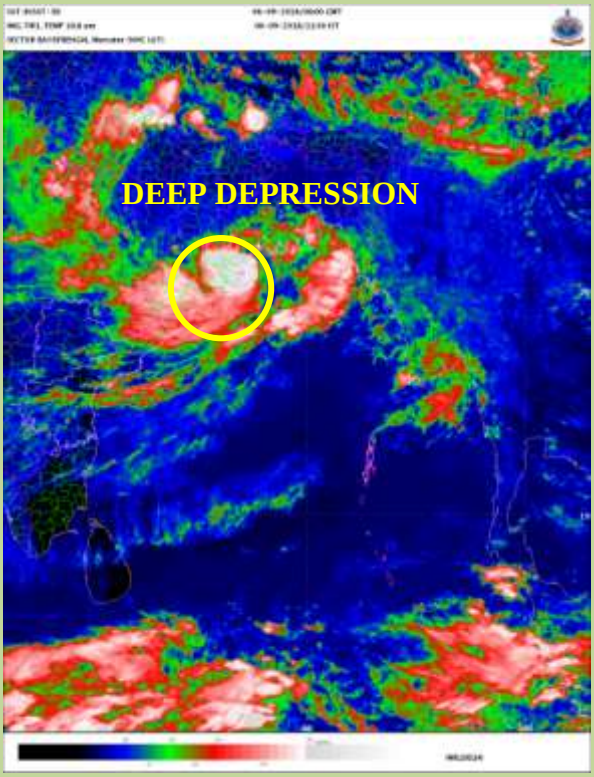
GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
INDIA METEOROLOGICAL DEPARTMENT

Deep Depression over Bay of Bengal (06-07 September, 2018): A Report



INSAT-3D enhanced coloured IR imagery based on 0600 UTC of 6th September

Cyclone Warning Division

India Meteorological Department

New Delhi

September 2018

Deep Depression over northwest Bay of Bengal and adjoining West Bengal & Odisha coasts
(06-07 September, 2018)

1. Introduction

Under the influence of a cyclonic circulation over north Bay of Bengal (BoB) and adjoining areas of Bangladesh & West Bengal coast, a low pressure area (LPA) formed over northwest BoB and neighbourhood in the early morning (0000 UTC) of 5th September. It lay as a well marked low pressure area (WML) over the same region in the evening (1200 UTC) of same day. Moving west-northwestwards, it concentrated into a depression (D) over northwest BoB and adjoining West Bengal Bangladesh coasts in the early morning (0000 UTC) of 6th. It moved slightly westwards, intensified into a deep depression (DD) over the same region in the same morning (0300 UTC) and crossed West Bengal coast close to Digha in the same forenoon during 0430-0530 UTC. It continued to move west-northwestwards and maintained it's intensity of DD for next 21 hours and weakened into a D over northwest Odisha and neighbourhood in the early morning (0000) of 7th.Thereafter, it moved northwestwards and weakened into a WML around the noon (0600 UTC) of same day over north Chattisgarh and neighbourhood. It weakened into an LPA over east Rajasthan and neighbourhood in the early morning (0000 UTC) of 9th. .

The salient features of the system were as follows:

(i) It moved initially nearly westwards till early morning (0000 UTC) of 7th and then northwestwards.
(ii) It had a life period of 30 hours (depression to depression).
(iii) Under the influence of this system and its remnant low pressure area widespread rainfall activity was observed over the northern and central parts of the country extending from Gangetic West Bengal, Odisha, Chhattisgarh, Jharkhand, Vidarbha, Madhya Pradesh, and East Rajasthan. Extremely heavy rainfall occurred over Odisha on 6th.

IMD mobilised all its resources to track the system and regular warnings w.r.t. track, intensity, landfall 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 including Bangladesh. Its genesis, movement and associated adverse weather could be predicted well by IMD

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

2. Brief life history

A cyclonic circulation extending upto 4.5 km above mean sea level lay over north BoB and adjoining areas of Bangladesh & West Bengal on 4th September, 2018. Under its influence, a low pressure area formed over northwest BoB & neighbourhood with the associated cyclonic circulation extending upto 7.6 km above mean sea level and tilting southwestwards with height on 5th September, 2018 morning. Another, cyclonic circulation at 7.6 km above mean sea level lay over westcentral BoB off south Odisha - north Andhra Pradesh coasts on 4th September, 2018. It merged with the cyclonic circulation associated with the low pressure area over northwest BoB & neighbourhood on 5th September, 2018.

It lay as a WML over the same region in the evening (1200 UTC) of 5th. At 1200 UTC of 5th. The low level relative vorticity at 850 hPa level was about 100x10^{-6} sec^{-1} over northwest BoB, was circularly organized and extended upto 500 hPa level. The wind shear was moderate about 15-20 knot (kt) over northwest BoB. It was low to moderate (10-15 kt)

along the expected direction of motion of system. The lower level convergence was about 10-15x$10^{-5}$$sec^{-1}$ over northwest & adjoining westcentral BoB. The upper level divergence was about 10 x$10^{-5}$$sec^{-1}$ over northwest and adjoining westcentral BoB.

Under these favourable conditions, the system intensified into a D at 0000 UTC of 6th. At 0000 UTC of 6th, the sea surface temperature (SST) was more than 26^0C over northwest BoB & adjoining Odisha-West Bengal coasts. The tropical cyclone heat potential was about 40-50 KJ/cm2 over north BoB to the north of 20^0N. Madden Julian Oscillation (MJO) index lay in phase 8 with amplitude equal to 1. The low level relative vorticity was about 150x$10^{-6}$$sec^{-1}$ over northwest BoB & adjoining west central BoB to the southwest of the system centre. It extended upto 500 hPa level. The lower level convergence was about 10 x$10^{-5}$$sec^{-1}$ off Odisha coast. The upper level divergence increased and was about 20x$10^{-5}$$sec^{-1}$ over south coastal Odisha to the southwest of system centre. The vertical wind shear was low to moderate (5-15 kt) over the north BoB. The mid-level wind shear was nearly easterly over north BoB. The upper tropospheric ridge lay far to the north of the system centre abd hence the easterly to east-southeasterly winds prevailed over the region in the upper troposphere. Under these conditions the system intensified into a DD at 0300 UTC of 6th and moving slightly westwards crossed West Bengal coast close to Digha during 0430-0530 UTC of 6th. Similar conditions continued and the system maintained its intensity of DD till 1800 UTC of 6th.

At 1800 UTC of 6th, the region of maximum vorticity (150x$10^{-6}$$sec^{-1}$) lay over north Odisha and it extended upto 500 hPa level. The lower level convergence decreased and was about 5x$10^{-5}$$sec^{-1}$ near system centre. The upper level divergence decreased and was about 10x$10^{-5}$$sec^{-1}$ over north Chattisgarh and adjoining Odisha. The vertical wind shear was low to moderate (5-15 kt) over the north BoB. Under these conditions, the system weakened into a D at 0000 UTC of 7th and WML at 0600 UTC of 7th. The middle to upper level winds were southeasterly. As a result the system moved northwestwards from 0000 UTC of 7th. The observed track and best track parameters of the deep depression are presented in Fig.1 and Table 1.

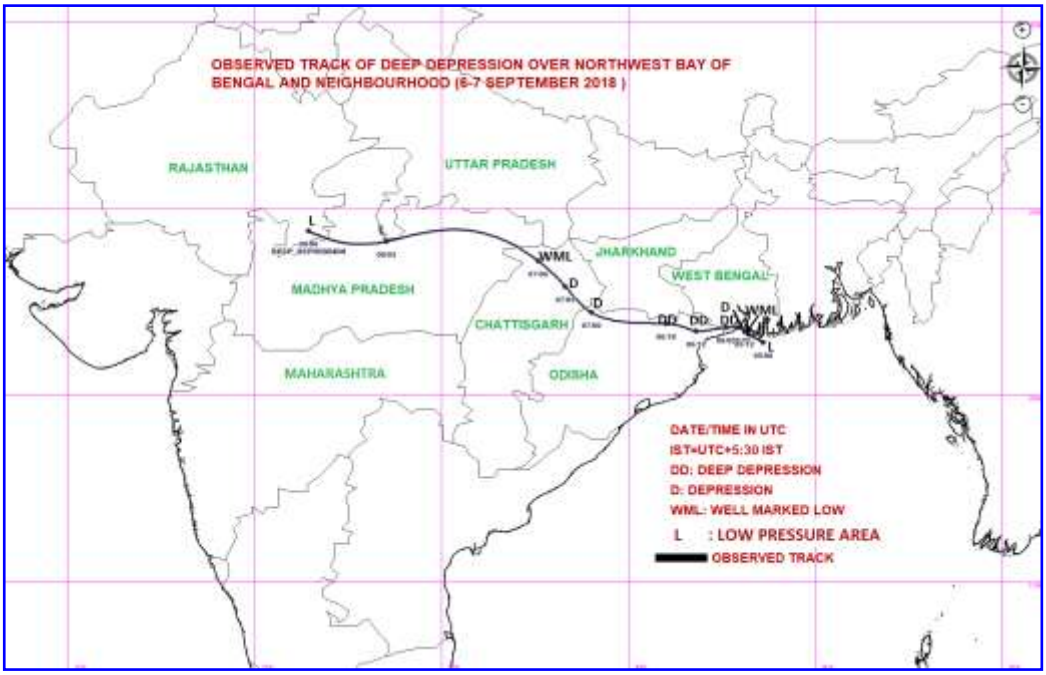


Fig.1. Observed track of Depression over northwest Bay of Bengal and neighborhood (06-07 September, 2018)

Table 1: Best track positions and other parameters of the Deep Depression over northwest BoB and adjoining West Bengal - Odisha coasts during 06-07 September, 2018

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. ^{0}N	long ^{0}E					
06/09/2018	0000	21.8	88.0	1.5		25	4	D
	0300	21.8	87.9	2.0		30	5	DD
	Crossed West Bengal coast close to Digha between during 0430-0530 UTC							
	0600	21.8	87.6	-		30	5	DD
	1200	21.7	86.8	-		30	5	DD
	1800	21.9	86.0	-		30	5	DD
07/09/2018	0000	22.2	84.0	-		25	4	D
	0300	22.9	83.3	-		20	3	D
	0600	**Weakened into a well-marked low pressure area over north Chhattisgarh & neighbourhood**						

3. Feature observed through Satellites and Radar:

Satellite monitoring of the system was mainly done by using half hourly INSAT-3D imageries. Satellite imageries of international geostationary satellites Meteosat-7 and ASCAT & SCAT Sat imageries were also considered. Typical INSAT-3D IR, visible, enhanced colored and cloud top brightness temperature imageries, ASCAT & SCAT SAT imageries are presented in Fig. 2.

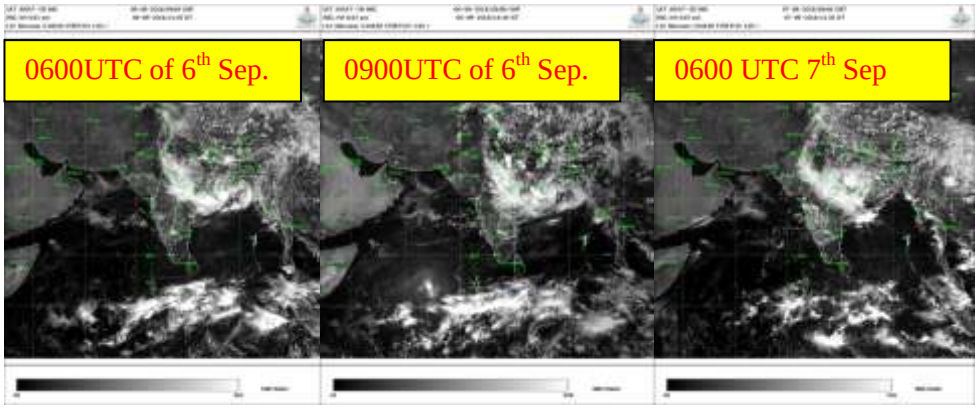


Fig. 2(i): INSAT-3D visible imageries during 6-7 September, 2018

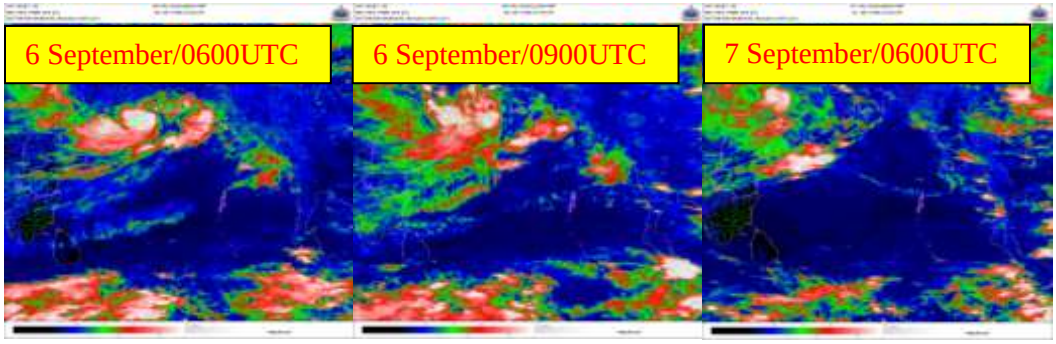


Fig. 2(ii): INSAT-3D enhanced colored imageries during 6-7 September, 2018

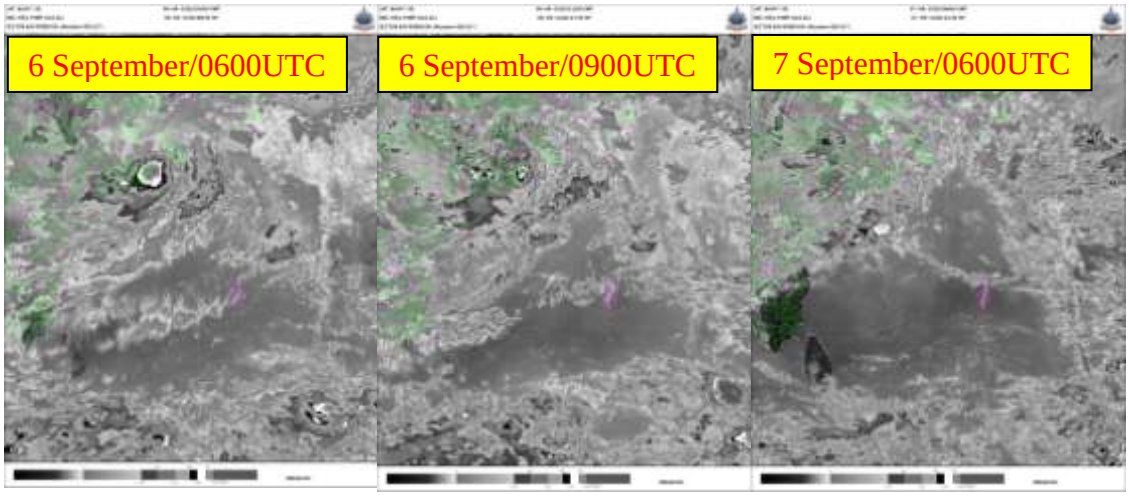


Fig. 2(iii): INSAT-3D enhanced grey scale imageries during 6-7 September, 2018

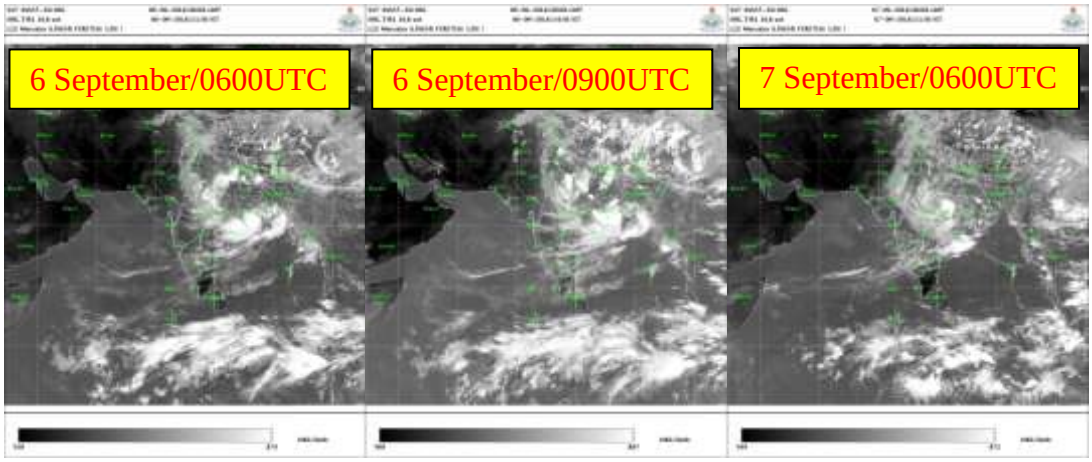


Fig. 2(iv): INSAT-3D IR imageries during 6-7 September, 2018

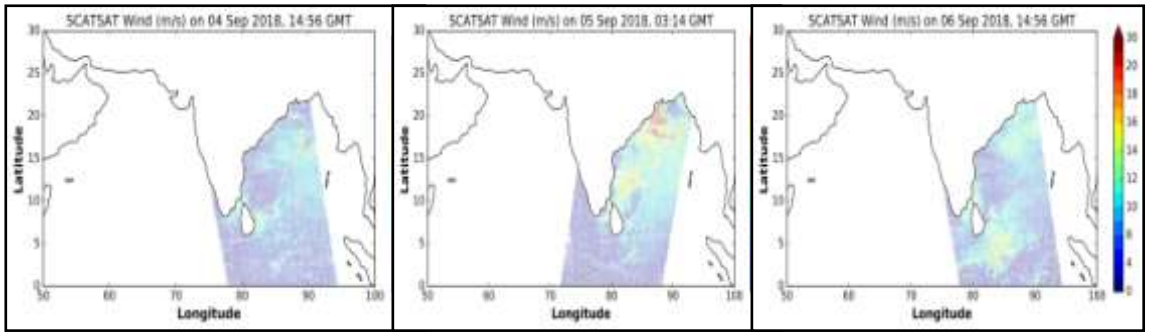


Fig. 2(v): SCAT SAT imageries during 6-7 September, 2018

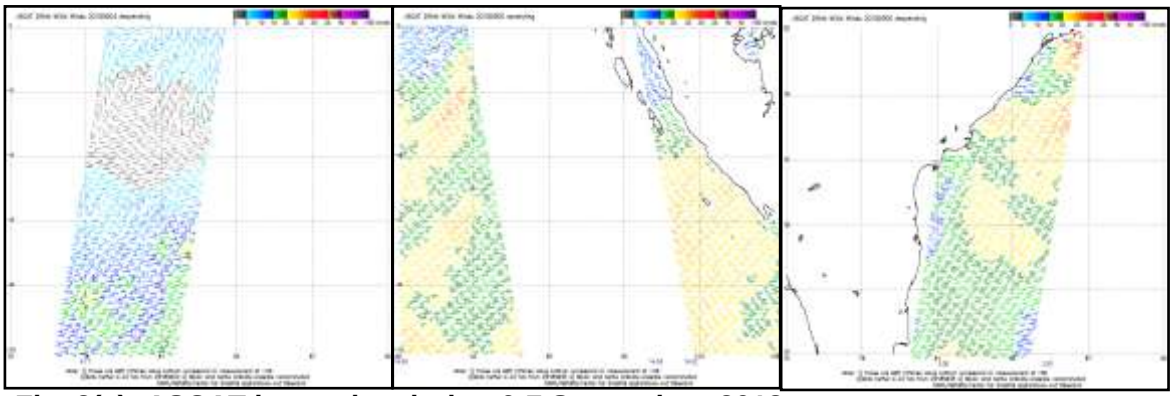


Fig. 2(v): ASCAT imageries during 6-7 September, 2018

3. 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 6th September, it indicated a depression over northwest BoB off west Bengal and Odisha coast. The circulation was seen upto 500 hPa level tilting southwestwards with height. Ridge was seen near 32^0N in association with anticyclonic circulation near 32^0N/99^0E. At 0000 UTC of 6th, the system lay as a depression over northwest BoB and adjoining West Bengal coast.

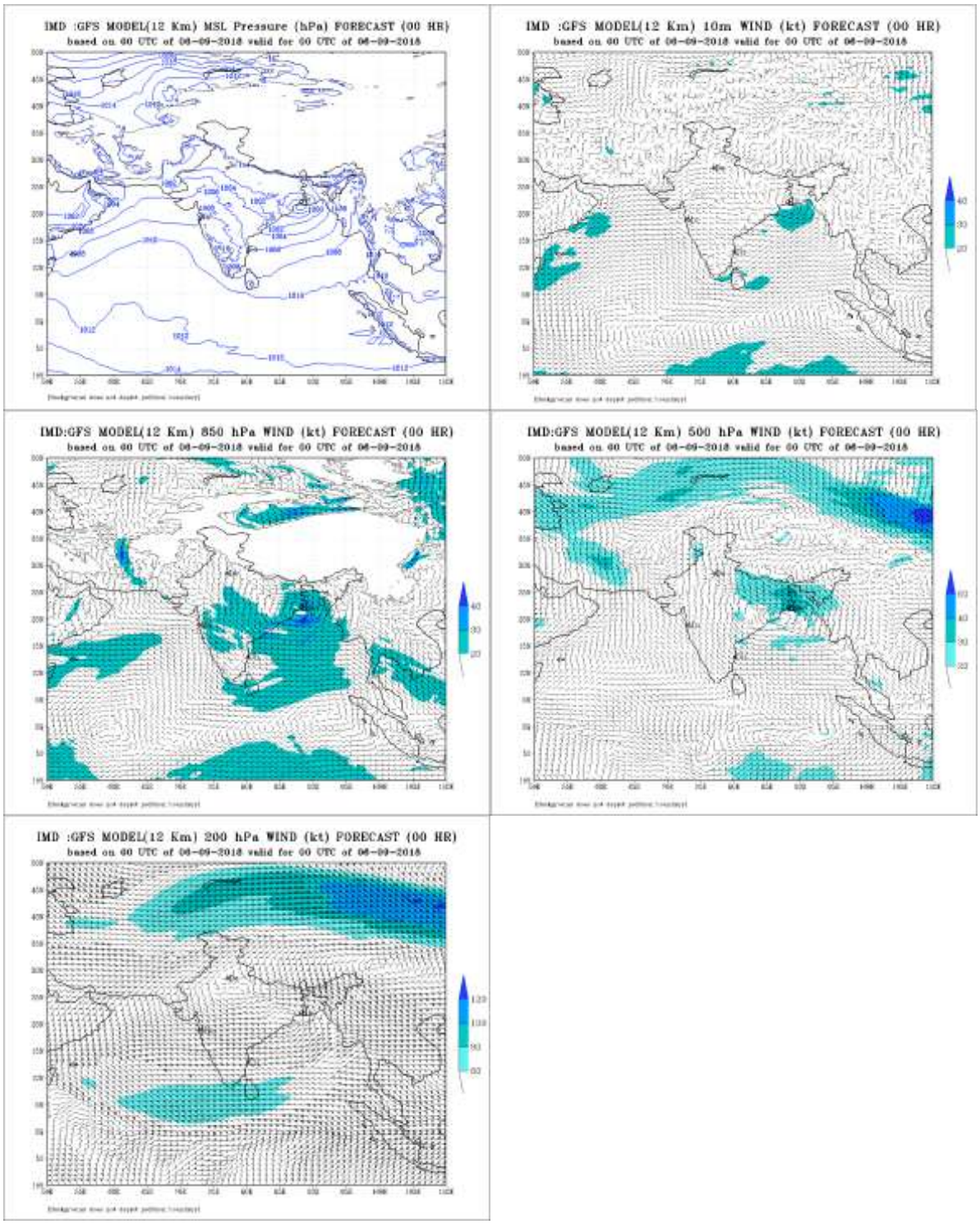


Fig4 (i): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 6th September

IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10 m, 850, 500 and 200 hPa levels are presented in Fig.5. At 0000 UTC of 7th September, it indicated a D over southwest Jharkhand and adjoining northwest Odisha and north Chhattisgarh. The circulation was seen upto 500 hPa level tilting southwestwards with height. Ridge was seen near 28^0N in association with anticyclonic circulation near 30^0N/95^0E. At 0000 UTC of 7th, the system lay as a depression over northwest Odisha and neighbourhood.

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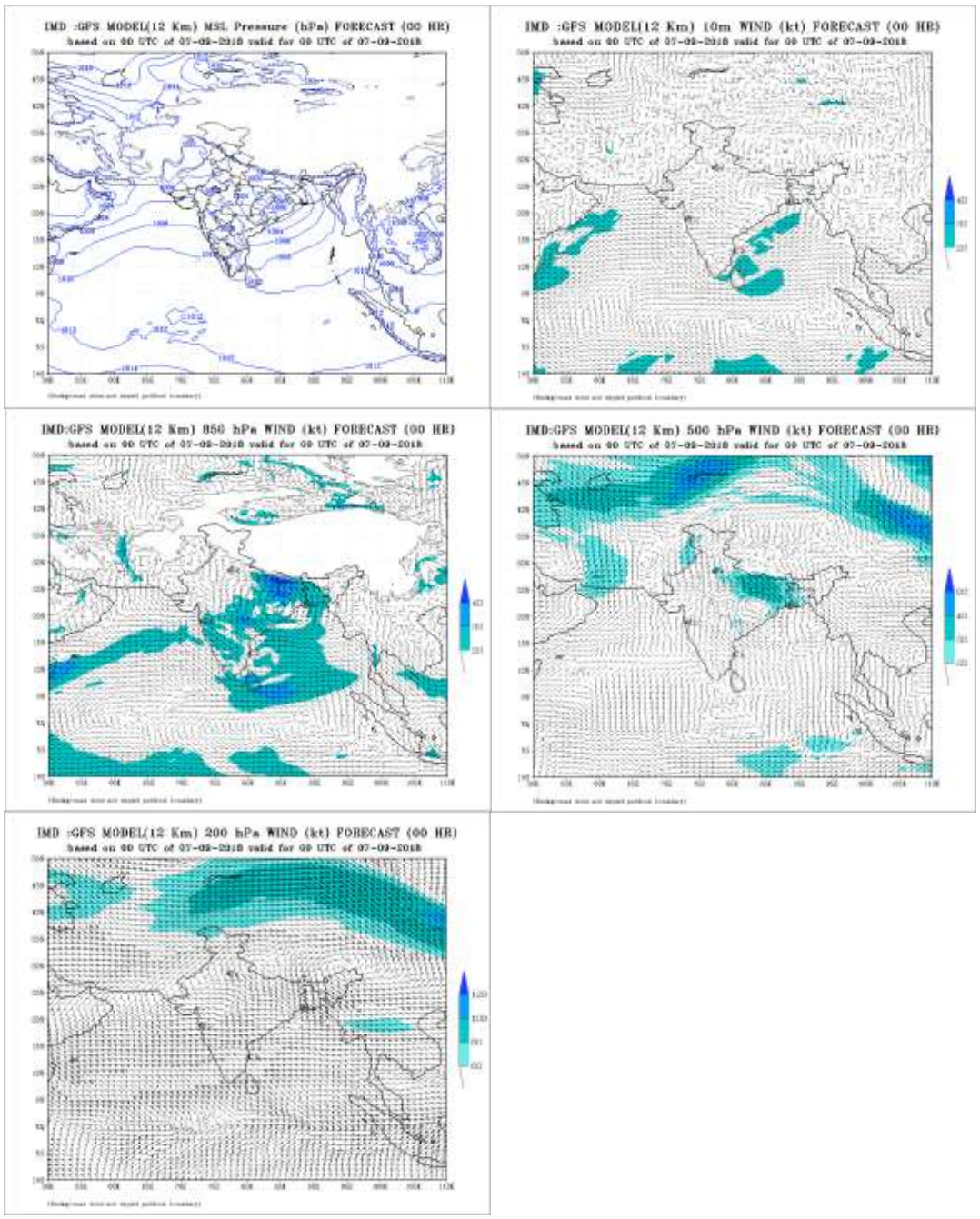

Fig.4 (ii): IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 7th September

Thus, IMD GFS could capture the genesis, intensification and movement of the system reasonably well.

4. Realized Weather:

4.1 Rainfall:

Under the influence of the system, on 5th September, isolated heavy rainfall occurred over Odisha & West Bengal. On 6th, heavy to very heavy rainfall occurred at isolated places over Gangetic West Bengal, heavy to very heavy at a few places with extremely heavy rainfall at isolated places occurred over Odisha and heavy rainfall at isolated places occurred over Jharkhand, Chhattisgarh and Madhya Pradesh. On 7th, heavy to very heavy rainfall at a few places over Odisha & at isolated places over Chhattisgarh and heavy rainfall at isolated places over Jharkhand & Madhya Pradesh was registered. On 8th, isolated heavy rainfall over West Madhya Pradesh, Chhattisgarh & Vidarbha and isolated heavy to very heavy rainfall over East Madhya Pradesh was recorded. On 9th, heavy to very heavy rainfall at isolated places over west Madhya Pradesh and East Rajasthan was observed.

The daily rainfall distribution ending at 0300 UTC of each date during September, 2018 based on merged gridded rainfall data of IMD/NCMRWF is shown in Fig.4.

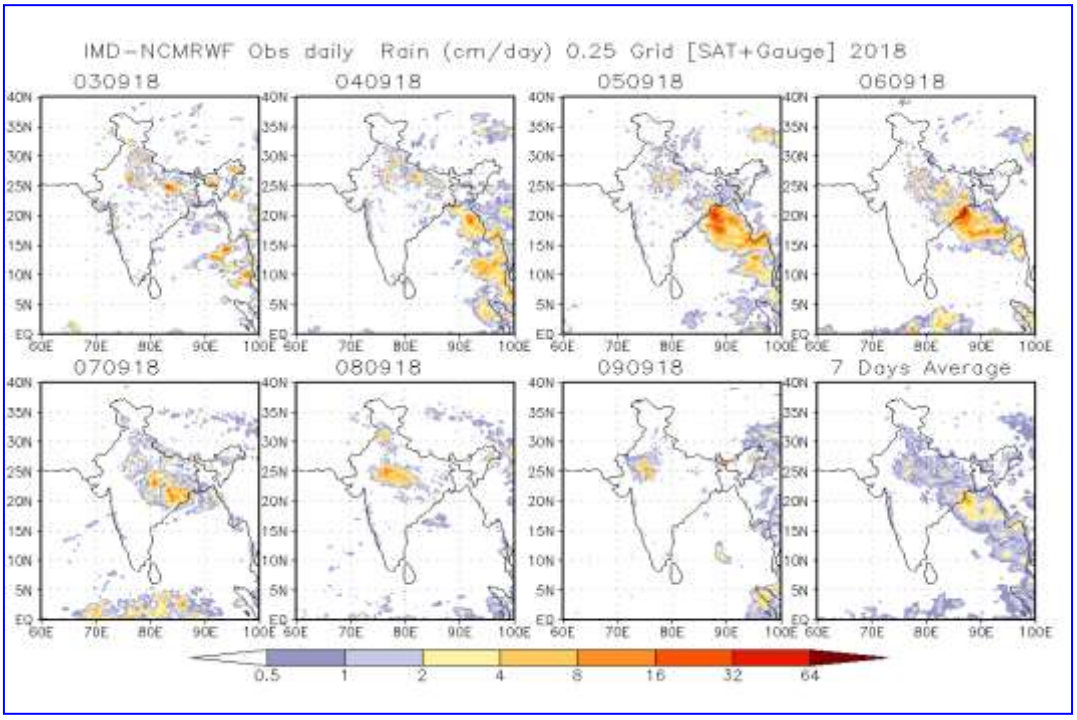

Fig.4: Daily rainfall distribution based on merged gridded rainfall data of IMD/NCMRWF during 3-9 September, 2018

(Heavy rainfall distribution: Isolated places: upto 25%, A few places: 26-50%, Many places: 51-75%, Most places: 76-100% of total stations in the region;
Heavy rainfall: 64.5 – 115.5 mm, Very heavy rainfall: 115.6 – 204.4 mm, Extremely heavy rainfall: 204.5 mm or more).

The 24 hour cumulative rainfall (≥ 7 cm) ending at 0830 hours IST of date during 5th-9th September is presented below:

5th September

West Bengal

Alipore - 7

Odisha:
Chandanpur - 7

6th September
Gangetic West Bengal:
Tusuma - 14, Kharidwar- 13, D.P.Ghat- 11, Kansabati Dam & Phulberia– 8 each, Simula– 7
Odisha:
Paradeep - 41, Kujanga - 37, Kendrapara & Marsaghai – 34 each, Pattamundai - 31, Derabis - 30, Bari - 27, Tirtol - 26, Salepur - 25, Binjharpur & Garadapur – 24 each, Raghunathpur & Alipingal – 21 each, Jagatsinghpur, Chandbali, Jajpur – 19 each, Rajkanika - 18, Mahanga, Kantapada & Niali – 15 each, Balikuda - 14, Kakatpur, Chandikhol, Balipatna & Akhuapada – 13 each, Joshipur, Nischintakoili & Dhamnagar – 12 each, Nimpara, Phiringia, Astaranga & Cuttack – 11 each, Pipili, Tihidi & Bhubaneswar – 10 each, Gop, Banki, Naraj, Athmalik, Birmaharajpur & Danagadi – 9 each, Kalinga - 8, Boudhgarh, Mundali, Madanpur Rampur, G Udayagiri, Baliguda, Tikabali, Bhadrak & Batlig – 7 each
Jharkhand:
Bokaro - 8, Chandil - 7
West Madhya Pradesh:
Udaipura & Mehgaon – 7 each
East Madhya Pradesh:
Sagar & Panna – 9 each, Gadarwara – 8, Narsinghpur - 7
Chhattisgarh:
Ramanujganj & Manendragarh – 9 each

7th September
Odisha:
Phiringia & Ambabhona – 19 each, , K Nuagaon - 18 , Binika - 17 , Batli - 16 , Baliguda & Nawana - 15 each, Rajkanika & Narsinghpur – 14 each, Birmaharajpur, Joda, Ullunda, Raikia, Chandbali & Binjharpur – 13 each, Jhumpura & Dunguripalli - 12 each, Tensa, Jajpur, Akhuapada, Tihidi & Sonepur – 11 each, Khairamal, Korei, Danagadi, Salebhatta, Pattamundai, Gania, Athmalik & Rajkishorenagar - 10 each, Deogarh, Daringibadi, Panposh, Boudhgarh, Barpalli, Rairakhol, Daspalla & Dhamnagar – 9 each, Bonth, Bargarh, Barmul, Tikabali, Sukinda, Kantamal, Banki, Hindol & Joshipur - 8 each, Bargaon, Daitari, Rajgangpur, Jamankira, Madanpur Rampur, Saintala & Mandira Dam – 7 each
Jharkhand:
Kurdeg – 8
Chhattisgarh:
Raigarh - 13 , Gharghoda & Janakpur – 9 each
East Madhya Pradesh:
Umaria & Dindori – 8 each, Satna & Anuppur - 7 each

8th September
West Madhya Pradesh:
Guna & Sheopur – 11 each, Biaora - 8, Begumganj & Rajgarh – 7 each
East Madhya Pradesh:
Umaria - 16, Panna, Chahtarpur & Khurai – 9 each, Tikamgarh - 8, Buxwaha & Katni – 7 each
Chhattisgarh:
Pathalgaon & Manendragarh - 7 each,
Vidarbha:
Mul – 7

9th September

East Rajasthan:

Pisagan - 12, Mangrol -11, Bakani & Degod – 10 each, Bijoliya, Hindoli, Patan, Bundi & Kotri – 9 each, Jahazpur, Anta, Pachpahar – 8 each, Talera, Sarwar, Mandalgarh, Banera, Arai & Kota – 7 each

West Madhya Pradesh:

Neemuch -11, Bhanpura - 8

5. Bulletins issued by IMD

IMD issued regular bulletins to WMO/ESCAP Panel member countries including Bangladesh and Myanmar, National & State Disaster Management Agencies of Andhra Pradesh, Odisha, Chattisgarh, Jharkhand, Madhya Pradesh, Maharashtra, Telangana, Uttar Pradesh and Rajasthan, general public and media. Regular Bulletins every six hourly were issued since formation of depression over northwest BoB. In addition, RSMC New Delhi also issued Press Release and SMS to 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	8	1. IMD's website 2. FAX and e-mail to Control Room NDM, Ministry of Home affairs, Control Room NDMA, Cabinet Secretariat, Minister of Sc. & Tech, Secretary MoES, DST, HQ Integrated Defence Staff, DG Doordarshan, All India Radio, DG-NDRF, Director Indian Railways, Indian Navy, IAF, Chief Secretary: Andhra Pradesh, West Bengal, Odisha, Chattisgarh, Jharkhand, Maharashtra, Madhya Pradesh, Maharashtra, Telangana, Rajasthan and Gujarat
2	RSMC Bulletin	2	1. IMD's website 2. All WMO/ESCAP member countries through GTS and E-mail. 3. Indian Navy, IAF by E-mail
3	Press Release	2	1. Disaster Managers, Media persons by email and uploaded on website
4	Facebook /Twitter	5 times	Highlights uploaded on facebook/twitter since formation of depression.
5	SMS	269	Twice daily

Table-2(b): Bulletins issued by Cyclone Warning Centre (CWC) Bhubaneswar/ACWC Kolkata/ Meteorological Centre (MC) Raipur

S. N.	Type of Bulletin	Number of Bulletins		
		CWC Bhubaneswar	ACWC Kolkata	MC Raipur
1.	Sea Area Bulletins	NA	4	NA
2.	Coastal Weather Bulletins	08	WB Coast- 04 A & N Coasts-04	NA
3.	Fishermen Warnings issued	13	WB Coast -04 A & N Coasts-Nil	NA
4.	Port Warnings	10	WB -02 A & N Ids -02	NA
5.	Heavy Rainfall Warning	04	GWB- 1	3
6.	Wind Warning	13	4	NA
7.	Storm surge warning	NIL	NIL	NA
8.	Information & Warning issued to State Government and other Agencies	08	06	3
9.	SMS/ Whatsapp (message in group)/email	1050	900 (Appx)	0/~ 20(+) / ~ 30(+)
10.	Press Release	03	-	-

6. Operational Forecast Performance

- The first information regarding formation of low pressure area over north BoB and neighbourhood around 6th was issued at 0630 UTC of 3rd September (about 41 hours in advance). The low pressure area formed over northwest BoB and adjoining areas of Bangladesh and West Bengal at 0000 UTC of 5th September.
- First information regarding formation of depression over northwest BoB off West Bengal & Odisha coasts during 6th to 7th September was issued at 1500 UTC of 5th September (about 13 hours in advance). The depression formed over northwest BoB and adjoining areas of coastal Bangladesh, West Bengal and Odisha at 0000 UTC of 6th September.
- In the first bulletin issued in the morning at 0300 UTC (base time of observation 0000 UTC) of 6th August, it was predicted that depression would move west-northwestwards and cross West Bengal coast close to Digha around noon (0600 UTC) and moving further west-northwestwards weaken gradually during next 24 hours. The system moved nearly westwards, intensified into a DD at 0300 UTC and crossed West Bengal coast close to Digha during 0430-0530 UTC. It maintained the intensity of DD till 1800 UTC of 6th and weakened into a D at 0000 UTC & into a WML at 0600 UTC of 7th.

The verification of heavy rainfall warnings issued by IMD for the depression during 5th -8th September is presented in Table 3. It can be found that the occurrence of heavy rainfall in association with the system could be predicted well in advance.

Table 3 : Verification of heavy rainfall warning issued by IMD for Deep Depression over coastal Odisha (6th – 7th August, 2018)

Date/ Base Time (UTC)	Forecast Issued	Realised Rainfall
06/0300	• Heavy to very heavy falls at a few places with extremely heavy falls at isolated places on 7th and heavy falls at isolated places on 8th over Odisha • Heavy to very heavy falls at isolated places over West Bengal, Jharkhand, Chattisgarh on 7th with isolated heavy falls over Jharkhand and isolated heavy to very heavy falls over Chattisgarh on 8th. • Heavy falls at isolated places over north coastal Andhra Pradesh, Telangana, Vidarbha, East & West Madhya Pradesh on 7th and heavy falls at isolated places over Telangana & Vidarbha, heavy to very heavy falls at isolated places over east & west Madhya Pradesh on 8th and isolated heavy falls over west Madhya Pradesh on 9th.	**7th September** **Odisha:** Phiringia & Ambabhona – 19 each, , K Nuagaon - 18 , Binika - 17 , Batli - 16 , Baliguda & Nawana - 15 each, Rajkanika & Narsinghpur – 14 each, Birmaharajpur, Joda, Ullunda, Raikia, Chandbali & Binjharpur – 13 each, Jhumpura & Dunguripalli - 12 each, Tensa, Jajpur, Akhuapada, Tihidi & Sonepur – 11 each, Khairamal, Korei, Danagadi, Salebhatta, Pattamundai, Gania, Athmalik & Rajkishorenagar - 10 each, Deogarh, Daringibadi, Panposh, Boudhgarh, Barpalli, Rairakhol, Daspalla & Dhamnagar – 9 each, Bonth, Bargarh, Barmul, Tikabali, Sukinda, Kantamal, Banki, Hindol & Joshipur - 8 each, Bargaon, Daitari, Rajgangpur, Jamankira, Madanpur Rampur, Saintala & Mandira Dam – 7 each **Jharkhand:** Kurdeg – 8 **Chhattisgarh:** Raigarh - 13 , Gharghoda & Janakpur – 9 each **East Madhya Pradesh:** Umaria & Dindori – 8 each, Satna & Anuppur - 7 each **8th September** **West Madhya Pradesh:** Guna & Sheopur – 11 each, Biaora - 8, Begumganj & Rajgarh – 7 each **East Madhya Pradesh:** Umaria - 16, Panna, Chahtarpur & Khurai – 9 each, Tikamgarh - 8, Buxwaha – 7 & Katni – 7 each **Chhattisgarh:** Pathalgaon & Manendragarh - 7 each, **Vidarbha:** Mul – 7 **9th September** **East Rajasthan:** Pisagan - 12, Mangrol -11, Bakani & Degod – 10 each, Bijoliya, Hindoli, Patan, Bundi & Kotri – 9 each, Jahazpur, Anta, Pachpahar – 8 each, Talera, Sarwar, Mandalgarh, Banera, Arai & Kota – 7 each **West Madhya Pradesh:** Neemuch -11, Bhanpura - 8
07/0300	• Heavy falls at isolated places over Odisha & Vidarbha on 8th and heavy to very heavy falls at isolated places over Chattisgarh, east & west Madhya Pradesh on 8th and heavy falls at isolated places over west Madhya Pradesh during on 9th .	

7. Summary and Conclusions:

A depression (D) formed over northwest BoB and adjoining West Bengal and Bangladesh coasts in the early morning (0000 UTC) of 6th. It moved slightly westwards, intensified into a deep depression (DD) over the same region in the same morning (0300 UTC) and crossed West Bengal coast close to Digha in the forenoon during (0430-0530 UTC). It continued to move west-northwestwards and maintained it's intensity of DD for next 21 hours and weakened into a D over northwest Odisha and neighbourhood in the early morning (0000) of 7th. Thereafter, it moved northwestwards and weakened into a WML around the noon (0600 UTC) of the same day over north Chhattisgarh and neighbourhood.

Under the influence of this system and its remnant low pressure area widespread rainfall activity was observed over the northern and central parts of the country including Gangetic West Bengal, Odisha, Chattisgarh, Jharkhand, Vidarbha, Madhya Pradesh, and East Rajasthan. Extremely heavy rainfall occurred over Odisha on 6th.

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, National Institute of Technology (NIOT) Chennai & Indian National Centre for Ocean Information Services (INCOIS), Hyderabad. The support from various Divisions/Sections of IMD including Area Cyclone Warning Centre Kolkata, Regional Meteorological Centre Nagpur, Cyclone Warning Centre Bhubaneswar, Ahmedabad, Meteorological Centre Raipur, Ranchi, Jaipur, Bhopal, Doppler Weather Radar units at Kolkata, Gopalpur, Paradip & Bhopal, Numerical Weather Prediction (NWP) Division, Information System & Services Division (ISSD), Satellite and Radar Division at IMD HQ New Delhi is also duly acknowledged for monitoring and prediction of the system.