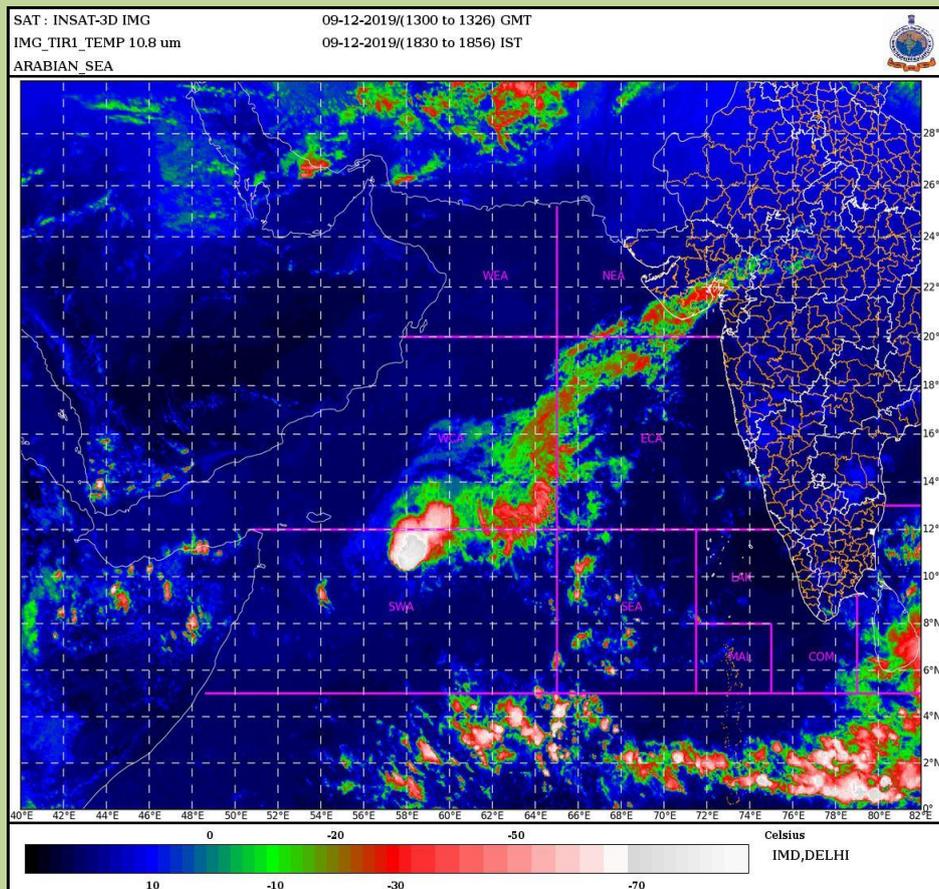




**GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
INDIA METEOROLOGICAL DEPARTMENT**

**Deep Depression over southwest Arabian Sea
(08-10 December, 2019): A Report**



INSAT-3D enhanced Colored IR imagery based on 1200 UTC of 09th December

**Cyclone Warning Division
India Meteorological Department
New Delhi**

Deep Depression over southwest Arabian Sea during 08-10 December, 2019

1. Introduction

A low pressure area formed over southeast Arabian Sea (AS) and adjoining equatorial Indian Ocean (EIO) in the early morning (0000 UTC) of 7th December, 2019. It lay as a well marked low pressure area over southeast & adjoining southwest AS in the early morning (0000 UTC) of 8th December. It concentrated into a depression in the same afternoon (0900 UTC) over southwest AS. It moved west-northwestwards and intensified into a deep depression in the early morning (0000 UTC) of 9th December over the same region. Thereafter, it entered into unfavorable environment and weakened into a depression over southwest AS in the same evening (1200 UTC) of 9th December and into a well marked low pressure area around noon (0600 UTC) of 10th December over southwest AS. The observed track of deep depression over southwest AS is presented in Fig.1.

The salient features of the system were as follows:

- (i) It had a straight track with initial west-northwestwards movement followed by westwards movement.
- (ii) It had a life period of 45 hours.
- (iii) It had a track length of 678 km.
- (iv) It did not cause any adverse weather over any land area.

IMD mobilised all its resources to track the system and regular warnings w.r.t. track, intensity, state of Sea and associated fishermen & Marine warnings for deep parts of Arabian Sea were issued to concerned central and state disaster management agencies, Mariners, print & electronic media and general public. Regular advisories were also issued to WMO/ESCAP Panel member countries including Yemen, Somalia and Socotra Islands.

The brief life history, associated weather and forecast performance of IMD/RSMC, New Delhi are presented in following sections.

2. Brief Life History:

2.1. Genesis

At 0000 UTC of 7th December, Madden Julian Oscillation (MJO) index lay in phase 2 with amplitude near to 1. The sea surface temperature (SST) was 28-30°C and tropical cyclone heat potential (TCHP) was 40-60 KJ/cm² over southeast AS. The low level vorticity was around $100 \times 10^{-6} \text{s}^{-1}$ over Equatorial Indian Ocean (EIO) and adjoining southeast AS. The lower level convergence was about $30 \times 10^{-5} \text{s}^{-1}$ and upper level divergence was $40 \times 10^{-5} \text{s}^{-1}$ over EIO and adjoining southeast AS. Under these conditions, an LPA formed over southeast AS and adjoining EIO at 0000 UTC of 7th December. Similar favourable conditions ensued and the system further organised into a WML on 8th December.

2.2. Intensification and movement

At 0900 UTC of 8th, the MJO lay in phase 2 with amplitude close to 1. Similar sea conditions prevailed. The low level relative vorticity increased and was $150 \times 10^{-6} \text{s}^{-1}$ around the system center. The lower level convergence was about $10 \times 10^{-5} \text{s}^{-1}$ around the system center. The upper level divergence was about $20\text{-}30 \times 10^{-5} \text{s}^{-1}$ to the southeast of the system center. The vertical wind shear was moderate (10 knots) over the system area. The upper tropospheric ridge ran along 11°N . The system lay to the south of upper tropospheric ridge and was steered by middle and upper tropospheric winds. Under these conditions, it concentrated into a depression over southwest AS near $9.4^\circ \text{N}/62.2^\circ \text{E}$

At 0000 UTC of 9th, similar sea conditions prevailed. MJO lay in phase 2 with amplitude close to 1. Warm air advection was taking place into the core of the system from southern sector. Upper tropospheric ridge lay near 11°N . The low level relative vorticity decreased and was about $50 \times 10^{-6} \text{sec}^{-1}$ around the system center. It was extending upto 500 hPa level. The lower level convergence was about $05 \times 10^{-5} \text{s}^{-1}$ around the system center. The upper level divergence was about $20 \times 10^{-5} \text{s}^{-1}$ the system center. The vertical wind shear was moderate (10-15 knots) over the system area. The upper tropospheric ridge extended along 11°N . The system lay in a marginally favourable environment and intensified into a DD over southwest AS near $10.3^\circ \text{N}/60.0^\circ \text{E}$. It moved west-northwestwards, as it lay to the south of upper tropospheric ridge and was steered by middle and upper tropospheric winds.

At 1200 UTC of 9th, similar MJO conditions prevailed. However, tropical cyclone heat potential decreased slightly. SST was around 28°C near the system centre with a slight reduction in westward direction. Warm air advection continued into the core of the system. The low level relative vorticity was $50 \times 10^{-6} \text{s}^{-1}$ around the system center and was vertically extending upto 500 hPa level. The lower level convergence was about $10 \times 10^{-5} \text{s}^{-1}$ to the south of the system center. The upper level divergence decreased and was about $10 \times 10^{-5} \text{s}^{-1}$ over the system area. The vertical wind shear was moderate to high (20-25 knots) over the system area. The upper tropospheric ridge shifted northwards and extended along 13°N . The system moved into an unfavourable environment and weakened into a depression over southwest AS near $10.6^\circ \text{N}/58.5^\circ \text{E}$. The movement was steered by middle and upper tropospheric winds.

At 0600 UTC of 10th, similar MJO and sea conditions prevailed. Low level vorticity and upper level divergence remained the same. However, no significant convergence was seen associated with the system in the lower levels. The vertical wind shear was high (20-25 knots) over the system area. The upper tropospheric ridge ran along 12°N . Under these conditions, the system weakened into a WML over southwest AS.

The observed track of the system is presented in Fig.1. The best track parameters of the system are presented in Table 1. Typical satellite imageries during the life cycle of the system are presented in Fig. 2.

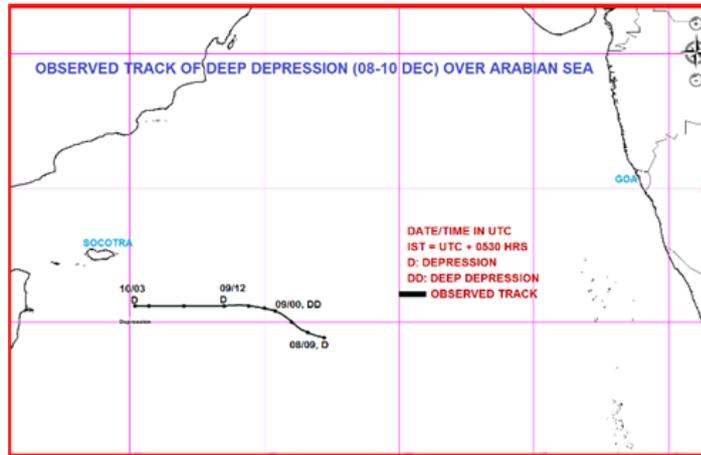


Fig.1. Observed track of the deep depression over southwest Arabian Sea

Table 1: Best track positions and other parameters of the Deep Depression over the Arabian Sea during 08th–10th December, 2019

Date	Time (UTC)	Centre lat. ^o N/ long. ^o E		C.I. No.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimated Pressure drop at the Centre (hPa)	Grade
08/12/2019	0900	9.4	62.2	1.5	1002	25		D
	1200	9.6	61.6	1.5	1002	25		D
	1800	10.0	61.0	1.5	1002	25		D
09/12/2019	0000	10.4	60.4	2.0	1000	30		DD
	0300	10.5	60.0	2.0	1000	30		DD
	0600	10.6	59.4	2.0	1000	30		DD
	1200	10.6	58.5	1.5	1002	25		D
	1800	10.6	57.0	1.5	1002	20		D
10/12/2019	0000	10.6	55.7	1.5	1002	25		D
	0300	10.6	55.2	1.5	1002	25		D
	0600	Weakened into a Well Marked Low over Southwest Arabian Sea.						

3. Feature observed through Satellites:

India Meteorological Department (IMD) maintained round the clock watch over the north Indian Ocean and the system was monitored since 4th December about 3 days prior to formation of LPA over southeast Arabian Sea (AS) and adjoining EIO on 7th December, 2019. In the bulletin issued at 0600 UTC of 7th, it was indicated that the system would concentrate into a depression around 8th with low probability (1-25%) and around 9th with moderate probability (51-75%). From 8th December onwards, it was indicated that the system would intensify marginally and move initially west-northwestwards followed by westward movement.

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 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 models' guidance, decision making process and warning product generation. Typical satellite imageries are presented in Fig. 2.

At 0900 UTC of 8th December, the satellite images indicated increase in convection and increased organisation of clouds around the system center. The intensity of the system was T1.5. Broken low and medium clouds with embedded intense to very intense convection lay over southwest and adjoining southeast AS between latitude 8.5⁰N & 14.5⁰N and longitude 60.0⁰E & 67.0⁰E. Minimum cloud top temperature (CTT) was - 90⁰C.

At 0000 UTC on 09th December, 2019, the clouds further organized and the intensity of the system was T2.0. Broken low & medium clouds with embedded intense to very intense convection lay over southwest and adjoining southeast AS between latitude 9.5⁰N & 13.0⁰N and longitude 58.0⁰E & 63.0⁰E. Minimum CTT was - 88⁰C.

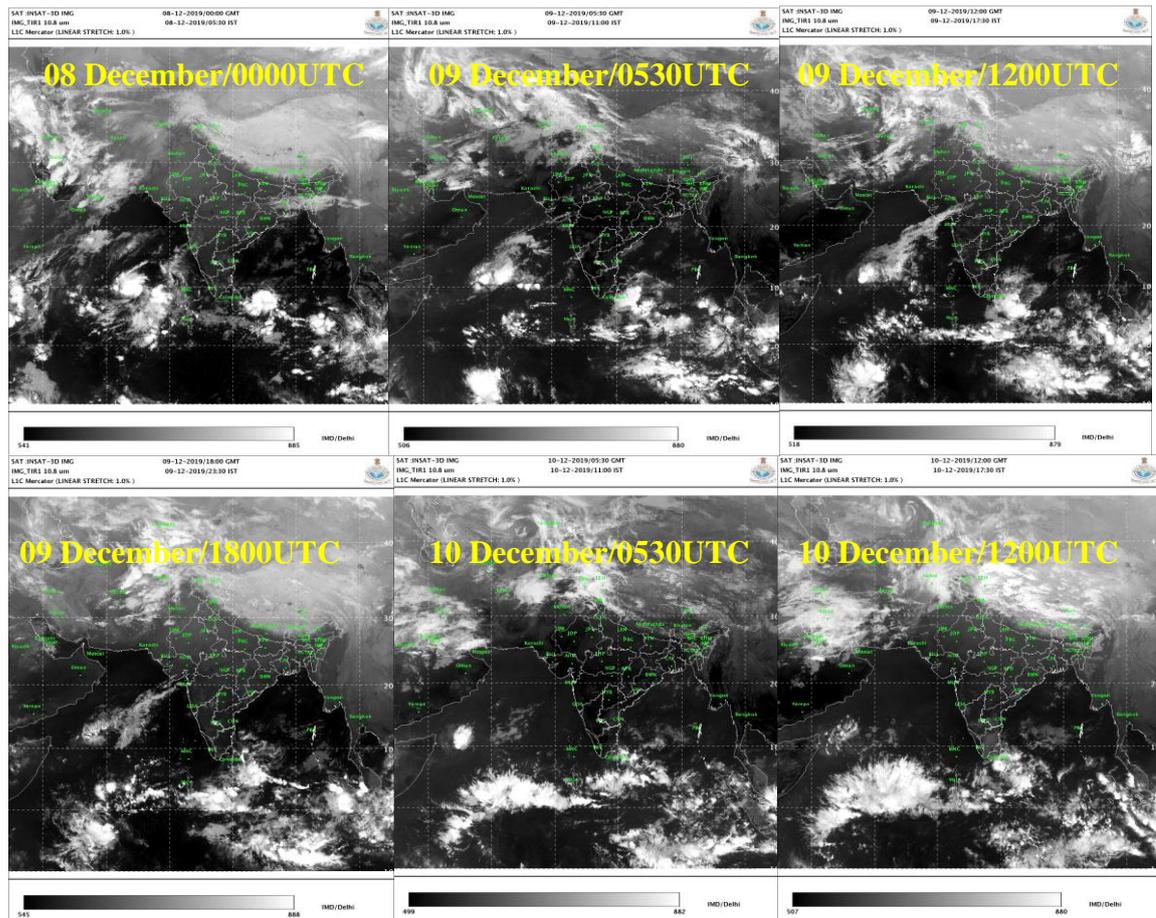


Fig. 2(i): INSAT-3D IR imageries during 08-10 December, 2019

At 1200 UTC of 9th, the wind shear over the system increased. The cloud mass started disorganizing and the current intensity of the system was T1.5. Broken

low & medium clouds with embedded intense to very intense convection lay over southwest and adjoining southeast AS between latitude 10.3°N & 13.0°N and longitude 58.0°E & 64.0°E. Minimum CTT was - 91°C.

At 0600 UTC on 10th, the unfavourable environment persisted and the clouds further disorganized. The intensity of the system was T1.0. Broken low & medium clouds with embedded intense to very intense convection lay over southwest and adjoining southeast AS between latitude 9.5°N & 12.5°N and longitude 54.5°E & 56.5°E. The height of convection also decreased with minimum CTT as - 86°C.

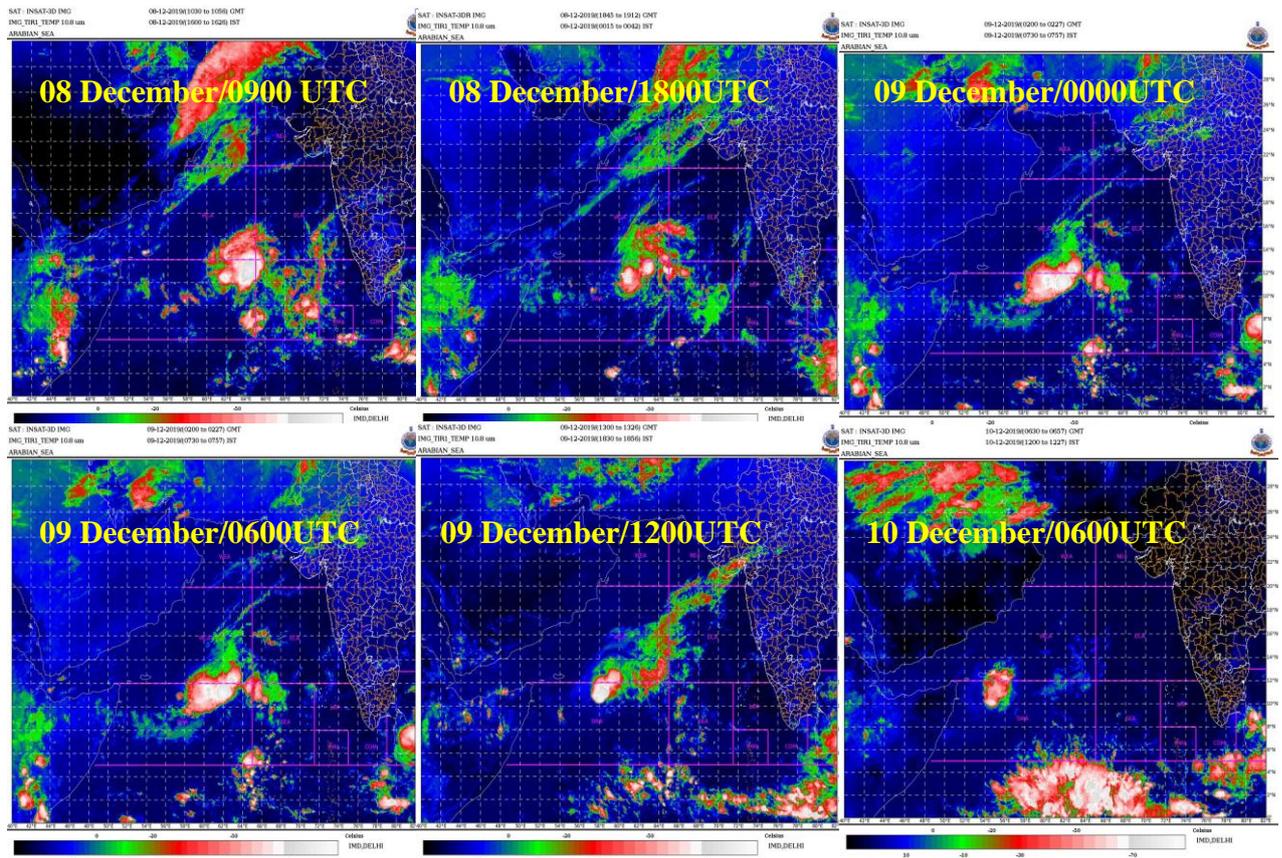


Fig. 2(ii): INSAT-3D enhanced colored imageries during 08-10 December, 2019

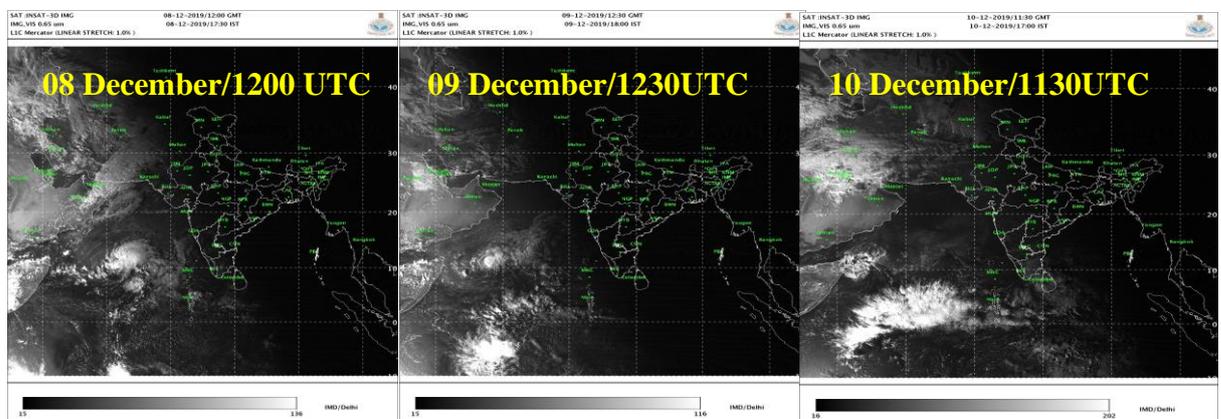


Fig. 2(iii): INSAT-3D visible imageries during 08-10 December, 2019

4. Dynamical features

IMD GFS (T1534) analysis fields of mean sea level pressure (MSLP), winds at 10 m, 850, 500 and 200 hPa levels are presented in Fig.4. At 0000 UTC of 8th December, it indicated a low pressure area over southwest AS near 9.0°N/64.5°E. The circulation was seen extending upto 500 hPa level tilting southwestwards with height. On 8th, it lay as a depression over southwest AS near 9.4°N/64.2°E. GFS indicated an anticyclone to the northeast of system centre, steering it nearly west-northwestwards. IMD GFS picked up the location correctly but underestimated the intensity of the system.

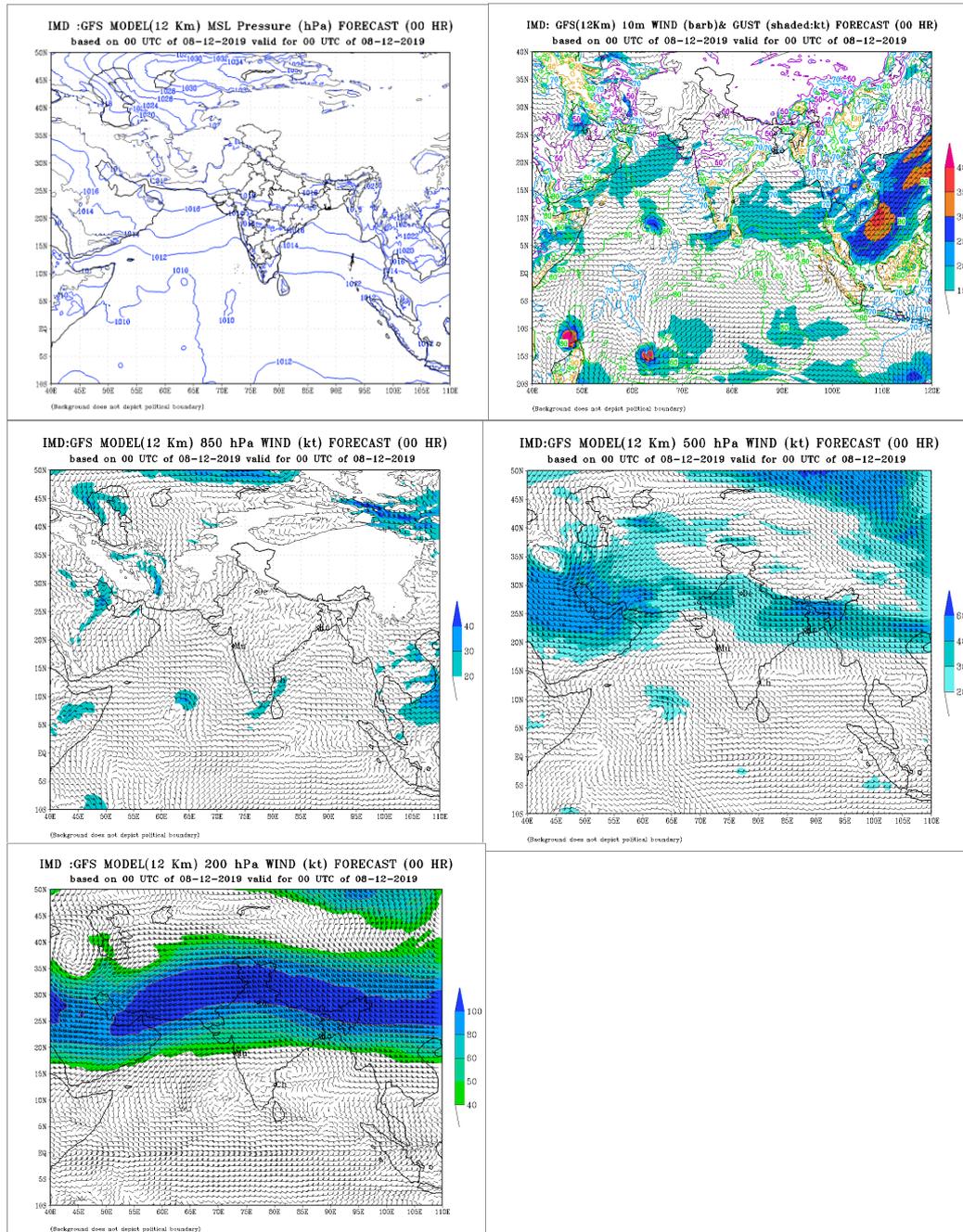


Fig4 (i): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 8th December, 2019

At 0000 UTC of 9th December, it indicated a DD over southwest AS near 10.0°N/60.0E. The circulation was seen extending upto 500 hPa level tilting southwestwards with height. On 9th, it lay as a DD over southwest AS near 10.4°N/60.4°E. GFS indicated an anticyclone to the northeast of system centre, steering it west-northwestwards. IMD GFS picked up the location, intensity and movement correctly.

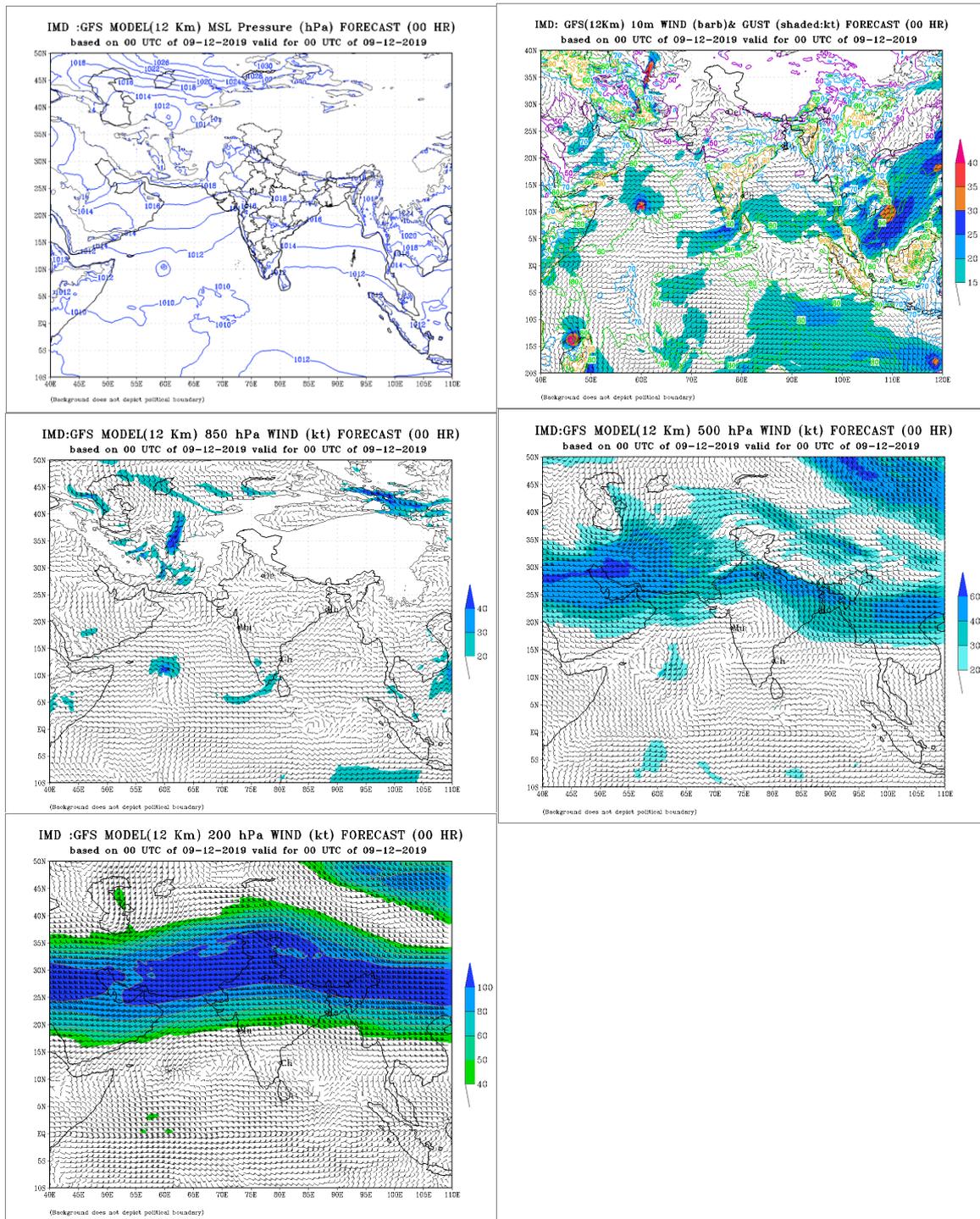


Fig4 (ii): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 9th December, 2019

At 0000 UTC of 10th December, it indicated an LPA over southwest AS near 10.5°N/56.0E. The circulation was seen extending upto 500 hPa level tilting southwestwards with height. On 10th, it lay as a depression over southwest AS near 10.6°N/55.7°E. GFS also indicated easterly flow in the mid levels, steering the system westwards. IMD GFS picked up the location and movement correctly. However, intensity was under estimated.

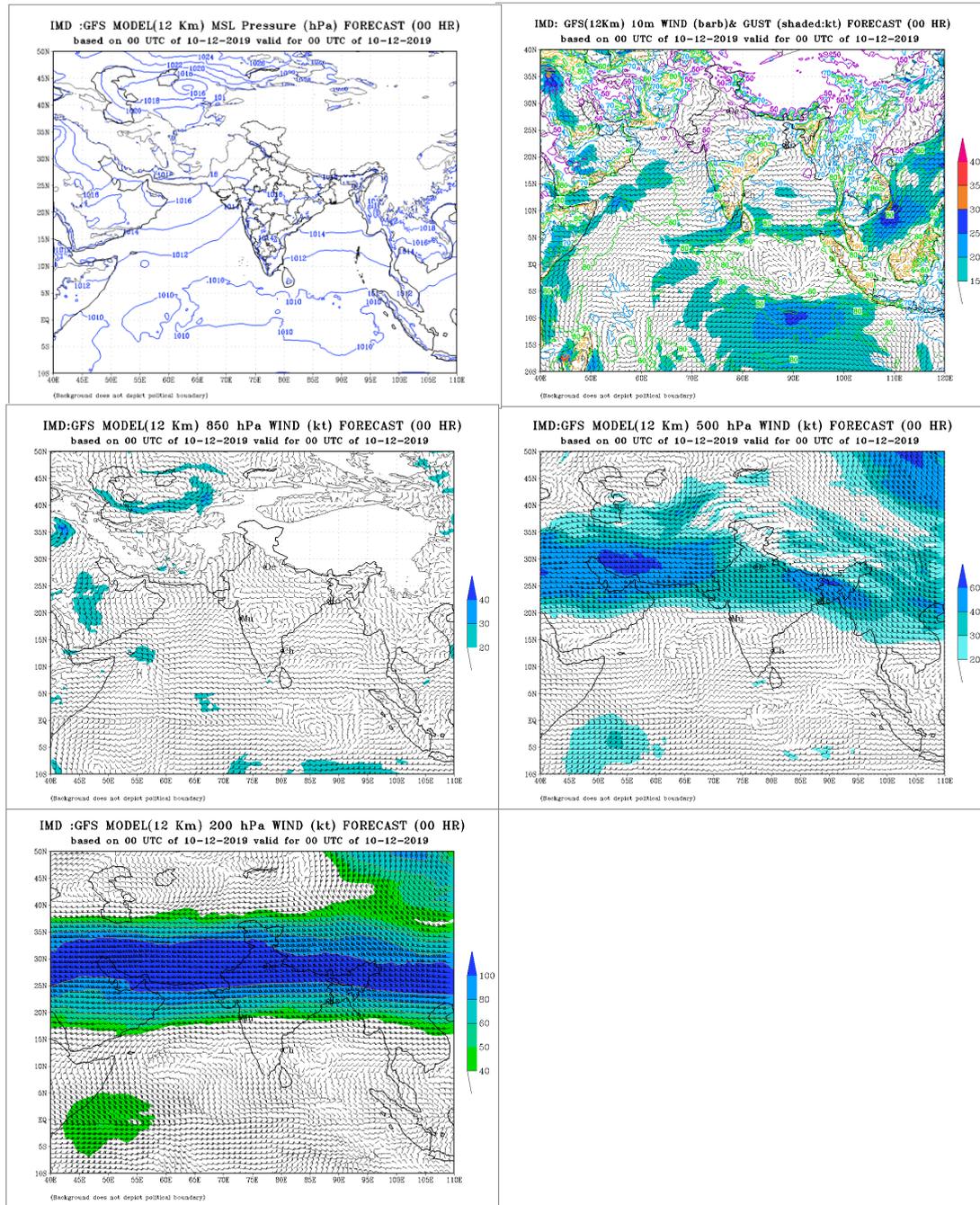


Fig4 (iii): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 10th December, 2019

6. Bulletins issued by IMD

IMD issued regular bulletins to WMO/ESCAP Panel member countries National Disaster Management Agencies, general public and media. Regular Bulletins every six hourly were issued since formation of low pressure area over southwest AS to all the WMO/ESCAP Panel member countries including Somalia, Yemen and Socotra Islands. In addition, RSMC New Delhi also issued Press Release and SMS to registered users in particular wrt the warnings for fishermen and ships in deep sea over west Arabian Sea.

6.1 Bulletins issued by Cyclone Warning Division, New Delhi

Bulletins issued by Cyclone Warning Division of IMD in association with the system are given in Table 2

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

S. No.	Bulletins	No. of Bulletins	Issued to
1	National Bulletin	11	1. IMD's website 2. FAX and e-mail to Control Room NDMA, Ministry of Home affairs, Cabinet Secretariat, Minister of Sc. & Tech, Secretary MoES, DST, HQ Integrated Defense Staff, DG Doordarshan, All India Radio, DG-NDRF, Chief Secretary: Karnataka, Kerala, Administrator: Lakshadweep Island, Director Indian Railways, UNI
2	RSMC Bulletin	11	1. IMD's website 2. All WMO/ESCAP member countries through GTS and E-mail.
3	GMDSS Bulletins	6	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	Press Release	3	1. Disaster Managers, Media persons by email and uploaded on website
5	Facebook /Twitter	4 times a day	Highlights uploaded on Facebook/twitter since formation of depression.
6	SMS	4 times a day	To disaster managers of central and state level and general public registered with RSMC website.

7. Summary and Conclusions:

A low pressure area formed over southeast AS and adjoining EIO on 7th December, 2019. It concentrated into a depression on 8th over southwest Arabian Sea. It moved west-northwestwards and intensified into a deep depression on 9th December over the same region. Thereafter, it entered into unfavourable environment and weakened into a depression in the evening of 9th and into a well marked low pressure area in the noon of 10th December over southwest AS.

IMD maintained round the clock watch and monitored the system since 4th December, 3 days prior to the formation of LPA. Regular warnings were issued for fishermen in deep Sea since the development of LPA.

8. Acknowledgements:

India Meteorological Department (IMD) duly acknowledges the contribution from all the stake holders who contributed to the successful monitoring, prediction and early warning service of the system. We specifically acknowledge the contribution from Indian Space Research Organisation (ISRO) and all sister organizations of Ministry of Earth Sciences including National Centre for Medium Range Weather Forecasting Centre (NCMRWF) NOIDA, Indian Institute of Tropical Meteorology, Pune, National Institute of Technology (NIOT) Chennai & Indian National Centre for Ocean Information Services (INCOIS). Numerical Weather Prediction (NWP) Division, Information System & Services Division (ISSD) and Satellite Division at IMD HQ New Delhi is also duly acknowledged for monitoring and predicting the system.
