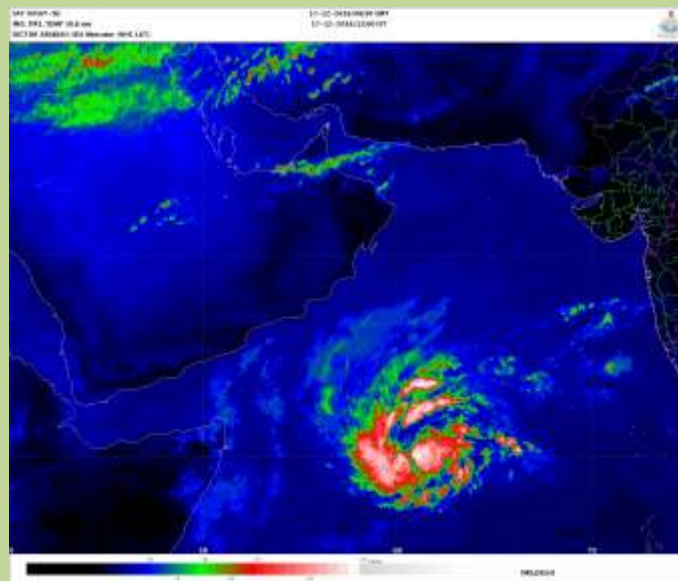**GOVERNMENT OF INDIA**
MINISTRY OF EARTH SCIENCES
INDIA METEOROLOGICAL DEPARTMENT

Depression over the Arabian Sea
(17-18 December 2016): A Report

INSAT-3D enhanced colored IR imagery

Cyclone Warning Division

India Meteorological Department

New Delhi

December 2016

Depression over the Arabian Sea
(17-18 December 2016)

1. Introduction

The remnant of the very severe cyclonic storm (VSCS), Vardah (06-13 Nov. 2016), which crossed Tamil Nadu coast near Chennai on 12th December 2016 emerged into southeast Arabian Sea as a low pressure area on 14th December. It moved gradually westwards and became well marked over southeast and adjoining southwest Arabian Sea on 16th December. It concentrated into a depression (D) and lay centered at 0300 UTC of 17th over southwest Arabian Sea near latitude 11.0^0N and longitude 62.5^0E. It moved west-southwestwards and lay over southwest Arabian Sea near latitude 09.4^0N and longitude 56.8^0E at 0300 UTC of 18th December 2016. Under the influence of the unfavourable environmental conditions like colder sea surface temperature (SST) and Ocean thermal energy over the southwest Arabian Sea, it weakened into a well marked low pressure area at 0900 UTC of 18th December 2016. The salient features of the system are as follows.

(i) It was the only cyclonic disturbance over the Arabian Sea during the post-monsoon season of 2016. Thus the cyclonic activity over the Arabian Sea has been below normal during post-monsoon season, 2016.

(ii) It developed from the remnant of the VSCS, Vardah over the Bay of Bengal

(iii) It moved west-southwestwards and dissipated over the sea

Brief life history, characteristic features and associated weather along with performance of NWP and operational forecast of IMD are presented and discussed in following sections.

2. Monitoring of Depression

The depression was monitored & predicted continuously since its inception by IMD. The best track parameters of the systems are presented in Table 1. The track of the system is presented in Fig.1. Throughout its life cycle, the system was monitored mainly with satellite, buoys and ships coastal observations. Various national and international NWP models and dynamical-statistical models including IMD's and NCMRWF's global and meso-scale models, dynamical statistical models for genesis and intensity were utilized to predict the genesis, track and intensity of the system.

3. Brief life history
3.1. Genesis

The remnant of the very severe cyclonic storm (VSCS), Vardah (06-13 Nov. 2016), which crossed Tamil Nadu coast near Chennai on 12th December 2016 emerged into southeast Arabian Sea as a low pressure area on 14th December. It moved gradually westwards and became well marked over southeast and adjoining southwest Arabian Sea on 16th December. It concentrated into a depression (D) and lay centered at 0300 UTC of 17th over southwest Arabian Sea near latitude 11.0^0N and longitude 62.5^0E.

On 16th and 17th December, the large scale dynamical and thermodynamical features became gradually favourable. At 0300 UTC of 17th, the vertical wind shear was 15-20 kts (moderate), upper level divergence was $(5\text{-}10)\times10^{-5}$ s^{-1}, lower level convergence was $(5\text{-}10)\times10^{-5}$ s^{-1} and relative vorticity at 850 hPa was around 80×10^{-6} s^{-1}. Sea surface temperature was 26-28^{0}C. The ocean thermal energy was about 60- 80 KJ/cm^2 around the system centre over central BOB. According to satellite imagery, a low level cyclonic circulation lay over southeast Arabian Sea on 14th and 15th Dec. and it became a vortex with T1.0 at 1200 UTC of 16th Dec. 2016 over the southeast Arabian Sea. The associated convection gradually organized on 17th. Broken low/medium clouds with embedded intense to very intense convectioin lay over Arabian Sea between latitude 8.5^{0}N to 12.5^{0}N and longitude 58.5^{0}E to longitude 64.5^{0}E at 0300 UTC of 17th. Intensity of system was T 1.5. The convection showed banding pattern at the time of genesis, covering 0.3 in logarithmic spiral. The lowest cloud top temperature was about -85^0 C. The estimated central pressure was 1006 hPa and maximum sustained wind speed of 25 knots.

3.2. Intensification and movement

The upper tropospheric ridge ran along latitude 16^{0}N At 0300 UTC of 17th. Hence the depression centre lay far to the south of the ridge and was thus steered initially westwards and then west-southwestwards. The west-southwestward movement was mainly triggered by the anti-cyclonic circulation lying to the northwest of the system centre over the Arabia-Africa. As the system moves west-southwestwards, it experienced colder water and lower Ocean thermal energy leading to weakening of the system into a well marked low pressure area at 0600 UTC of 18th December. Under the above mentioned anti-cyclonic circulation, there was also intrusion of dry and cold air to the core of depression, which helped in weakening of the system.
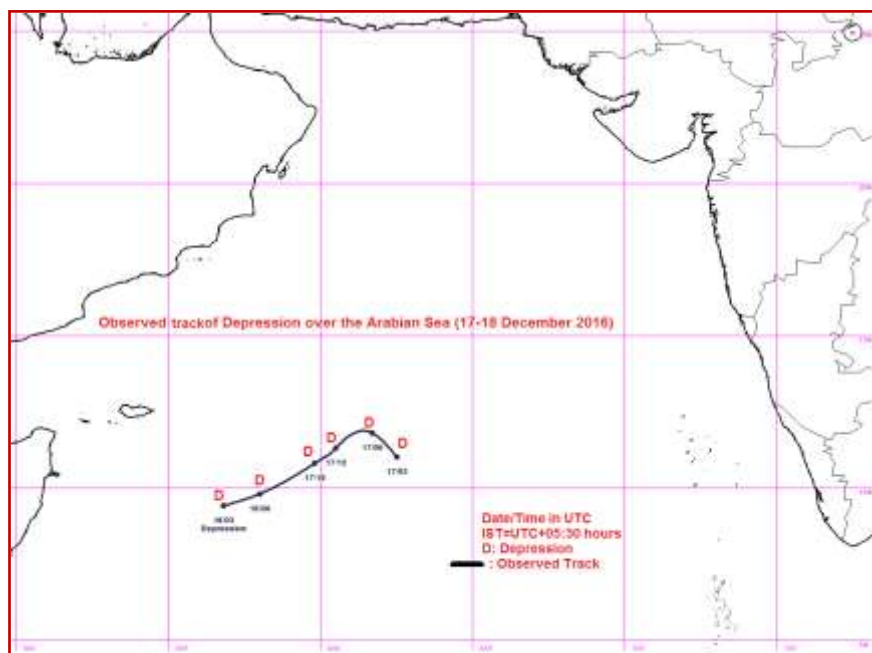

**Fig.1 Observed track of depression over BoB during 02-06 October 2016**

Table 1: Best track positions and other parameters of the depression over the Arabian Sea (17th-18th December 2016)

| Date	Time (UTC)	Centre lat.^{0} N/ long. ^{0} E	CI No.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind(kt)	Estimated Pressure drop at the Centre (hPa)	Grade
17th Dec.	0300	11.0 / 62.5	1.5	998	25	3	D
	0600	11.8/61.7	1.5	998	25	3	D
	1200	11.3/ 60.5	1.5	998	25	3	D
	1800	10.8/59.8	1.5	998	25	3	D
18th Dec.	0000	9.8/58.0	1.5	996	25	3	D
	0300	9.4/56.8	1.5	994	20	3	D
	0600	weakened into a well marked low pressure area over southwest Arabian Sea					

The best track parameters are shown in Table 1. The best track of the system is shown in Fig.1. Typical INSAT 3D imageries are presented in Fig.2. The water vapour imageries in association with the system are presented in Fig. 3 respectively.
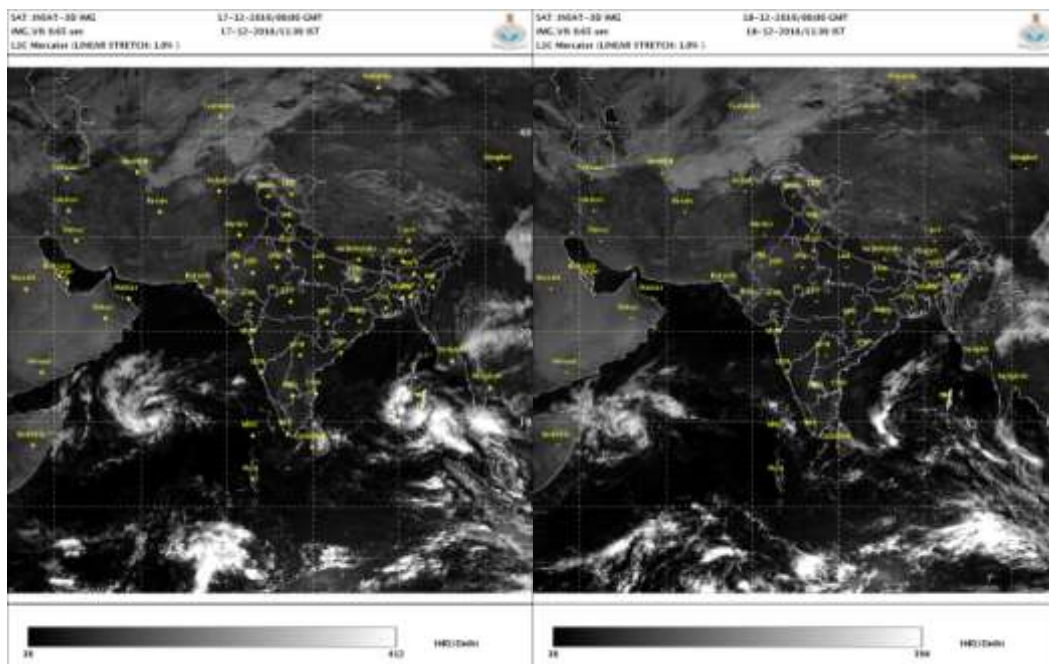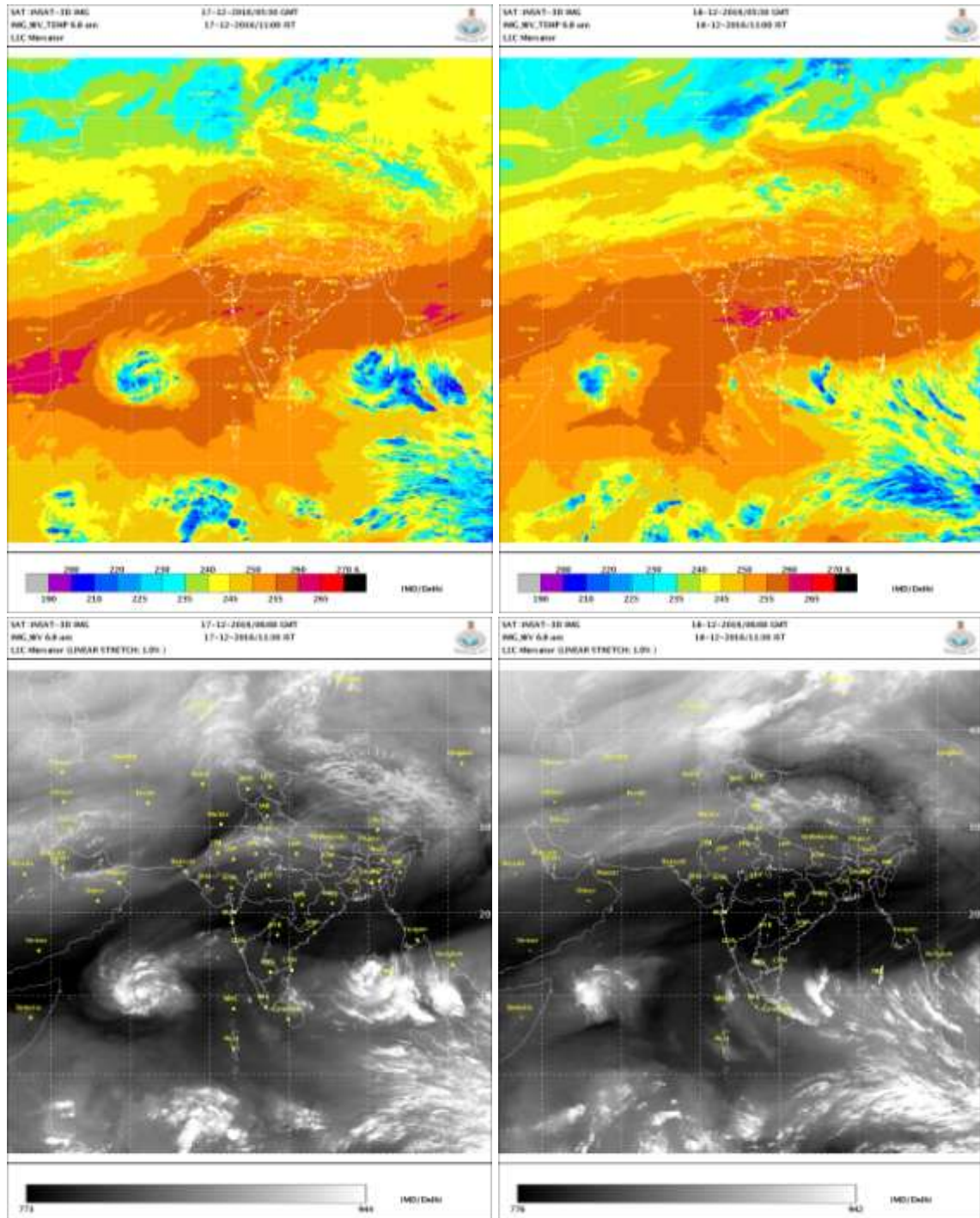

Fig.2a: Typical INSAT-3D visible imageries at 0600 UTC of 17-18 Dec. 2016
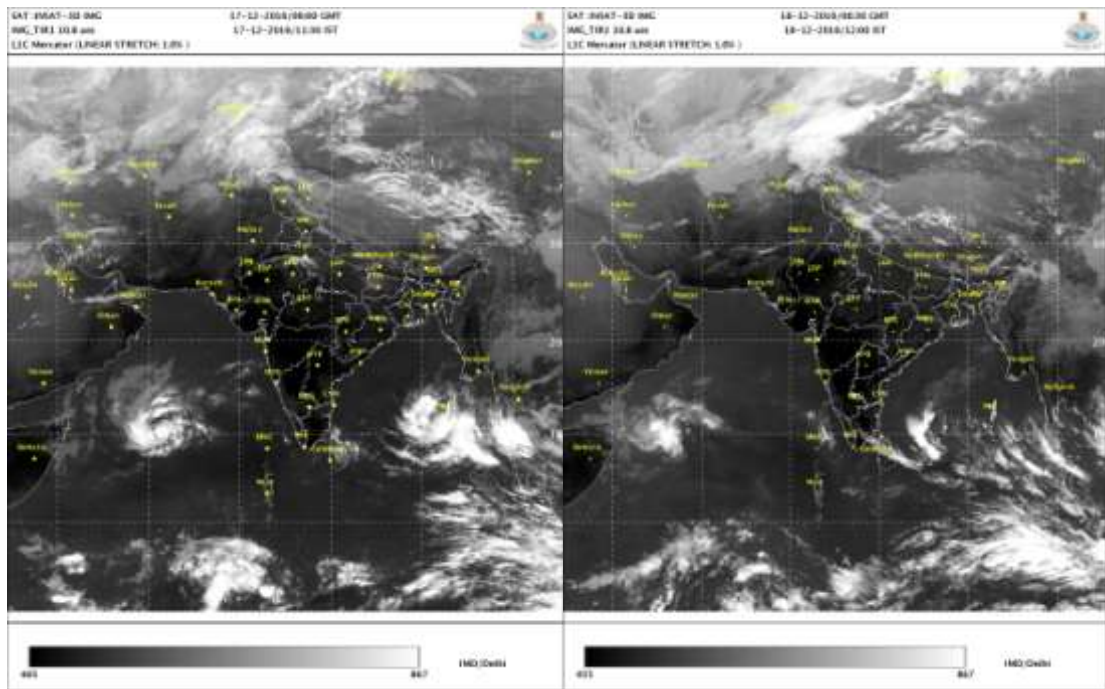
Fig.2b: Typical INSAT-3D visible imageries at 0300 UTC of 02-06 Nov 2016

17 Dec/0630UTC

18 Dec/0530UTC

Depression
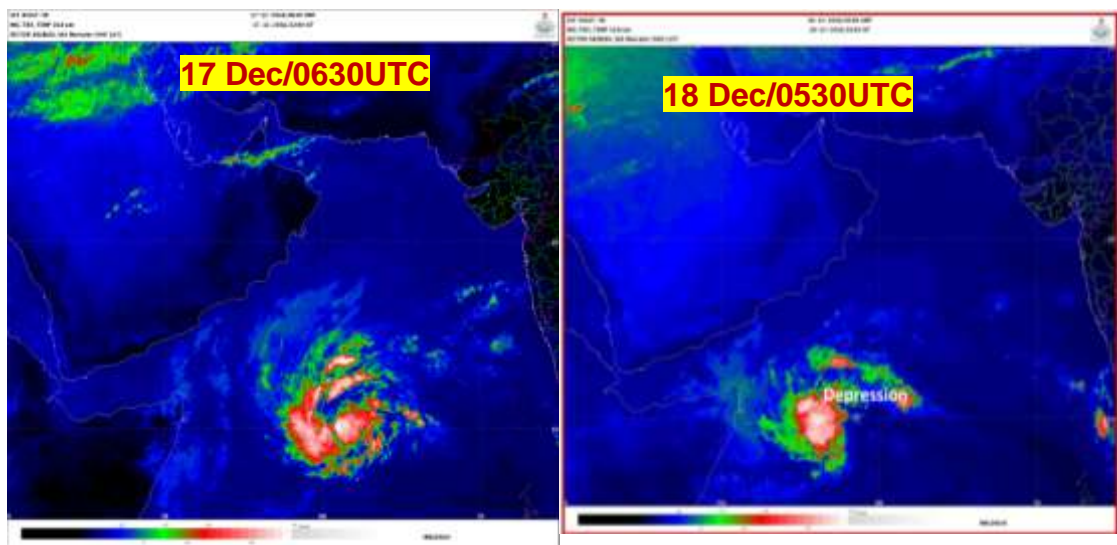
**Fig.2c: Typical INSAT-3D enhanced colored imageries during 02-06 Nov 2016**

**Fig.3: Water Vapour and brightness temperature Imageries at 0600 UTC of 17-18 December 2016**

4. Climatological aspects

Considering the area of genesis (+/- 2^0 around the genesis point), the cliamtological tracks of the cyclonic disturbances during 1891-2015 are presented in Fig.4. It indicates that climatologically, most of the tdisturbances moved west-northwestwards or

northwestwards. However, there were three disturbances that moved northeastwards. Out of nine systems, five have developed into cyclonic storms or higher intensity.
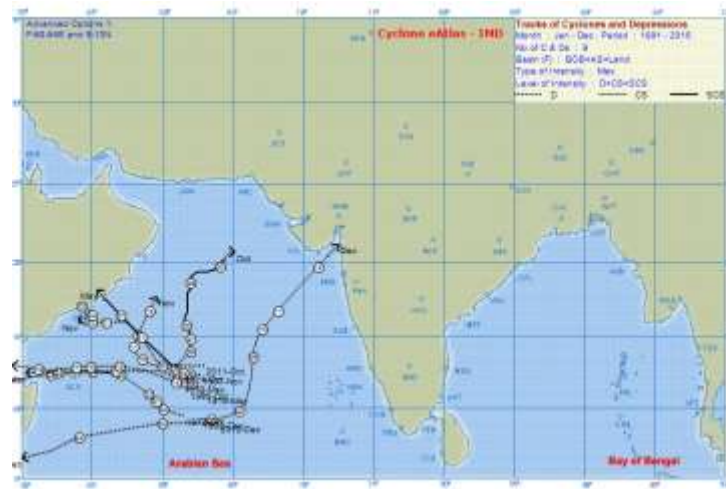
Fig.4. Climatological tracks of cyclonic disturbances formed within +/- 2^0 around the genesis point during 1891-2015.
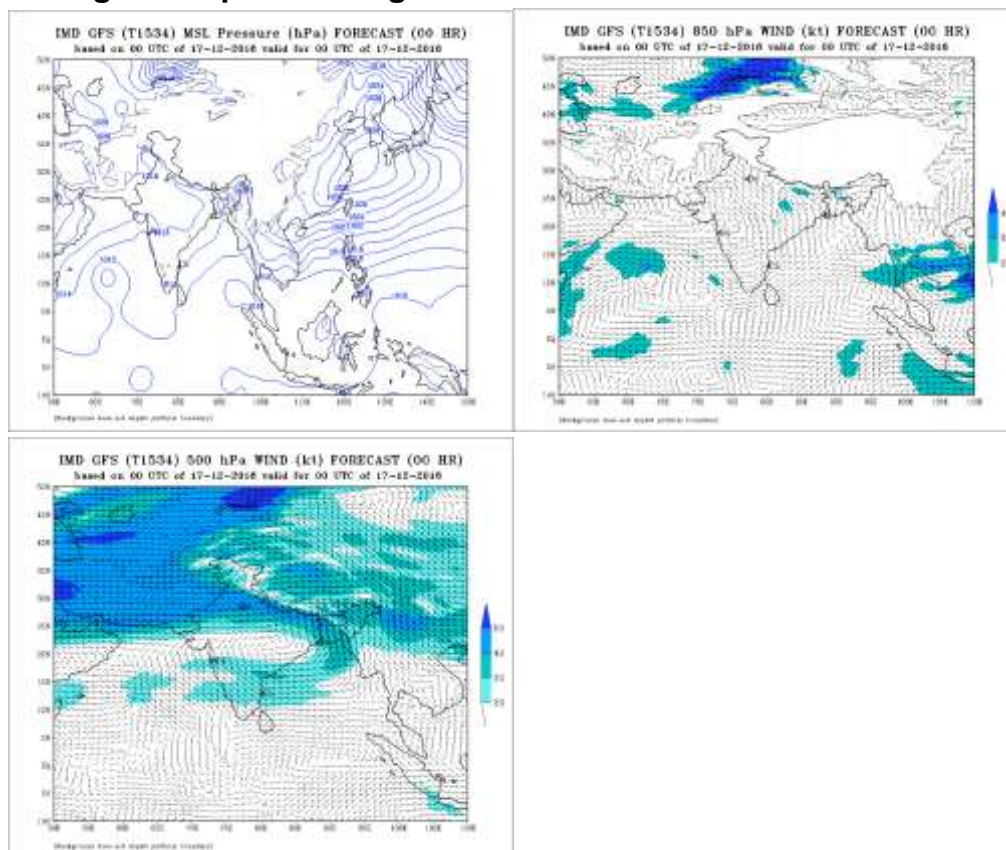
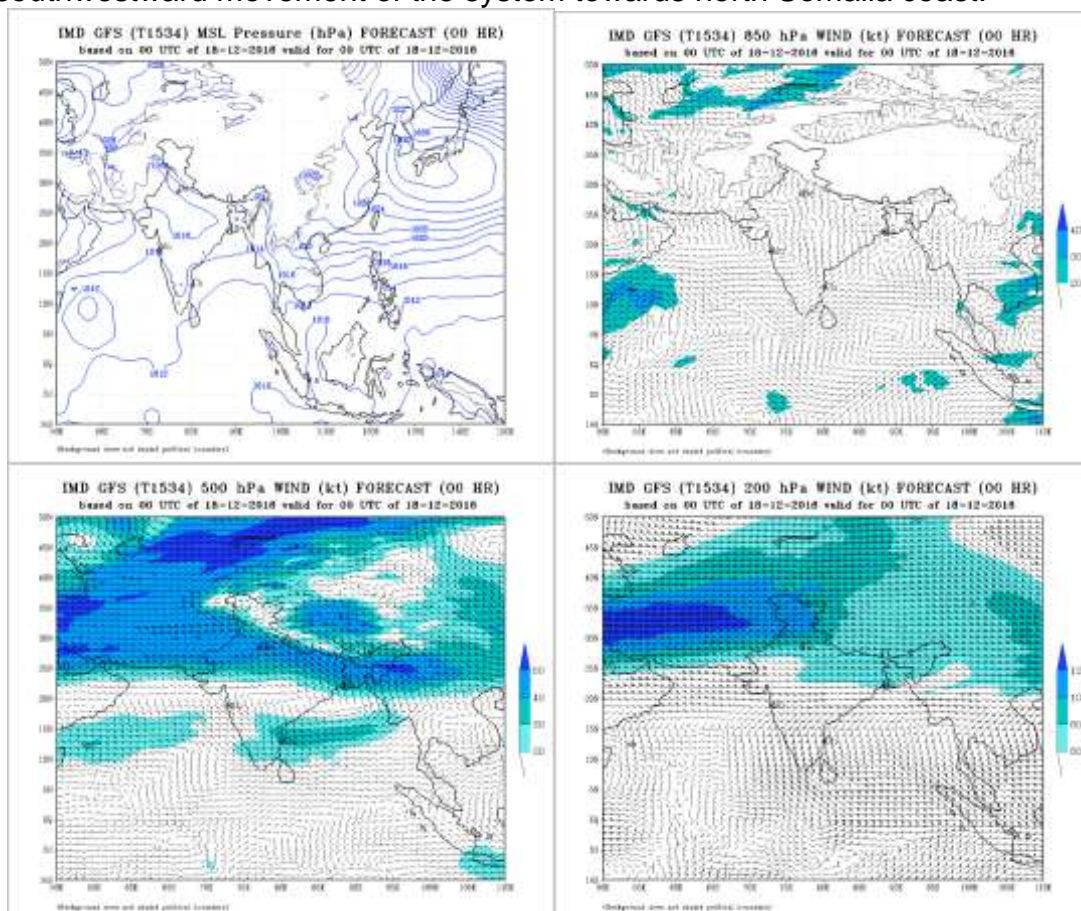**Fig. 5a: IMD GFS (1534) analysis of MSLP and winds at 850 and 500 hPa levels based on 0000 UTC of 17th December 2016.**

4. Dynamical features

IMD GFS (T1534) mean sea level pressure (MSLP), winds at 850, 500 and 200 hPa levels are presented in Fig.5. IMD GFS analysis could detect the formation of low pressure system with underestimation of intensity. Also it could detect higher wind in the

northern sector under the influence of the northeast monsoon condition. It also detected west-southwestward movement of the system towards north Somalia coast.

Fig. 5b: IMD GFS (1534) analysis of MSLP and winds at 850, 500 and 200 hPa levels based on 0000 UTC of 18th December 2016.

5. Realized Weather:

There was no adverse weather along west coast of India and Lakshadweep area as the depression formed over southwest Arabian Sea and moved west-southwestwards towards Somalia coast. No adverse weather has also been report by Yemen and Somalia due to this system.

6. Damage due to system

No damage has been reported due to this system

7. Performance of operational NWP models

7.1. Prediction of cyclogenesis (Genesis Potential Parameter (GPP)) for the system

Figure 6 shows the zone of cyclogenesis based on MD-GFS model. Grid point analysis and forecasts of GPP indicate the formation of cyclone over Arabian Sea on 17th against the formation of depression Hence, it showed over estimation of intensity. The GPP forecast fields shows a significant zone of GPP over northern parts of SE and adjoining SE Arabian Sea on 17th analysis, which moving in a westward direction is seen over SW Arabian Sea, off northern Somali coast on 19th and becomes less marked on 20th.
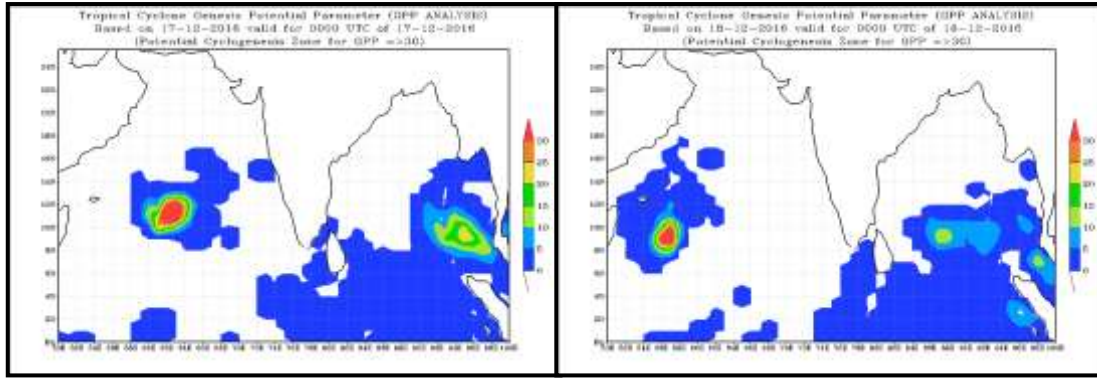
Fig.6. Zone of cyclogenesis based on 0000 UTC of 17 and 18 Dec. 2016

7.2. Prediction of track and intensity by models

IMD-GFS T1534: The forecast based on analysis of 00UTC on 17th December indicates the depression area over EC Arabian Sea moves in a WSW direction till 18th and is seen near north Somali coast on 19th as a low. It becomes less marked on 20th.

NCEP-GFS: The analysis on 17th and forecast fields show a depression over EC Arabian Sea which moving in a west-southwestward direction becomes low on 18th. It is seen off Somali coast on 19th and becomes less marked on 20th.

ECMWF: The analysis on 17th and forecast fields show a depression over EC Arabian Sea on 18th which is seen moving in a west-southwestward direction. It is seen off north Somali coast on 19th as a low and becomes less marked on 20th

Meteo-France ARP Model: The forecast based on 17th 00UTC analysis shows that the well marked low in the analysis field is seen moving in a south-westward direction and is seen off north Somali coast on 19th. It becomes less marked on 20th.

JMA: The analysis field on 17th shows a low over northern parts of SW Arabian Sea, which moves west-southwestwards till 18th and becomes less marked on 19th over the sea.

NCUM: The analysis on 17th indicates the low pressure system over SE Arabian Sea which moving in a west-southwestward direction becomes weaker on 18th and becomes less marked on 19th over northern parts of Somali coast.

NCMRWF- NEPS: The analysis on 17th show a depression over SE Arabian Sea which moving a west-southwestward direction is seen as a low on 19th northern parts of Somali coast, which becomes less marked on 20th.

IITM GEFS: The forecast based on 17th December analysis shows a low pressure area over northern parts of SW Arabian Sea and adjoining SE Arabian Sea on 18th which moving in a WSW direction is seen off the coast of north Somali on 19th and becomes less marked thereafter.

Most of the models indicated that the depression over SE Arabian Sea would take a west-southwestward movement towards north Somali coast by 19th December without significant intensification over Arabian Sea. The environmental parameters were indicating weakening trend as the system approaches the coast on 18th onwards, mainly due to colder sea and intrusion of dry and cold air from northwest.

8. Operational Forecast Performance

IMD successfully predicted its genesis on 17th Dec. 2016 over Arabian Sea from the remnant of VSCS, Vardah. It also could predict its westward movement towards north Somalia coast from the first bulletin itself issued in connection with formation of depression. However, contrary to the prediction of possible intensification into a deep depression in the

bulletin issued in the morning of 17th, the system maintained its intensity of depression throughout.

9. Bulletins issued by IMD

IMD continuously monitored, predicted and issued bulletins giving track positions based on 00, 03, 12 and 18 UTC observations till the system weakened into a low pressure area. The prognostics and diagnostics of the systems were described in the RSMC bulletins.

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

SN	Bulletin	No. of Bulletins	Issued to
1	National Bulletin	03	1. IMD's website 2. FAX and e-mail to Control Room NDM, Cabinet Secretariat, Minister of Sc. & Tech, Secretary MoES, DST, HQ Integrated Defence Staff, DG Doordarshan, All India Radio, DG-NDRF, Indian Navy, IAF.
2	RSMC Bulletin	04	1. IMD's website 2. WMO/ESCAP Panel countries through GTS & e-mail. 3. Indian Navy, IAF by E-mail

Bulletins were also issued by Area Cyclone Warning Centre, Mumbai and Cyclone Warning Centre, Ahmedabad of IMD in association with the system for marine interest like sea area bulletin and port warning.

10. Summary and Conclusion:

The remnant of the very severe cyclonic storm (VSCS), Vardah (06-13 Dec. 2016), which crossed Tamil Nadu coast near Chennai on 12th December 2016 emerged into southeast Arabian Sea as a low pressure area on 14th December. It moved gradually westwards and became well marked over southeast and adjoining southwest Arabian Sea on 16th December. It concentrated into a depression (D) and lay centered at 0300 UTC of 17th over southwest Arabian Sea near latitude 11.0^0N and longitude 62.5^0E. It moved west-southwestwards and lay over southwest Arabian Sea near latitude 09.4^0N and longitude 56.8^0E at 0300 UTC of 18th December 2016. Under the influence of the unfavourable environmental conditions like colder sea surface temperature (SST) and Ocean thermal energy over the southwest Arabian Sea, it weakened into a well marked low pressure area at 0900 UTC of 18th December 2016.

IMD utilised all its resources to monitor and predict the genesis, track and intensification of the system. The forecast of its genesis (formation of Depression) on 17th Dec., its track and intensity were predicted well with sufficient lead time.

11. Acknowledgements:

RSMC New Delhi duly acknowledges the contribution of the valuable inputs and guidance from NCMRWF, INCOIS and NIOT Chennai. The inputs from Agricultural Meteorology Division, Pune, NWP Division, ISSD Division and Satellite Division at IMD HQ New Delhi and Area Cyclone Warning Centre (ACWC) Chennai and Cyclone Warning Centre (CWC) Ahmedabad are also appreciated.

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