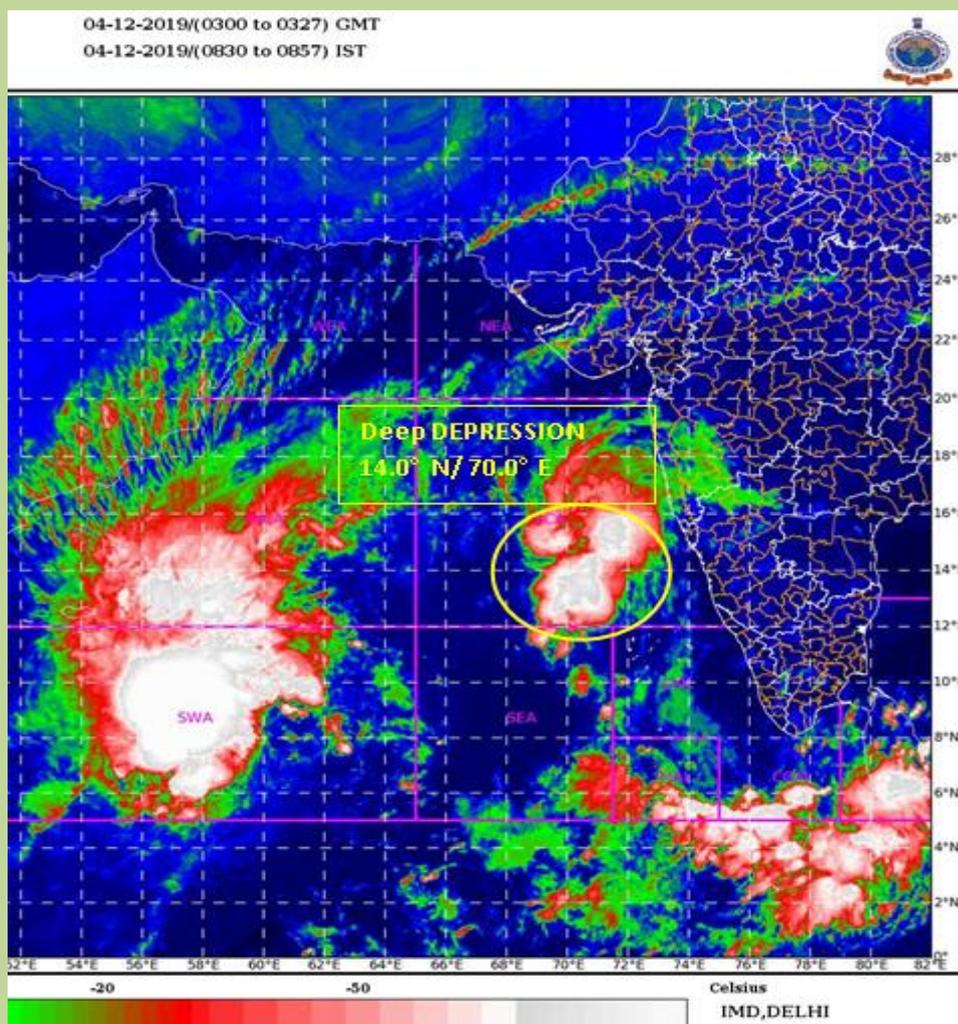




**GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
INDIA METEOROLOGICAL DEPARTMENT**

**Deep Depression over east central Arabian Sea
(03-05 December) 2019: A Report**



INSAT-3D enhanced Colored IR imagery based on 0300 UTC of 4th December

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

Deep Depression over east central Arabian Sea during 03-05 December 2019

1. Brief Life History

- Under the influence of the cyclonic circulation over Maldives and Comorin area, a low pressure area (LPA) formed over southeast Arabian Sea (AS) and adjoining Lakshadweep area in the morning (0300 UTC) of 1st December, 2019.
- It lay as a well marked low pressure area (WML) over southeast AS and adjoining areas of eastcentral AS & Lakshadweep in the morning (0300 UTC) of 3rd.
- Under favourable environmental conditions, it concentrated into a depression in the same midnight (1800 UTC of 3rd December) over eastcentral AS and adjoining areas of southeast AS & Lakshadweep.
- Moving northwestwards it intensified into a deep depression (DD) in the early morning (0000 UTC) of 04th December over the same region.
- Thereafter, it entered unfavourable environment and weakened into a depression in the early morning (0300 UTC) of 5th December over eastcentral Arabian Sea. It further weakened into a well marked low pressure area over the same region in the evening (1200 UTC) of 05th December, into a low pressure area in the early morning (0000 UTC) of 6th December over the same region and became less marked in the same morning (0300 UTC).
- The observed track of the deep depression over southeast AS and adjoining areas during 3rd to 5th December is presented in Fig.1 (i).
- The best track parameters of the system are presented in Table 1.

The salient features of the system were as follows:

- (i) It occurred simultaneously with cyclonic storm Pawan over southwest AS (2nd-7th December). Co-existence of CS Pawan over southwest AS and DD over southeast AS is the second such event after super cyclonic storm Kyarr and extremely severe cyclonic storm Maha co-existed in November, 2019 over AS during 1891-2019. Tracks of these simultaneously occurring systems are presented in Fig. 1(ii).
- (ii) It had an anticlockwise recurving track.
- (iii) It had a life period of 42 hours.
- (iv) It had a track length of 542 km.
- (v) It moved with 6 hourly average speed of 15.1 kmph.
- (vi) The system did not cause any adverse weather along the west coast of India or any of the WMO/ESCAP countries adjoining Arabian Sea and weakened over eastcentral Arabian Sea.

IMD mobilised all its resources to track the system and regular warnings w.r.t. track, intensity, state of Sea and associated adverse weather were issued to concerned central and state disaster management agencies, print & electronic media and general public. Regular advisories were also issued to WMO/ESCAP Panel member countries along the Arabian Sea. Its genesis, movement and associated adverse weather could be predicted well by IMD

The brief life history, salient features, monitoring, associated weather and forecast performance of IMD/RSMC, New Delhi are presented in this report.

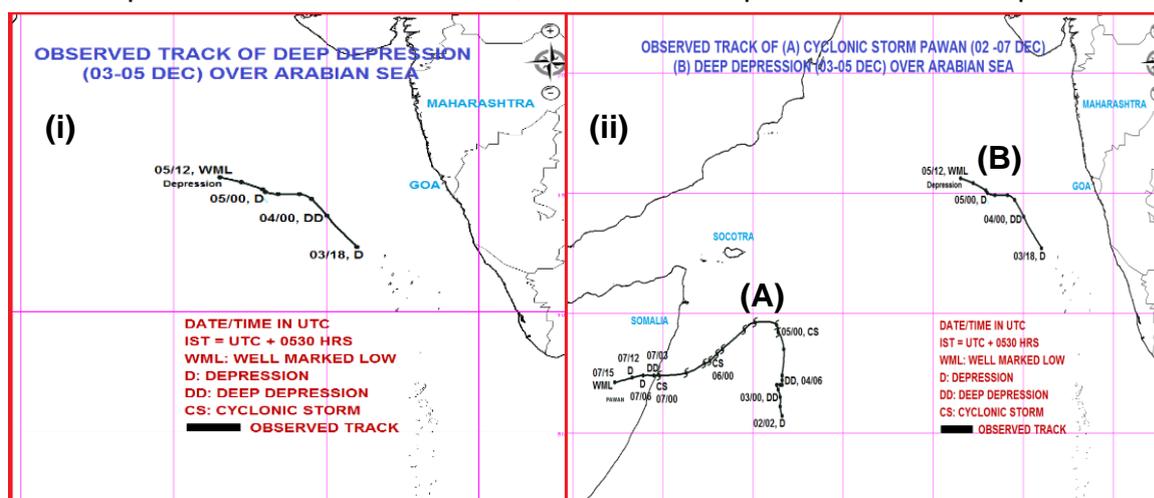


Fig.1.Observed track of the (i) deep depression over southeast AS and adjoining areas (03-05 Dec.) and (ii) simultaneously occurring cyclonic storm Pawan (02-07 Dec.) and deep depression (03-05 Dec.)

Table 1: Best track positions and other parameters of the deep depression over southeast AS during 03-05 December

| Date | Time (UTC) | Centre | | C.I. NO | Estimated Central Pressure (hPa) | Estimated Maximum Sustained Surface Wind (kt) | Estimated Pressure drop at the Centre (hPa) | Grade |
|------------|------------|---|----------------------|---------|----------------------------------|---|---|-----------|
| | | lat ($^{\circ}$ N) | long ($^{\circ}$ E) | | | | | |
| 03/12/2019 | 1800 | 12.7 | 71.0 | 1.5 | 1002 | 25 | 04 | D |
| 04/12/2019 | 0000 | 14.0 | 70.0 | 2.0 | 1000 | 30 | 06 | DD |
| | 0300 | 14.7 | 69.5 | 2.0 | 1000 | 30 | 06 | DD |
| | 0600 | 14.9 | 69.1 | 2.0 | 1000 | 30 | 06 | DD |
| | 1200 | 14.9 | 68.4 | 2.0 | 1000 | 30 | 06 | DD |
| | 1800 | 15.0 | 68.0 | 2.0 | 1000 | 30 | 06 | DD |
| 05/12/2019 | 0000 | 15.1 | 67.9 | 1.5 | 1002 | 25 | 04 | D |
| | 0300 | 15.2 | 67.5 | 1.5 | 1002 | 25 | 04 | D |
| | 0600 | 15.4 | 67.2 | 1.5 | 1004 | 20 | 02 | D |
| | 1200 | Weakened into a Well Marked Low Pressure Area over east central Arabian Sea | | | | | | |

2. Brief life history:

2.1. Genesis:

An LPA formed over Lakshadweep area and adjoining southeast Arabian Sea in the morning of 1st December. The sea surface temperature was 27°C-28°C over Comorin, Lakshadweep and southeast Arabian Sea. Tropical cyclone heat potential was 80-100 KJ/cm² over the region. The Madden Julian Oscillation (MJO) lay in

phase 1 with amplitude close to 1. The low level relative vorticity was $50-60 \times 10^{-6} \text{ sec}^{-1}$ around the system area. Positive vorticity was extending upto 500 hPa level. The lower level convergence was about $10 - 20 \times 10^{-5} \text{ s}^{-1}$ and the upper level divergence was about $30 \times 10^{-5} \text{ s}^{-1}$ over Lakshadweep area. The vertical wind shear was low to moderate (10-20 knots) over the system area. The upper tropospheric ridge ran along 18°N . These favourable conditions ensued and the system lay as a WML over southeast AS and adjoining areas of eastcentral AS & Lakshadweep in the morning (0300 UTC) of 3rd.

At 1800 UTC of 3rd, similar MJO conditions prevailed. The sea surface temperature was $27^{\circ}\text{C}-28^{\circ}\text{C}$ over eastcentral Arabian Sea. Tropical cyclone heat potential was $80-100 \text{ KJ/cm}^2$ over the region. The low level relative vorticity further increased and was about $60-80 \times 10^{-6} \text{ sec}^{-1}$ around the system area. Positive vorticity was extending upto 500 hPa level. The lower level convergence was about $10 \times 10^{-5} \text{ s}^{-1}$ and the upper level divergence increased and was about $40 \times 10^{-5} \text{ s}^{-1}$. The vertical wind shear was low to moderate (10-20 knots) over the system area. The upper tropospheric ridge ran along 16°N . Under these favourable conditions the system developed into a depression over eastcentral AS and adjoining areas of southeast AS & Lakshadweep near $12.7^{\circ}\text{N}/71.0^{\circ}\text{E}$ in the midnight (1800 UTC) of 3rd December.

2.2. Intensification and movement:

At 0000 UTC of 4th, the MJO lay in phase 1 with amplitude close to 1. Similar Sea conditions prevailed. However, tropical cyclone heat potential was decreasing along the forecast track. The total precipitable water imagery indicated warm air advection into the system centre. The low level relative vorticity further increased and was about $150-200 \times 10^{-6} \text{ sec}^{-1}$ to the south of the system centre. Positive vorticity was extending upto 200 hPa level. The lower level convergence was about $20-30 \times 10^{-5} \text{ s}^{-1}$ and the upper level divergence was about $20 \times 10^{-5} \text{ s}^{-1}$ to the northwest of system centre. The vertical wind shear increased and was moderate to high (20-25 knots) over the system area. The upper tropospheric ridge ran along 13°N . Under these favourable conditions the system moved nearly northwestwards and intensified into a DD over eastcentral AS near $14.0^{\circ}\text{N}/70.0^{\circ}\text{E}$ in the early morning (0000 UTC) of 4th December.

At 1800 UTC of 4th, the MJO lay in phase 2 with amplitude more than 1. Similar Sea conditions prevailed. However, tropical cyclone heat potential was decreasing along the forecast track. The total precipitable water imagery indicated warm air advection into the system centre. The low level relative vorticity decreased and was about $100 \times 10^{-6} \text{ sec}^{-1}$ to the southeast of the system centre. Positive vorticity was extending upto 200 hPa level. The lower level convergence decreased and was about $10 \times 10^{-5} \text{ s}^{-1}$ to the southeast of system centre. 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 ran along 13°N . Increasing vertical wind shear and decreased vorticity, convergence and divergence led to weakening of the system over eastcentral AS near $15.0^{\circ}\text{N}/68.0^{\circ}\text{E}$ in the midnight (1800 UTC) of 4th December.

The unfavourable environment further ensued. At 0000 UTC of 5th, similar Sea and MJO conditions prevailed. However, tropical cyclone heat potential was decreasing along the forecast track. The low level relative vorticity further decreased and was about $50 \times 10^{-6} \text{ sec}^{-1}$ to the southeast of the system centre. Positive vorticity

was extending upto 200 hPa level. The lower level convergence was $10 \times 10^{-5} \text{s}^{-1}$ to the southeast of system centre. The upper level divergence decreased and was about $5 \times 10^{-5} \text{s}^{-1}$ to the southeast of system centre. The vertical wind shear was moderate to high (20-25 knots) over the system area. The upper tropospheric ridge ran along 13°N . The system thus lay in an unfavourable environment as a depression over eastcentral AS near $15.1^\circ\text{N}/67.9^\circ\text{E}$ in the early morning (0000 UTC) of 5th December and weakened into a WML over the eastcentral AS in the evening (1200 UTC) of 5th December.

3. Monitoring and Prediction:

India Meteorological Department (IMD) maintained round the clock watch over the north Indian Ocean and the cyclone was monitored since 2nd December, on development of LPA over Lakshadweep area and adjoining southeast Arabian Sea. The cyclone was monitored mainly 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 products generation. Typical satellite imageries are presented in Fig.2.

3.1. Feature observed through Satellites

At 1800 UTC of 03rd December, the current intensity of the system was T1.5. Broken to low and medium clouds with embedded intense to very intense convection lay over southeast Arabian Sea and adjoining Lakshadweep area between lat 11.5N & 15.0N and long 68.5E & 72.0E . Minimum cloud top temperature (CTT) was -93°C .

At 0000 UTC of 04th, the clouds further organized and the intensity of the system was T2.0. Broken low and medium clouds with embedded intense to very intense convection lay over eastcentral Arabian Sea between lat 11.5N & 16.0N and longitude 68.5E & 72.0E . Minimum CTT was minus -92°C .

At 1800 UTC of 04th, the clouds got disorganized under the influence of high wind shear. The current intensity of the system was C.I.1.5. Broken low and medium clouds with embedded intense to very intense convection lay over eastcentral Arabian Sea between lat 11.5N & 16.0N & long 68.0E & 72.0E . Minimum CTT was minus -83°C .

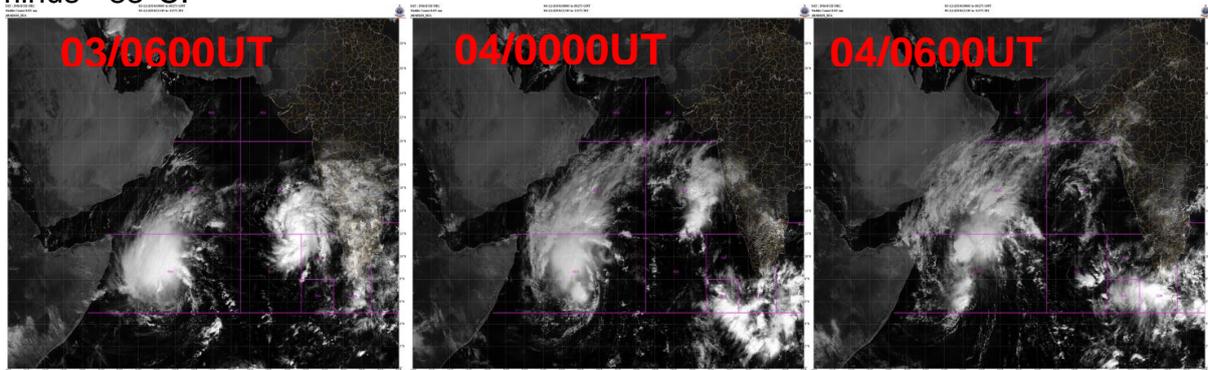


Fig. 2(i): INSAT-3D visible imageries during 3-5 December 2019

At 0000 UTC of 05th, the intensity of the system was T1.5. Broken low and medium clouds with embedded intense to very intense convection lay over eastcentral Arabian Sea between lat 10.5N & 14.0N and long 68.0E to 71.0E. Minimum CTT was minus - 58°C.

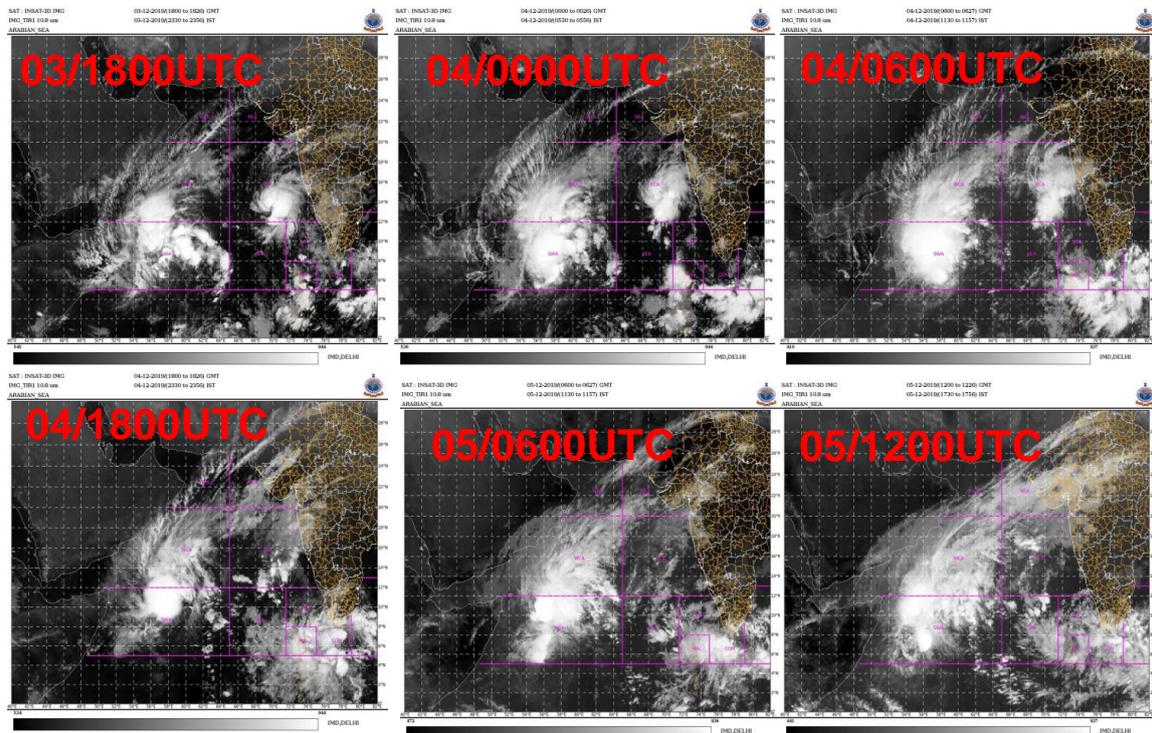


Fig. 2(ii): INSAT-3D IR imagerys during 3-5 December 2019

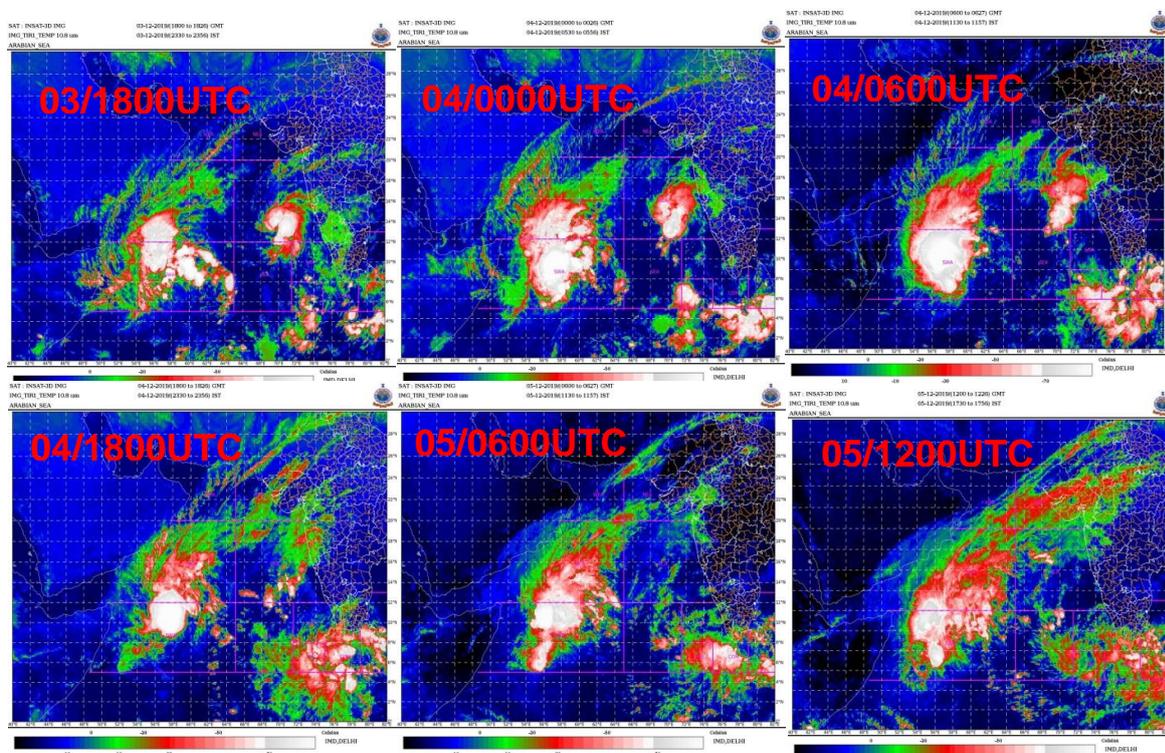


Fig. 2(iii): INSAT-3D enhanced colored imagerys during 3-5 December 2019

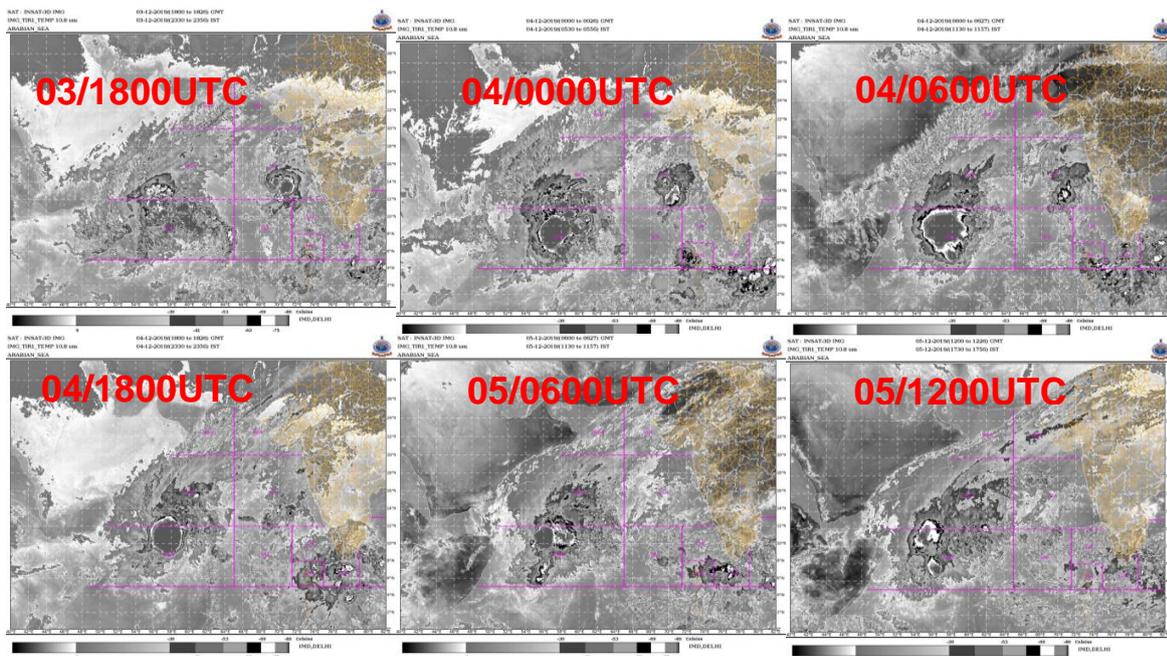


Fig. 2(iv): INSAT-3D BD curve imageries during 3-5 December 2019

4. Dynamical features

IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10 m, 850, 500 and 200 hPa levels are presented in Fig.4. At 0000 UTC of 3rd December, it indicated a low pressure area over westcentral Arabian Sea. The circulation was seen upto 500 hPa level.

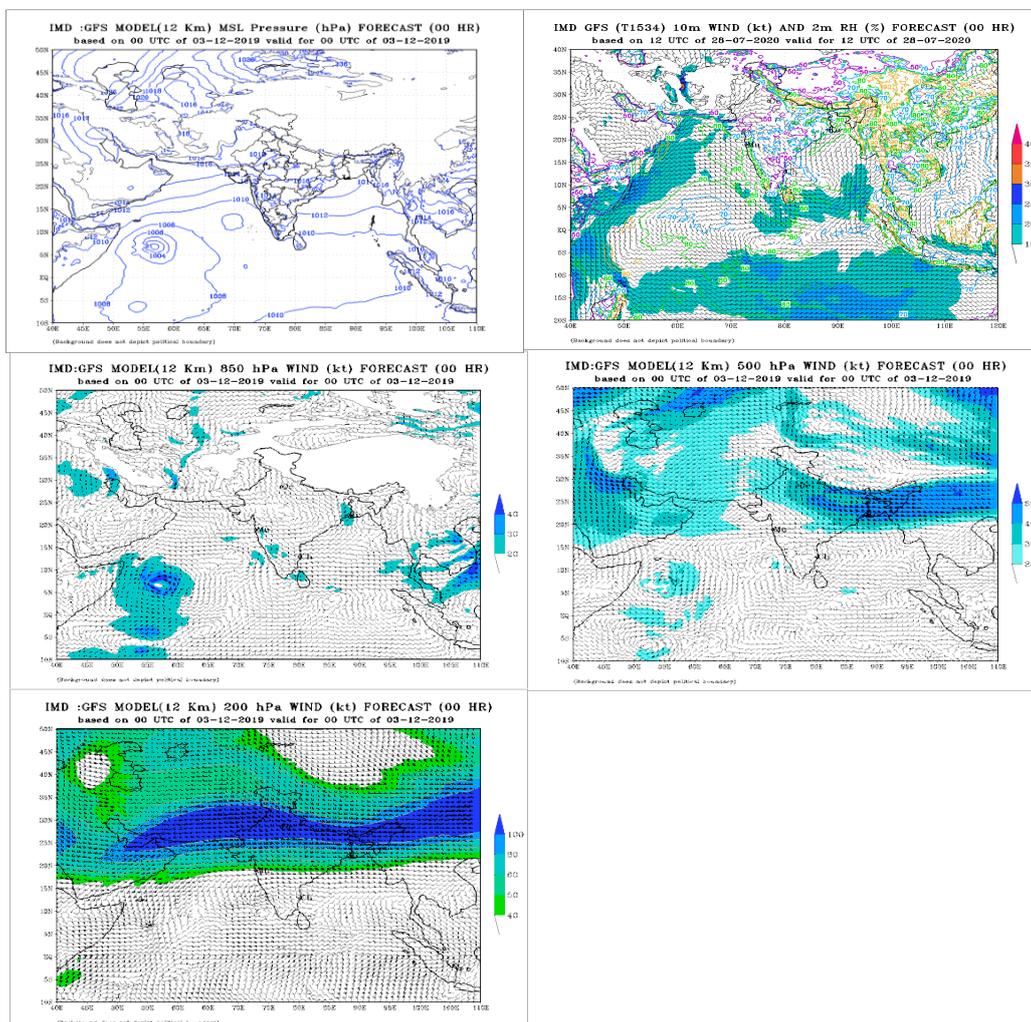


Fig4 (i): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 3rd December 2019

At 0000 UTC of 4th December, it indicated intensification of the system into a depression over east central Arabian Sea. The circulation was seen upto 500 hPa level. The ridge was seen near 14⁰N. Actually, the system lay as a DD over east central AS.

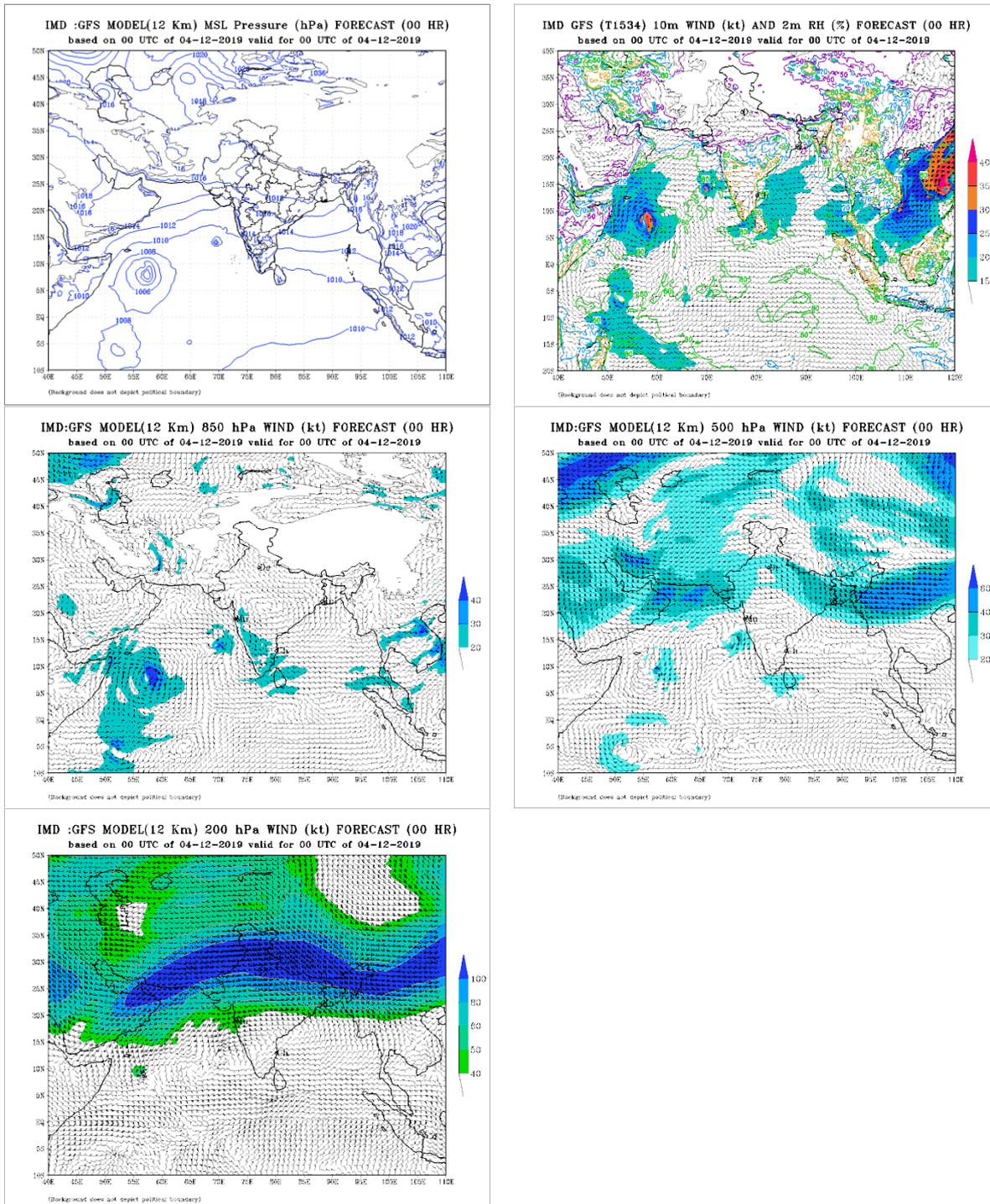


Fig4 (ii): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 4th December 2019

At 0000 UTC of 5th December, it indicated weakening of the system into a WML. Actually, the system lay as a depression over eastcentral AS.

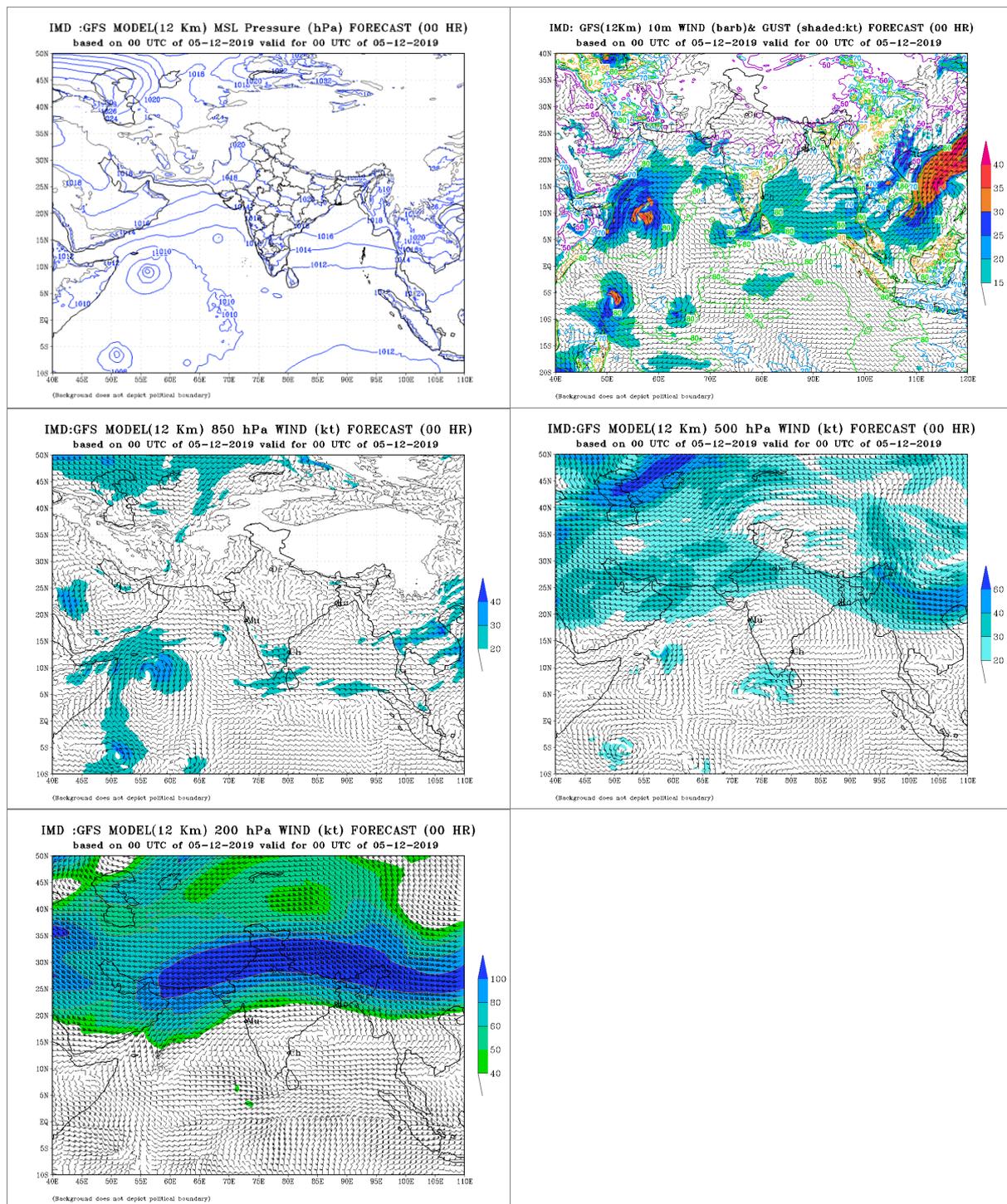


Fig4 (iii): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 5th December 2019
Thus IMD GFS could not capture the genesis, intensification and weakening of the system correctly. However, the location and movement was correctly picked up.

4. Realized Weather:

4.1 Rainfall: The system didn't affect any of the states along the west coast of India. No heavy rainfall warning was issued for any of the coastal states.

5. Bulletins issued by IMD

IMD issued regular bulletins to National & State Disaster Management Agencies, general public and media along the west coast of India including Kerala, Karnataka, Goa, Maharashtra, Gujarat and Lakshadweep Islands with respect to state of Sea and fishermen warning. Regular Bulletins at every six hourly interval were issued since formation of low pressure area over southeast Arabian Sea and adjoining Lakshadweep area. In addition, RSMC New Delhi also issued Press Release and SMS for media and registered users.

5.1. 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 | 17 | 1. IMD's website, RSMC Website 2. FAX and e-mail to Ministry of Home Affairs, Control Room NDMA, Cabinet Secretariat, Minister of Sc. & Tech, Secretary MoES, DST, HQ Integrated Defense Staff AND CDS, PIB MoES, UNI, DG Doordarshan, All India Radio, DG-NDRF, Director Indian Railways, Indian Navy, IAF, Chief Secretary: Kerala, Karnataka ,Goa, Maharashtra, Gujarat, Administrator: Lakshadweep Islands, Daman & Diu, Dadra Nagar Haveli |
| 2 | RSMC Bulletin | 17 | 1. IMD's website ,RSMC Website 2. All WMO/ESCAP member countries through GTS and E-mail. 3. Indian Navy, IAF by E-mail |
| 3 | Press Release | 3 | 1. Disaster Managers, Media persons by email and uploaded on website |
| 4 | Facebook /Twitter | 17 times | Highlights uploaded on Face book/twitter since formation of Low pressure Area. |
| 5 | SMS | 55000 | To concerned states and related agencies |

6. Operational Forecast Performance

- The first information regarding formation of low pressure area over Southeast Arabian Sea & adjoining Lakshadweep area during next 48 hours with low (1-25%) probability of formation of depression during subsequent 48 hours was issued by RSMC New Delhi in its Tropical Weather Outlook (TWO) issued at 0600 UTC of 30th November (21 hours in advance of formation of LPA). The low pressure area formed over northwest BoB and neighbourhood at 0300 UTC of 1st December and depression formed over eastcentral AS and adjoining areas of southeast AS & Lakshadweep at 1800 UTC of 3rd December.
- The information was further updated in the TWO issued at 0600 UTC of 1st December that it will become more marked during next 24 hours with low probability (0-25%) of formation of Depression.
- In the first bulletin issued on 3rd evening (1800 UTC), it was predicted that depression would move northwestwards. It intensified into a deep depression (DD) in the early morning (0000 UTC) of 04th December over the eastcentral AS & Lakshadweep area. It entered into unfavourable environment and weakened into a depression in the early morning (0300 UTC) of the 5th December, 2019 over eastcentral Arabian Sea. It further weakened into a well marked low pressure area over the same region in the evening (1200 UTC) of 05th December 2019

IMD issued regular warning bulletins to the concerned central and state disaster management authorities and press & media.

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, (IITM) Pune, National Institute of Technology (NIOT) Chennai & Indian National Centre for Ocean Information Services (INCOIS). The support from various Divisions/Sections of IMD including Area Cyclone Warning Centre Chennai & Mumbai, Cyclone Warning Centre Thiruvananthapuram, Ahmedabad, Meteorological Centre Goa, Numerical Weather Prediction (NWP) Division, Information System & Services Division (ISSD) and Satellite and Radar Division at IMD HQ New Delhi is also duly acknowledged for monitoring and predicting the system.
