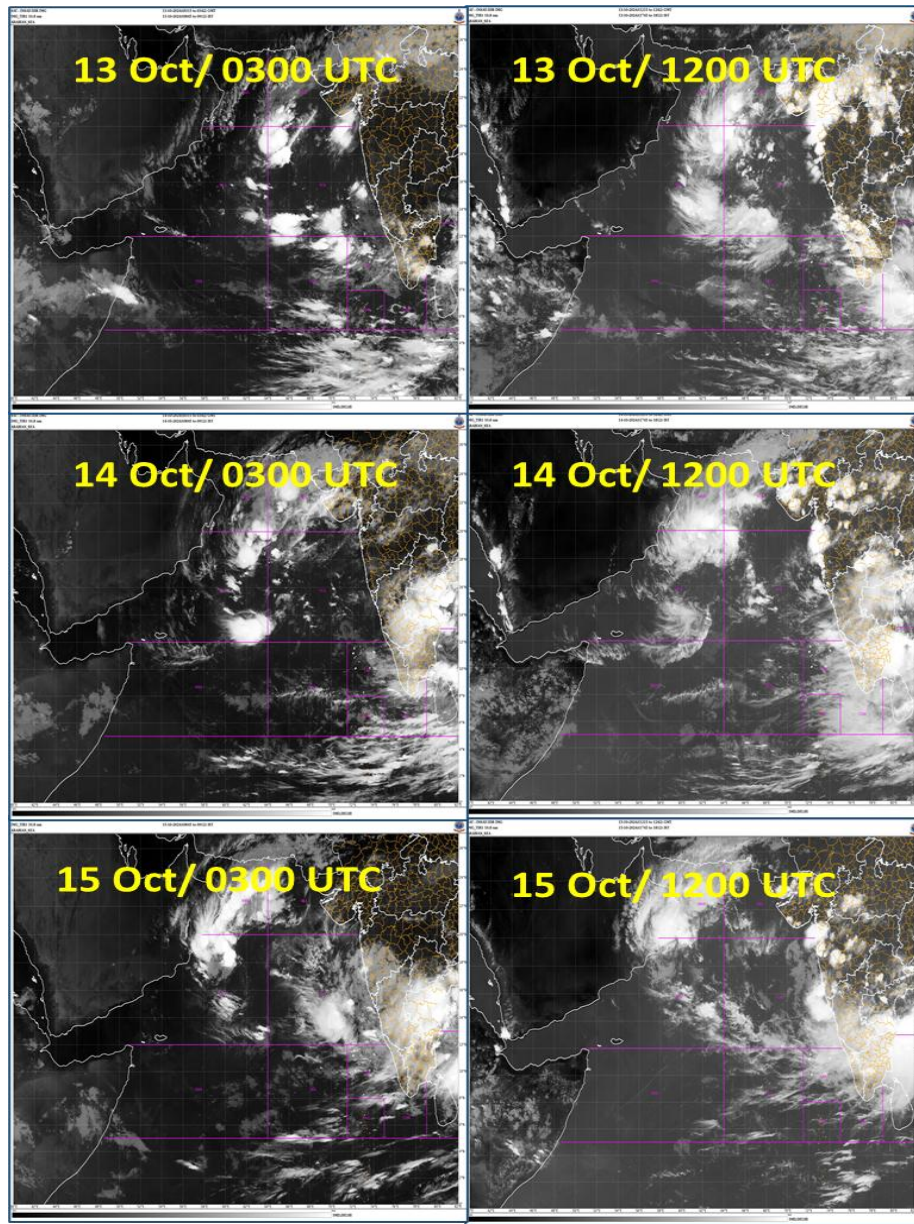


Fig.2 (b): INSAT-3D Visible imageries during life cycle of Depression over central AS during 13th Oct-15th Oct 2024

At 1200 UTC of 13th October 2024, Intensity of the system was characterised as CI1.5. Associated scattered low/med clouds with embedded intense to very intense convection lay over AS between latitude 10.0°N & 23.0°N and Longitude 60.0°E & 72.0°E. Minimum CTT was minus 80-90°C. Multi-satellite based winds indicated stronger winds in the southwest and northwest sector. At 0300 UTC of 14th October 2024, Intensity of the system was characterised as T1.5. Associated scattered low/med clouds with embedded intense to very intense convection lay over AS between latitude 12.0°N & 23.0°N and longitude 60.0°E & 68.0°E. Minimum CTT was minus 80-90 °C. Multi-satellite based winds indicated stronger winds in the northeast sector.

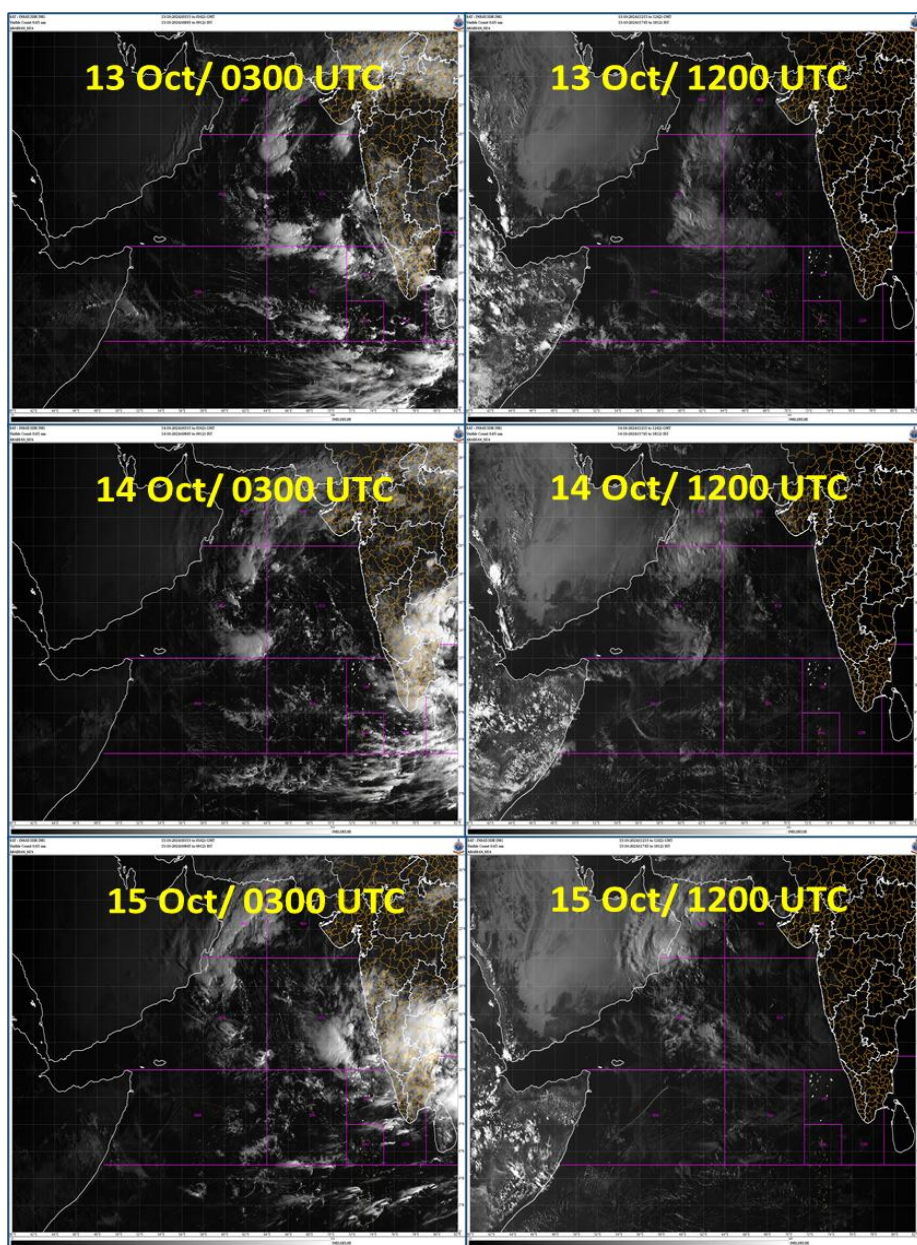


Fig.2 (c): INSAT-3D IR imageries during life cycle of Depression over central AS during 13th Oct-15th Oct 2024

At 0300 UTC of 15th October 2024, Intensity of the system was characterised as CI1.5. Associated scattered to broken low/med clouds with embedded intense to very intense convection lay over westcentral and north AS. Minimum CTT was minus 75-90°C. At 1200 UTC of 15th October 2024, Intensity of the system was characterised as CI1.5. Associated scattered to broken low/med clouds with embedded intense to very intense convection lay over westcentral and north AS. Minimum CTT was minus 75-80 °C

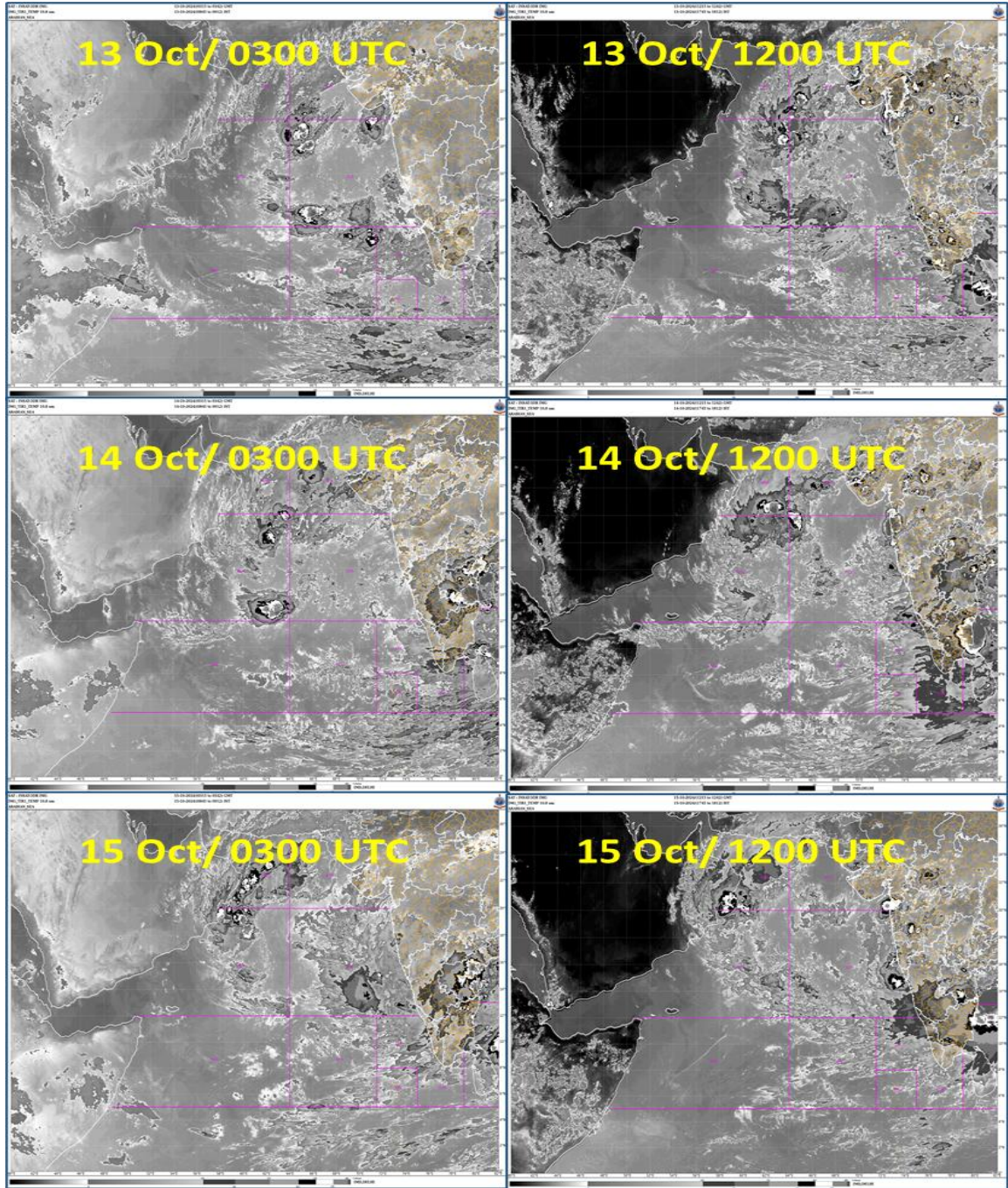


Fig.2 (d): INSAT-3D Enhanced IR imageries during life cycle of Depression over central AS during 13th Oct-15th Oct 2024

4. Dynamical Features

IMD GFS (T1534) daily analysis at 0000 UTC of mean sea level pressure (MSLP), winds at 10 m, 850, 500 and 200 hPa levels from 13thOct to 15thOct are presented in **Fig. 3 (a) to (c)** respectively.

At 0000 UTC of 13th October, the MSLP analysis field indicated a depression over central AS near 15.0°N/65.0°E. Actually, the system was located near 15.4°N/66.4°E at 0000 UTC of 13th October, 2024. The model showed that vertically, the system extended upto 500 hPa level. Ridge was seen near 18°N. Thus, GFS was capturing the location on 13th October. However, the model overestimated the intensity of the system.

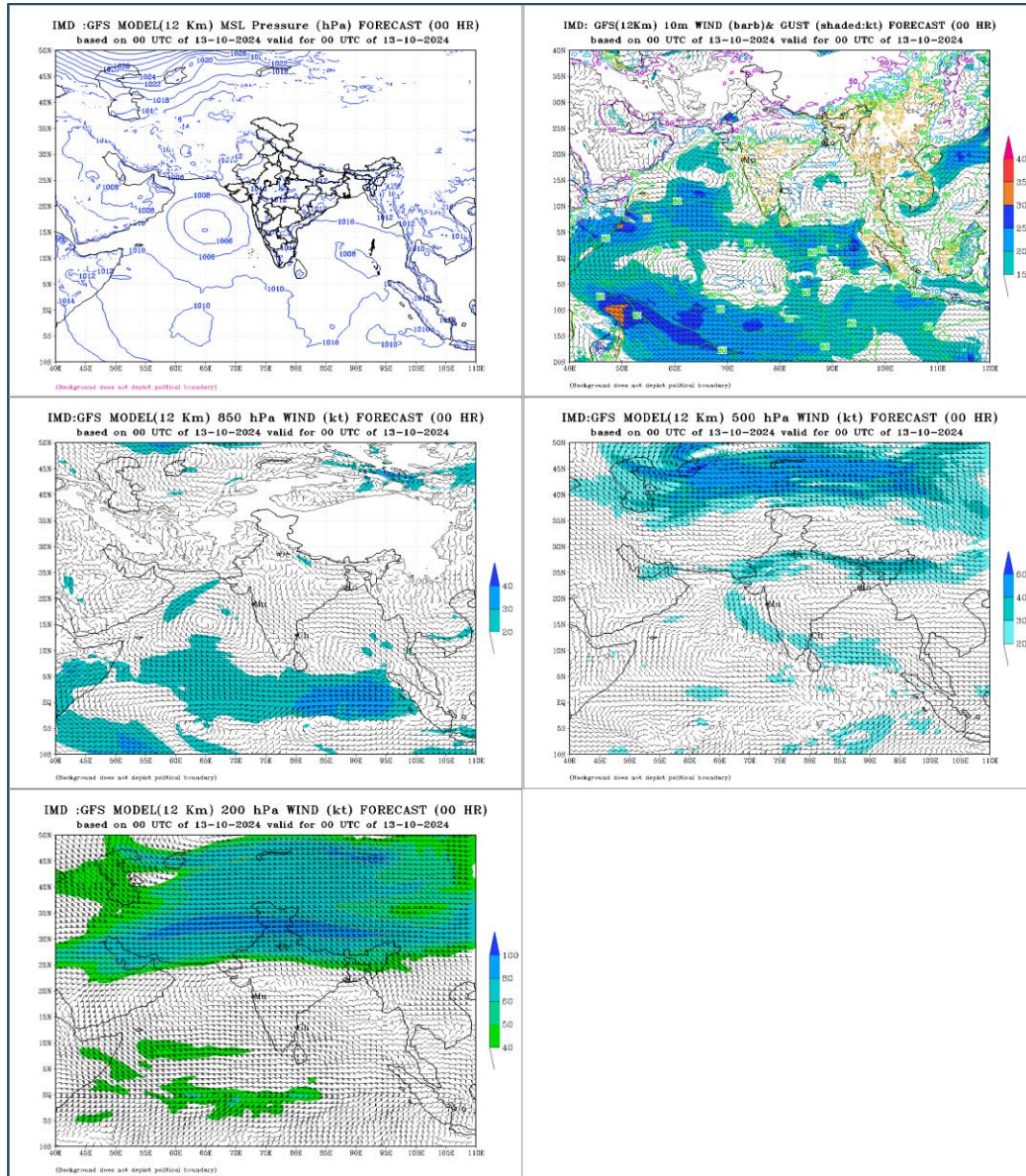


Fig. 3 (a): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 13th October 2024

At 0000 UTC of 14th October, the MSLP analysis field indicated weakening of the system into a well marked low pressure area over westcentral AS near 16.0°N/64.5°E. Actually, the system lay as a depression over westcentral AS near 15.8°N/64.5°E at 0000 UTC of 14th October, 2024. Thus, GFS was capturing the

location on 14th October. However, the model underestimated the intensity of the system.

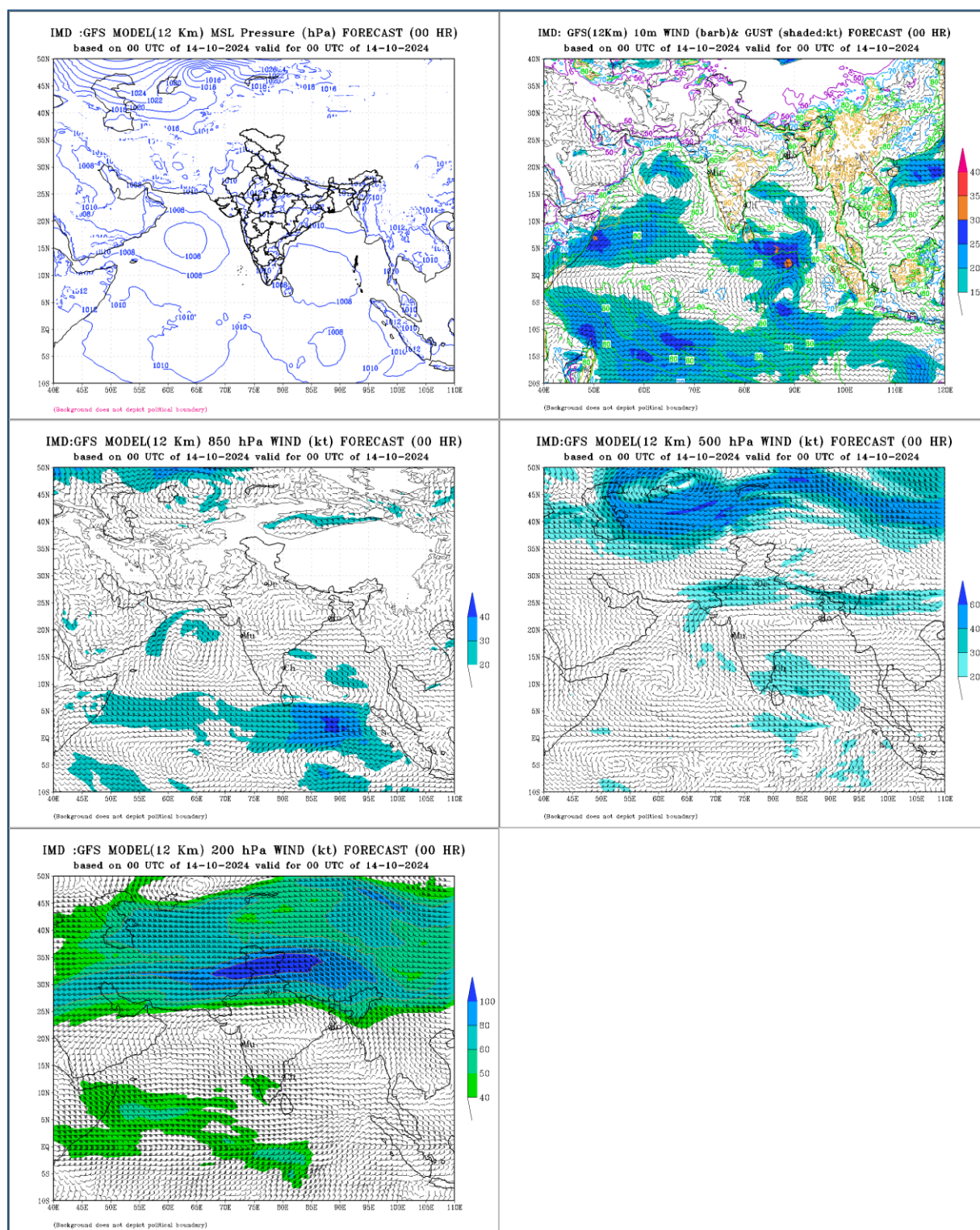


Fig. 3(b): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 14thOctober 2024

At 0000 UTC of 15th October, the MSLP analysis field indicated further weakening of the system into a low pressure area over westcentral AS off Oman coast near

16.8°N/58.0°E. Actually, the system lay as a depression over westcentral AS near 16.1°N/61.0°E at 0000 UTC of 15th October, 2024. Thus, GFS model couldn't capture the initial conditions correctly.

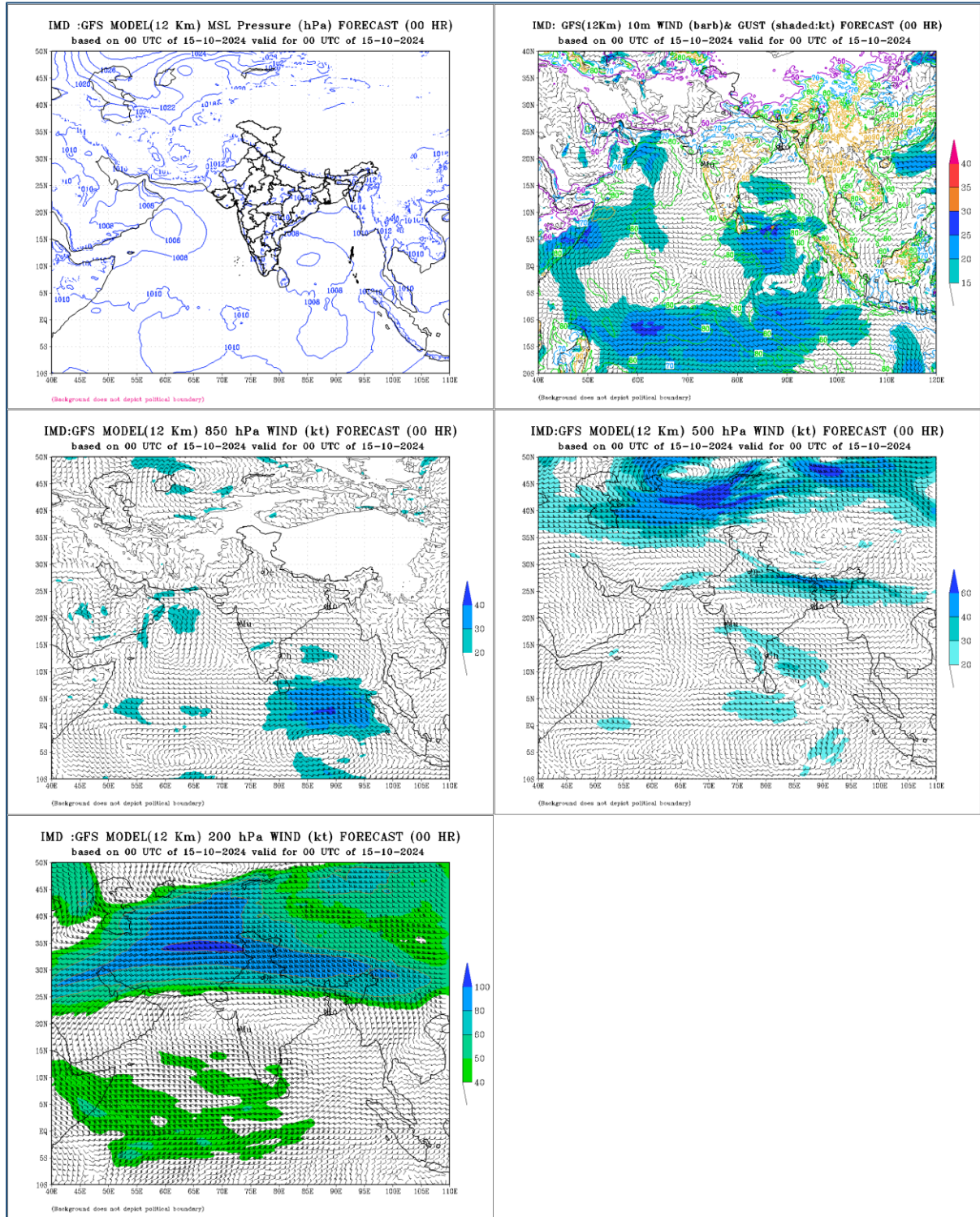


Fig. 3(c): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 15thOctober 2024

i. Operational Forecast Performance

- The daily tropical weather outlook issued at 1130 hours IST (0600 UTC) of 7th October, 2024 indicated formation of low pressure area over Lakshadweep and adjoining Southeast & Eastcentral AS around 9th October. Actually low pressure area formed on 9th October.
- The extended range outlook issued on 10th October (3 days prior to formation of depression) indicated intensification of well marked low pressure over eastcentral AS into a Depression over central AS with high probability (67-100%) and its nearly west-northwestwards movement.
- The daily tropical weather outlook issued at 1130 hours IST (0600 UTC) of 10th October, 2024 indicated formation of depression over central AS during 12-13 October. Actually, depression formed over central AS on 13th October.
- In the Special Tropical Weather Outlook bulletin based on 1730 hours IST (1200 UTC) of 13th October, it was indicated that the depression would move west-northwestwards towards Oman coast till 15th October.
- Since beginning it was indicated that the system would reach peak intensification of depression only.
- Thus, the track, initial movement intensification/weakening of the system were well predicted by IMD/RSMC New Delhi.

ii. Bulletins issued by IMD

- Track, intensity and landfall forecast: IMD continuously monitored, predicted and issued bulletins containing track & intensity forecast from the stage of depression till the system weakened into a low pressure area. The forecast of these parameters were issued from the 13th October onwards along with the cone of uncertainty every six hourly for 00, +12, +24, +36 and +48 hours lead period.
- Adverse weather warning bulletins: The depression forecasts along with expected adverse weather like wind warning, sea condition were issued with every six hourly update to central, state and district level disaster management agencies including MHA NDRF, NDMA for all Lakshadweep, Karnataka, Kerala, Goa, Dadra & Nagar Haveli, Daman & Diu, Gujarat & Maharashtra. The bulletins also contained the suggested action for disaster managers and general public in particular for fishermen. These bulletins were also issued to Defense including Indian Navy & Indian Air Force, NDRF, Indian Coast Guard, ports, Shipping, Fishery, Railways, Surface Transport & Aviation Authorities.
- Warning and advisory for marine community: The 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 centre of IMD at Mumbai and Cyclone Warning Centres at Thiruvananthapuram & Ahmedabad to ports, fishermen, coastal and high sea shipping community.

- Fishermen Warning: Regular warnings for fishermen for deep sea of AS and the states of Karnataka and Kerala were issued since 8th October onwards.
- Warning and advisory through social media: Daily updates (every six hourly or whenever there was any significant change in intensity/track) were uploaded on Facebook and tweeter regularly during the life period of the system from 9th morning onwards on formation of low pressure area, updates were posted on facebook and tweeter.
- Diagnostic and prognostic features of Depression: The prognostics and diagnostics of the system were described in the RSMC bulletins.

Statistics of bulletins issued by RSMC New Delhi in association with this system are given in Table 2 and Bulletins issued by Area Cyclone Warning Centre (ACWC) Mumbai, Ahmedabad and Cyclone Warning Centre (CWC) Thiruvananthapuram are given in Table 3.

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

S. No.	Bulletins	No. of Bulletins	Issued to
1	National Bulletin	12	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, Ministry 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 Lakshadweep, Karnataka, Kerala, Goa, Dadra & Nagar Haveli, Daman & Diu, Gujarat & Maharashtra.
2	RSMC Bulletin	12	1. IMD's website 2. WMO/ESCAP member countries through GTS and E-mail.
3	GMDSS Bulletins	9	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	4653	4,653 to General Public and disaster manages along the east coast of India by IMD Headquarters.
5	Warnings through Social Media	12	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).
6	Press Release	1	Disaster Managers, Media persons by email and uploaded on website
7	Press Briefings	Daily	Regular & frequent briefing daily during 14th - 17th October

Table 3: Bulletins issued by Area Cyclone Warning Centre (ACWC)Mumbai, Ahmedabad and Cyclone Warning Centre (CWC) Thiruvananthapuram

S. No.	Bulletins	ACWC Mumbai	CWC Ahmedabad	CWC Thiruvananthapuram
1	Sea Area Bulletin for AS	4	-	-
2	Coastal Weather Bulletin for respective coastal area	4	4	3
3	Port Warnings for respective ports under jurisdiction	7	7	5
4	Fishermen Warnings for AS	9	9	9

iii. 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 contribution from WMO/ ESCAP panel member countries for sharing observations. 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)Ahmedabad and Cyclone Warning Centre (CWC)Thiruvananthapuram is duly acknowledged. 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.