Cyclonic storm 'KEILA' over the Arabian Sea (29 October- 04 November, 2011)

7.1 Introduction:

A cyclonic storm 'KEILA' developed over the Arabian Sea. It moved initially west-northwestwards and then northwestwards and crossed Oman coast close to the north of Salalah. It then remerged into the Arabian sea and dissipated gradually. It caused death of 14 people in Oman. It caused death of 14 people in OmanThe salient features of the system are given below. The system was mainly monitored by the satellite imageries and products. However, the crucial ship and buoy observation also helped in estimating the location and intensity of the system. When the system came close to the Oman coast, coastal observations were also useful.

7.2 Genesis:

In association with active ITCZ, convective cloud cluster developed over southeast and adjoining eastcentral Arabian Sea during last week of October 2011. It gradually concentrated into a low pressure area on 27th October, 2011. It became well marked, while moving west-northwestwards on 28th October and concentrated into a depression over westcentral and adjoining southwest Arabian Sea and lay centred at 0600 UTC of 29th October 2011 near lat. 13.0^{0}N and long. 62.0^{0}E with gradual increase in depth and organisation of convection. The intensity of the system was T1.5 as per Dvorak's technique applied to Kalpana imageries. The associated broken intense to very intense convection lay over the area between lat. 9.0^{0}N to 18.0^{0}N and long 56.0^{0}E to 72.0^{0}E. The lowest cloud top temperature (CTT) was -79^0 C. The sustained Maximum wind speed was 25 knots around the system centre with rough to very rough sea condition. The estimated central pressure was 1004 hPa.

The cyclogenesis on 29th occurred due to increase in relative vorticity and convection at lower levels and upper air divergence. It was also due to low to moderate vertical wind shear (5-10 knots) with decreasing tendency (5-10 knots in past 24 hours). The upper level divergence was provided by the anticyclonic circulation which lay to the northeast of the system centre with ridge running along 15^{0}N.

The best track parameters of the system are given in Table 7.1. The best track of the system is shown in Fig. 7.1. The typical satellite imageries showing the genesis and intensification/weakening of the system are shown in Fig. 7.2. The ECMWF analysis showing the lower level relative vorticity, lower level wind & upper level divergence and vertical wind shear are shown in Fig. 7.3. The genesis potential of the system could be picked up by the Genesis potential parameters of IMD.

7.3 Intensification and movement:

The favourable environmental condition prevailed over the Arabian Sea during 29-31 October 2011. However, the tropospheric ridge gradually moved northwards and ran along 18^{0}N on 1st November 2011. It resulted in west-northwestward movement of depression. The depression gradually intensified into a deep depression and lay centred at 0300 UTC of 1st November, 2011 over westcentral Arabian Sea near Lat. 16.0^{0}N and long. 56.0^{0}E, about 230 km east-southeast of Salalah (Oman).

As per Dvorak's technique, the intensity of the system was T2.0. The lowest CTT was -84^{0}C indicating increase in depth of convection. The maximum sustained wind speed was 30 knots and ECP was 1000 hPa.

The sea surface temperature over the central Arabian Sea and Gulf of Aden was about 28-29^{0}C as reported by the ships and buoys and the satellite estimation. However, the Ocean thermal energy was less (<40 KJ/cm^2) over Gulf of Aden and adjoining Arabian Sea. Considering all these the intensification of the system was slow. Further, the MJO was not favourable for intensification of the system as it lay in phase 8. Considering all these, the deep depression continued to move west-northwestwards, intensified into a cyclonic storm 'KEILA' and lay centred at 0300 UTC of 2nd November 2011 over westcentral Arabian Sea near lat 16.0^{0}N and long. 55.0^{0}E, about 150 km southeast of Salalah (Oman). The maximum sustained surface wind speed was 35 knots with ECP of 998 hPa. The intensity according to Dvorak's technique was T2.5. The lowest CTT was -85^{0}C.

As the cyclonic storm 'Keila' lay over colder sea surface and close to the land surface, it did not intensify further. Also there was cold air entrainment to the region. As a result, the cyclonic storm continued to move west-northwestwards and crossed Oman coast close to the north of Salalah between 1600-1700 UTC and lay centre at 1800 UTC of 2nd November 2011over coastal Oman close to Salalah as a deep depression. Around the time of landfall, Salalah reported maximum wind of 23 knots at 1500 UTC and 6 knots at 1800 UTC of 2nd November 2011. It indicates that the system weakened just after the landfall.

On 3rd November the system lay to the north of the upper tropospheric ridge and in the periphery of the anticyclonic circulation to the east. As a result, the system re-emerged into the Arabian Sea on 3rd November. The anticyclonic circulation over Oman-Yemen area emerged into the Arabian Sea on 3rd November eveningalso. As a result, the system lay close to the anticyclonic circulation and meander over the region. at last the system moved eastwards and then southwards over the west central Arabian Sea and weakened gradually. It weakened into a low pressure area on 4th November 2011over westcentral Arabian Sea off Oman coast.

Crucial observation with respect to location and intensity are given in Table7.2.

Table 7.1: Best track positions for cyclonic storm 'KEILA' (29 Oct-04Nov 2011)

Date	Time (UTC)	Centre lat.^{0}N/long^{0}E	C.I. No.	Estimated centre pressure (hPa)	Estimated maximum sustained surface wind (kts)	Estimated pressure drop at the centre (hPa)	Grade
29-10-2011	0600	13.0/62.0	1.5	1004	25	3.0	D
	1200	13.0/61.0	1.5	1004	25	3	D
	1800	13.0/61.0	1.5	1004	25	3	D
	0000	13.0/60.5	1.5	1004	25	3	D
30-10-2011	0300	13.0/60.0	1.5	1004	25	3	D
	0600	13.0/60.0	1.5	1002	25	3	D
	1200	13.5/59.5	1.5	1002	25	3	D

	1800	14.0/59.0	1.5	1002	25	3	D
31-10-2011	0000	14.5/59.0	1.5	1002	25	3	D
	0300	15.0/58.5	1.5	1000	25	3	D
	0600	16.0/57.0	1.5	1000	25	3	D
	1200	16.0/57.5	1.5	1000	25	3	D
	1800	16.0/57.0	1.5	1000	25	3	D
01-11-2011	0000	16.0/56.5	1.5	1000	25	3	D
	0300	16.0/56.0	2.0	1000	30	4	DD
	0600	16.0/56.0	2.0	1000	30	4	DD
	1200	16.0/55.5	2.0	1000	30	4	DD
	1800	16.0/55.5	2.0	1000	30	5	DD
02-11-2011	0000	16.0/55.3	2.0	1000	30	5	DD
	0300	16.0/55.0	2.5	998	35	7	CS
	0600	16.0/54.5	2.5	996	35	7	CS
	0900	16.0/54.5	2.5	996	35	7	CS
	1200	16.5/54.5	2.5	996	35	7	CS
	1500	16.8/54.3	2.5	996	35	6	CS
	The cyclonic storm 'KEILA' crossed Oman coast close to the north of Salalah (near lat.17.1^{0}N and long. 54.3^{0}E) between 1600-1700 UTC						
	1800	17.1/54.2	2.0	1000	30	5	DD
03-11-2011	0000	17.1/54.2	2.0	1000	30	5	DD
	0300	17.1/54.2	2.0	1000	30	4	DD
	0600	17.1/54.2	2.0	1000	30	4	DD
	1200	17.0/54.5	2.0	1000	30	4	DD
	1800	17.0/54.8	2.0	1001	30	4	DD
04-11-2011	0000	17.0/55.0	2.0	1001	30	4	DD
	0300	16.5/55.0	1.5	1002	25	3	D
	0600	The system weakened into a low pressure area over westcentral Arabian Sea off Oman coast.					

7.4 Realised Weather:

Heavy to very heavy rainfall occurred over coastal Oman.

7.5 Damage:

It caused death of 14 people and 200 people were injured.

7.6 Bulletin issued by IMD:

The system was continuously monitored and predicted since 27th November 2011. Once daily bulletin was issued to Oman/Yemen through e-mail in addition to the Tropical Weather Outlook. The Special Weather Outlook and Tropical cyclone Advisory was issued to Oman/Yemen 29 October-06 November 2011 giving details of the cyclonic storm 'KEILA' and its forecasts. The bulletin was also issued to control room, National Disaster Management (NDM), MHA, Govt. of India and other high officials. The statistics of the number of bulletins issued by IMD are given below.

Bulletins for national disaster management agencies : 10
Bulletin for WMO/ESCAP Panel counties : 14
Tropical cyclone advisory for international civil aviation : 06

Table 7.2 Crucial observation with respect to location and intensity of cyclonic storm 'KEILA;

Date/Time (UTC)	Station (Index/ Lat & Long.)	MSLP (hPa)	Wind (Direction/ speed)	Pressure fall (hPa)
30-10-2011/0300	Thumrait (41314)	--	--	-5.1
30-10-2011/1200	Salalah (41316)	1003.8	340/16	-2.8
	Yaaloni (41295)	1004.5	040/22	--
	Masirah (41288)	1007.1	090/18	--
	Buoy (16.3^{0}N/56.2^{0}E)	1003.2	--	-1.7
31-10-2011/0300	Al-ghaidah (41398)	1005.2	270/13	-1.8
	Salalah (41316)	1006.7	040/13	-1.7
	Buoy (16.3^{0}N/56.0^{0}E)	1003.6	--	--
	Ship (14.3^{0}N/59.4^{0}E)	1000.9	210/08	--
31-10-2011/1200	Salalah (41316)	1003.0	--	-0.9
	Ship(13.7^{0}N/55.4^{0}E)	1003.0	--	--
	Ship (14.5^{0}N/56.9^{0}E)	1002.5	310/12	--
01-11-2011/1200	Salalah (41316)	1004.0	--	-1.7
01-11-2011/1200	Salalah (41316)	1001.2	--	-1.8
02-11-2011/0300	Salalah (41316)	1004.0	--	--
	Buoy (16.3^{0}N/55.1^{0}E)	999.2	--	-1.1
02-11-2011/0600	Salalah (41316)	1005.9	350/13	--
	Buoy (16.5^{0}N/55.0^{0}E)	998.3		-1.0
02-11-2011/1200	Salalah (41316)	1000.5	320/16	-0.7
	Ship (15.6^{0}N/54.5^{0}E)	1003.5	--	-4.0
02-11-2011/1500	Salalah (41316)	1001.5	320/23	--
	Ship (16.5^{0}N/54.9^{0}E)	1002.5	--	--
02-11-2011/1800	Salalah (41316)	1003.4	330/16	-1.0
	Ship (16.2^{0}N/55.3^{0}E)	1009.1	190/23	+4.3
03-11-2011/0000	Salalah (41316)	1002.2	310/17	-1.2
03-11-2011/0300	Salalah (41316)	--	330/21	--
03-11-2011/1200	Salalah (41316)	1003.6	340/24	--

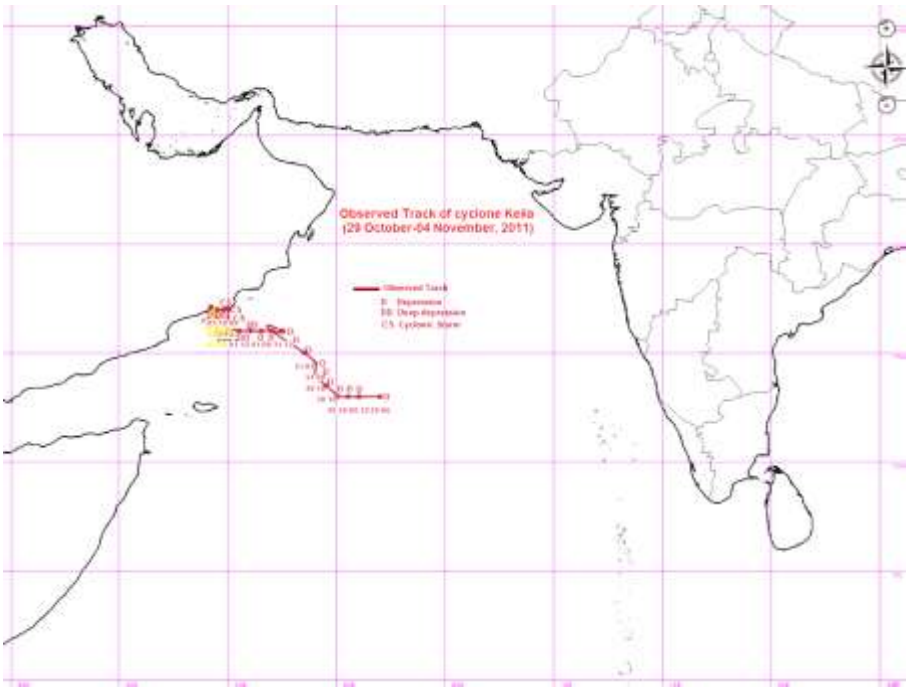


Fig. 7.1 Track of cyclonic storm, Keila over the Arabian Sea (29th October to 4th November, 2011

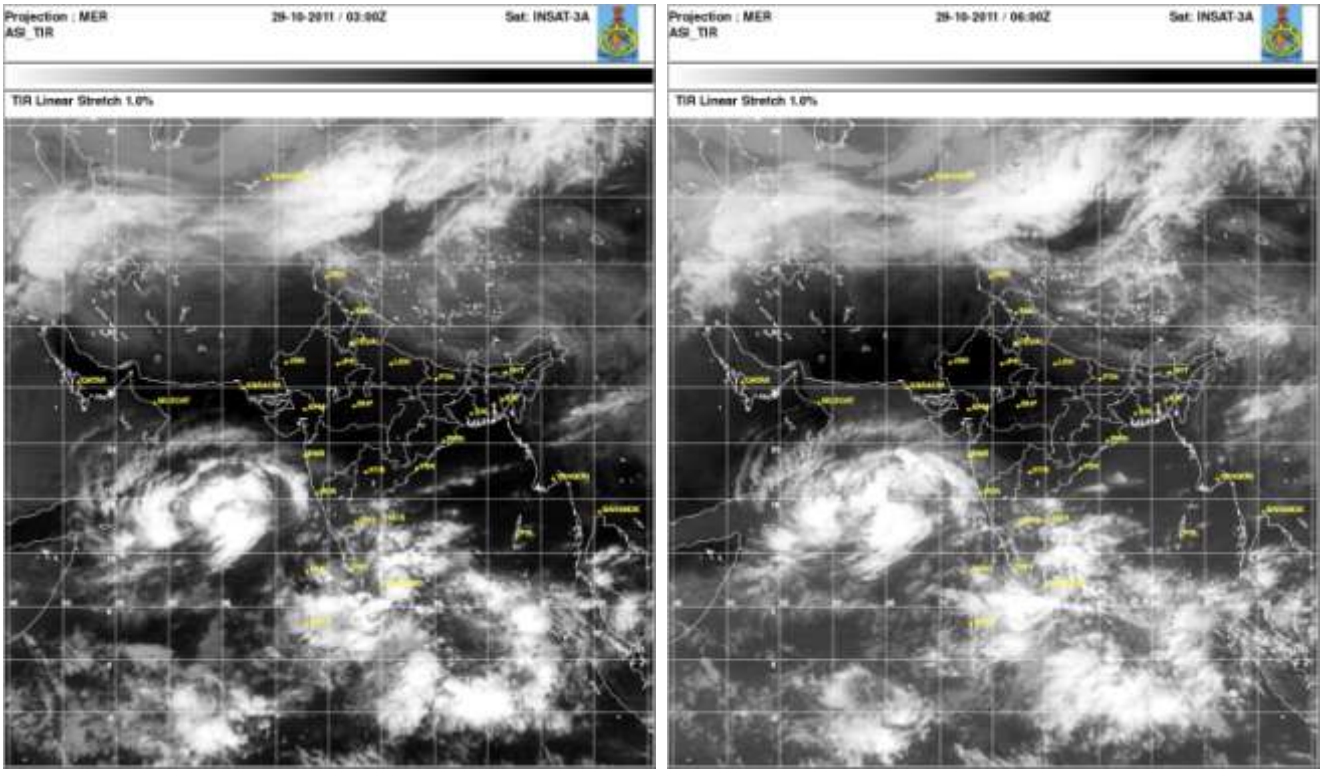


Fig.7.2 The typical satellite imageries showing the genesis and intensification/weakening of the system.

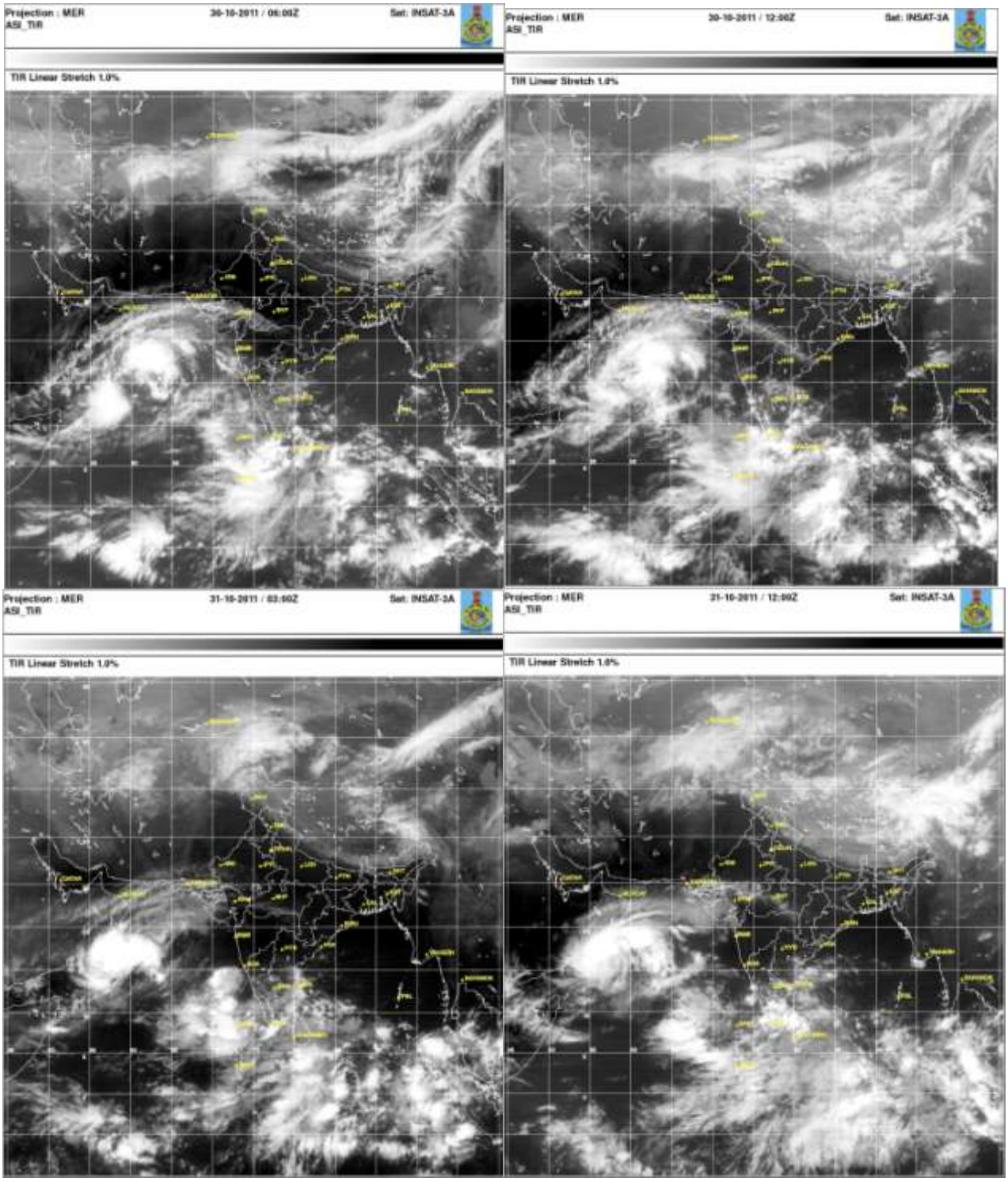


Fig.7.2 (continued) The typical satellite imageries showing the genesis and intensification/weakening of the system.

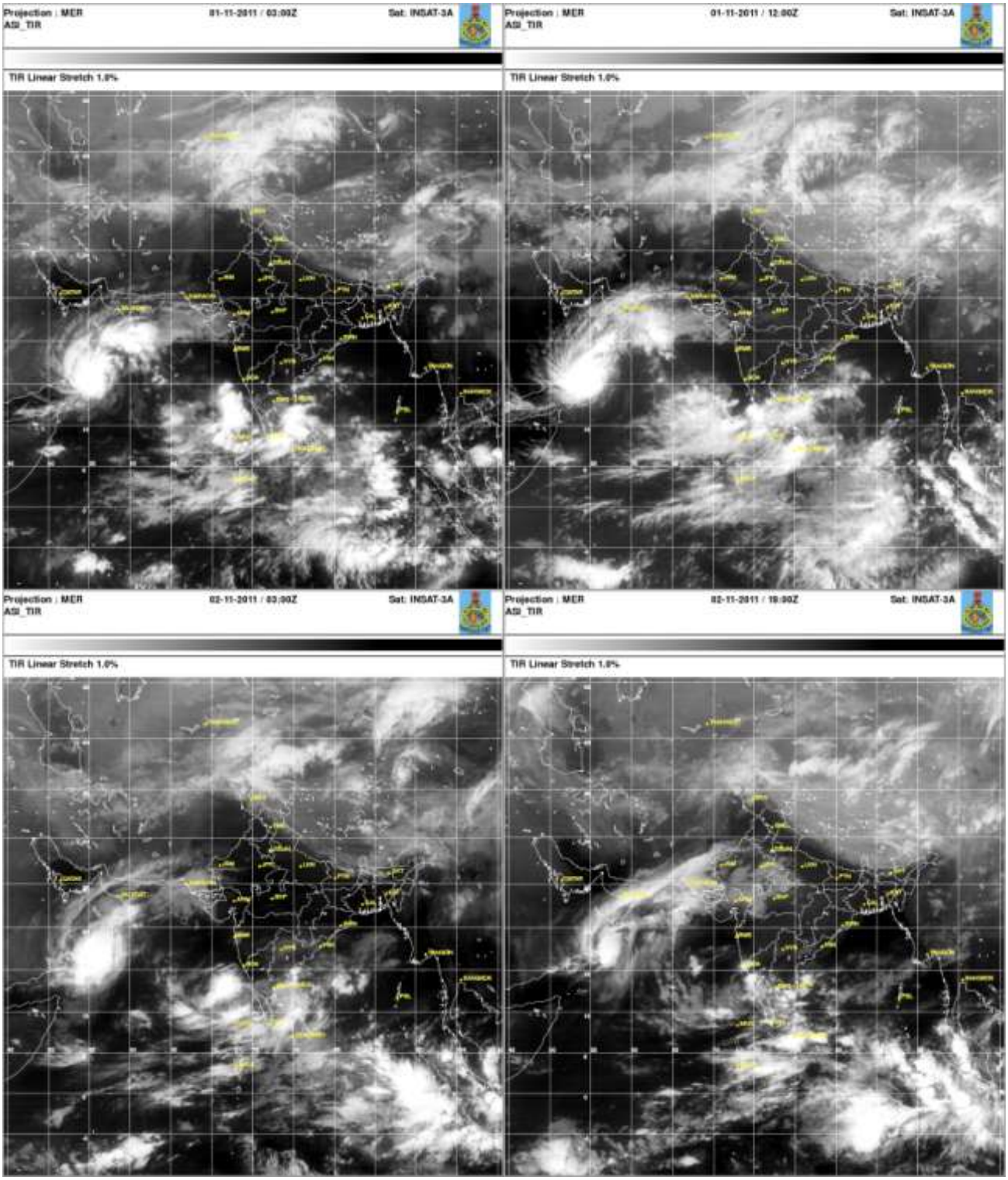
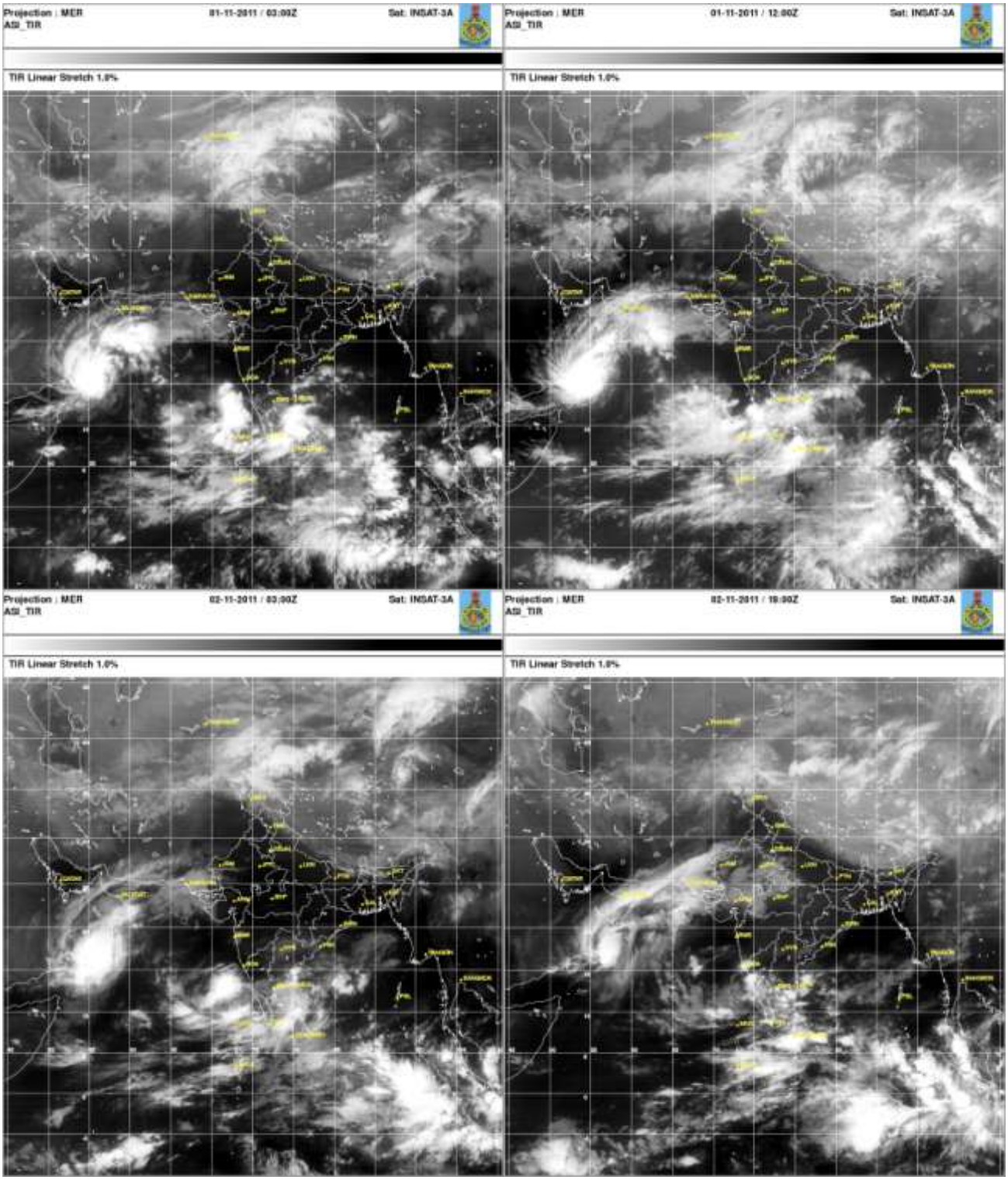


Fig.7.2 (continued) The typical satellite imageries showing the genesis and intensification/weakening of the system



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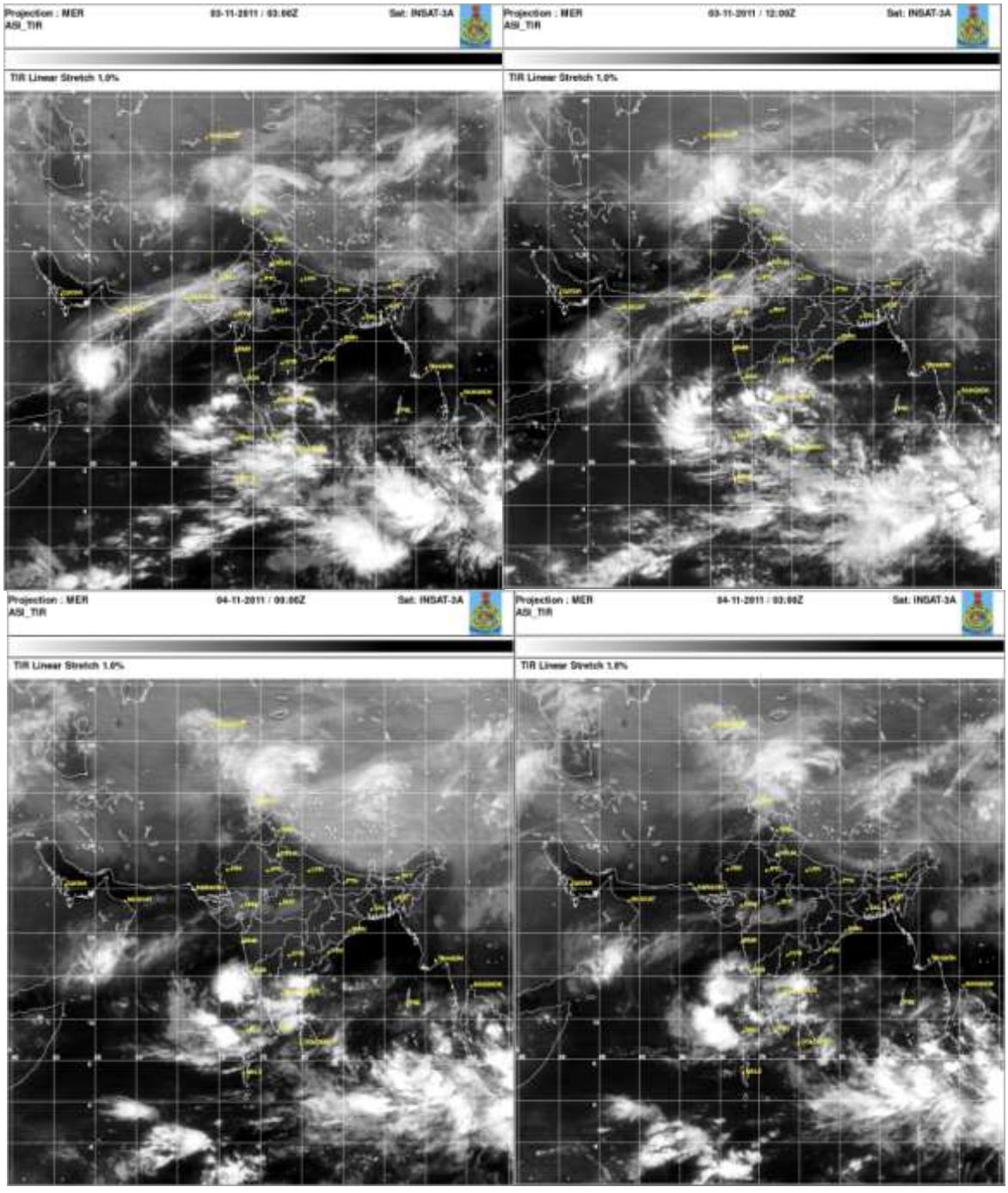

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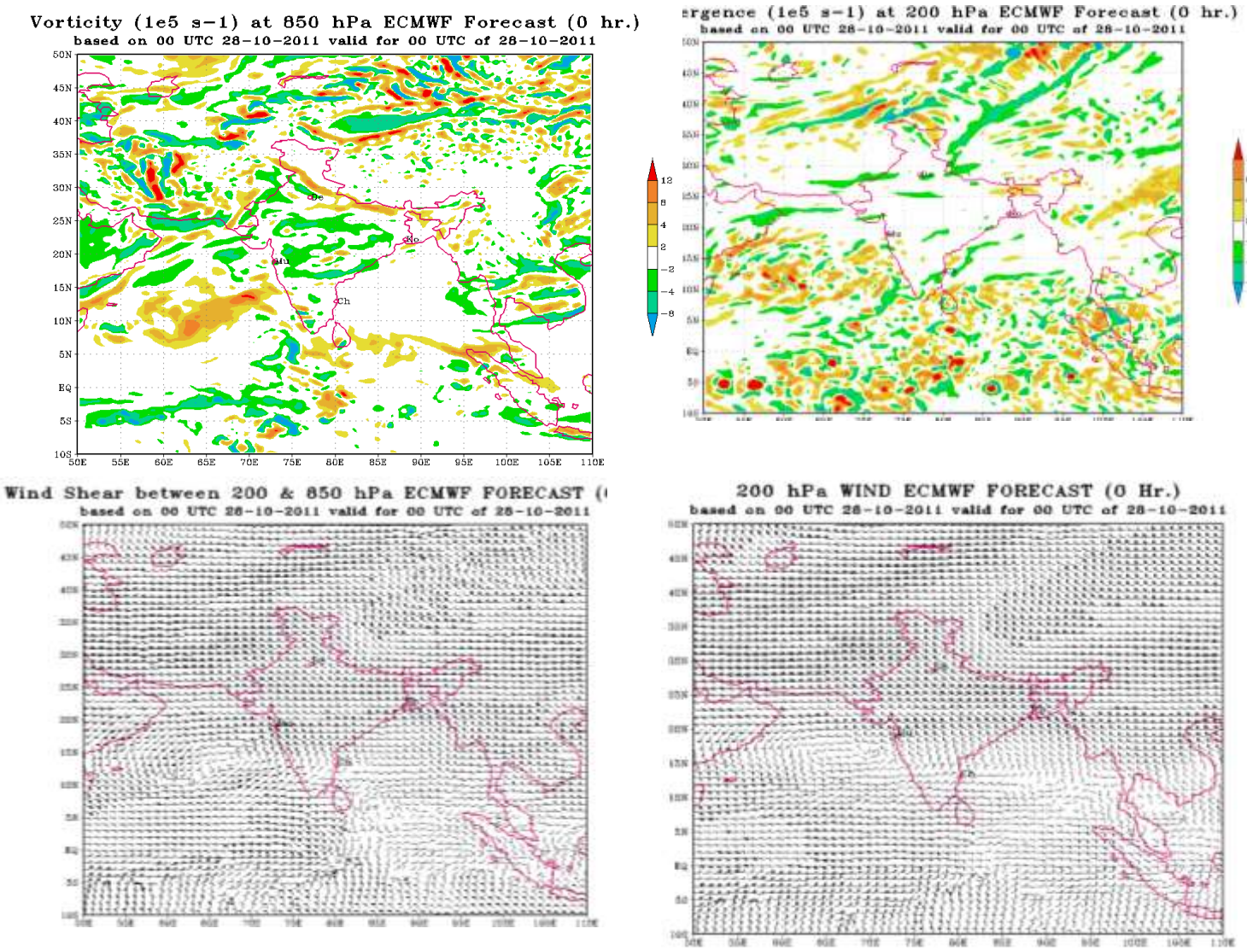


Fig. 7.3 (a) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) vertical wind shear of horizontal wind between 200 and 850 hPa level (iv) wind at 200 hPa level based on the ECMWF model analysis of 0000 UTC of 28th October, 2011.

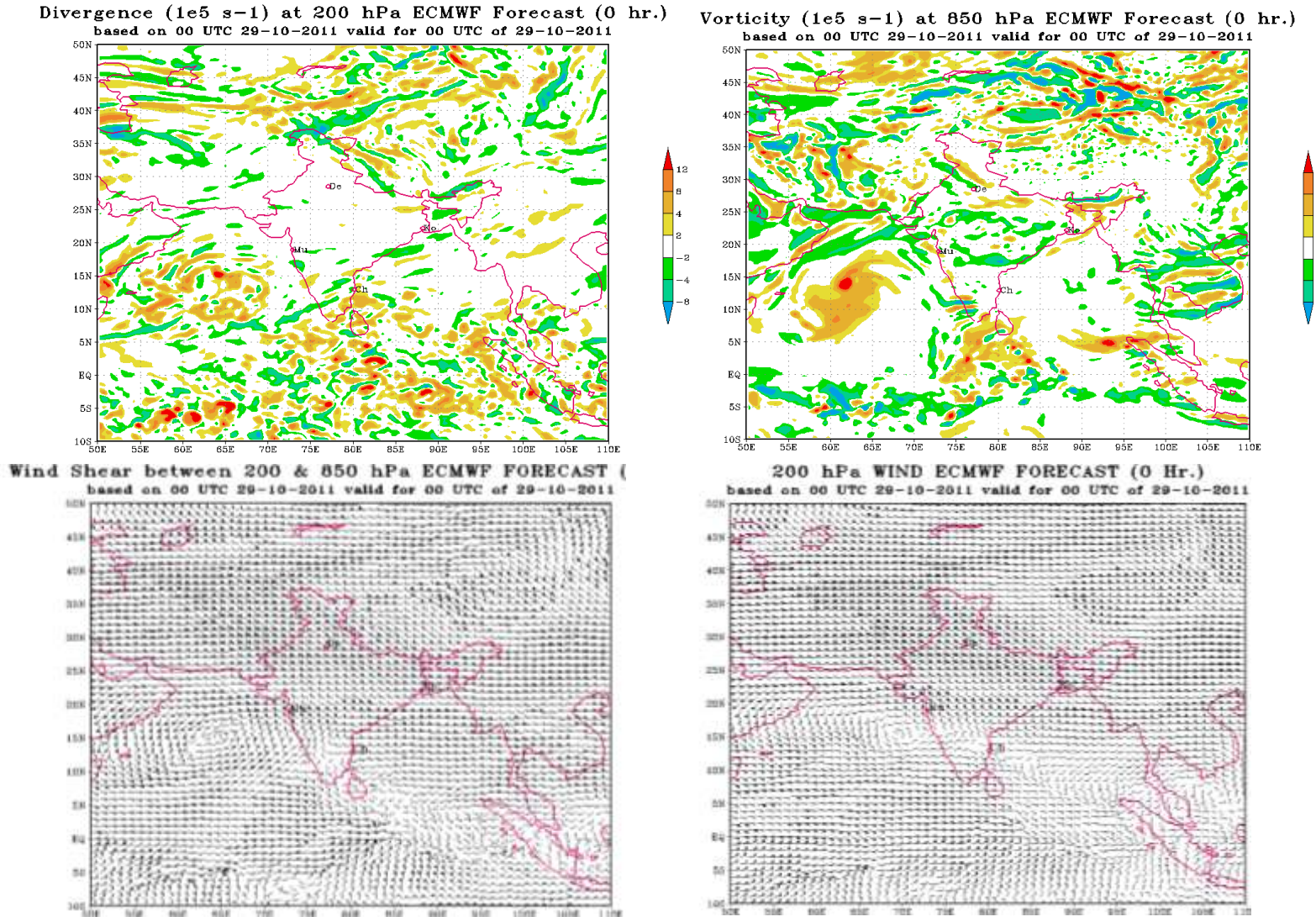


Fig. 7.3 (b) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) vertical wind shear of horizontal wind between 200 and 850 hPa level (iv) wind at 200 hPa level based on the ECMWF model analysis of 0000 UTC of 29th October, 2011.

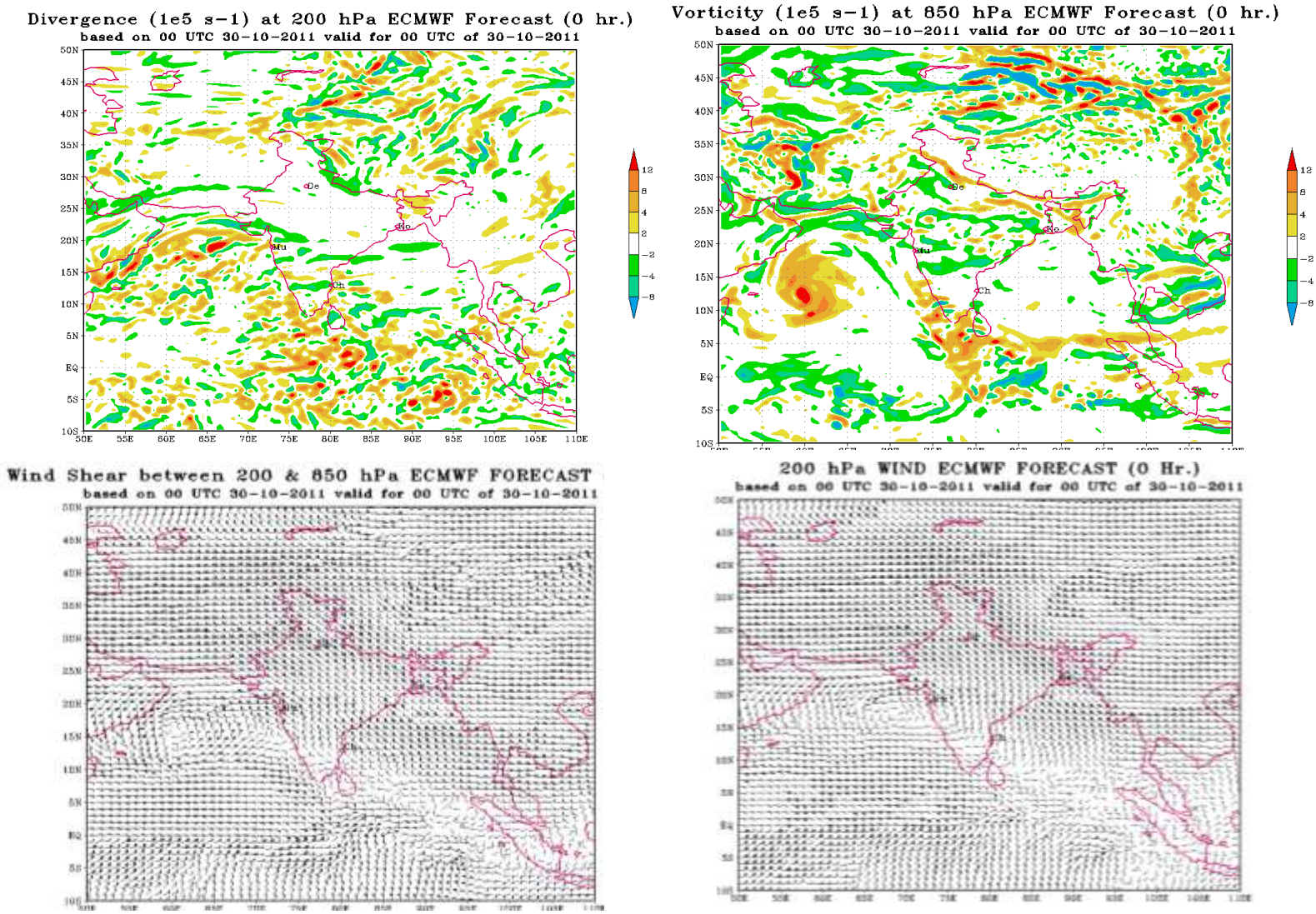


Fig. 7.3 (c) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) vertical wind shear of horizontal wind between 200 and 850 hPa level (iv) wind at 200 hPa level based on the ECMWF model analysis of 0000 UTC of 30th October, 2011.

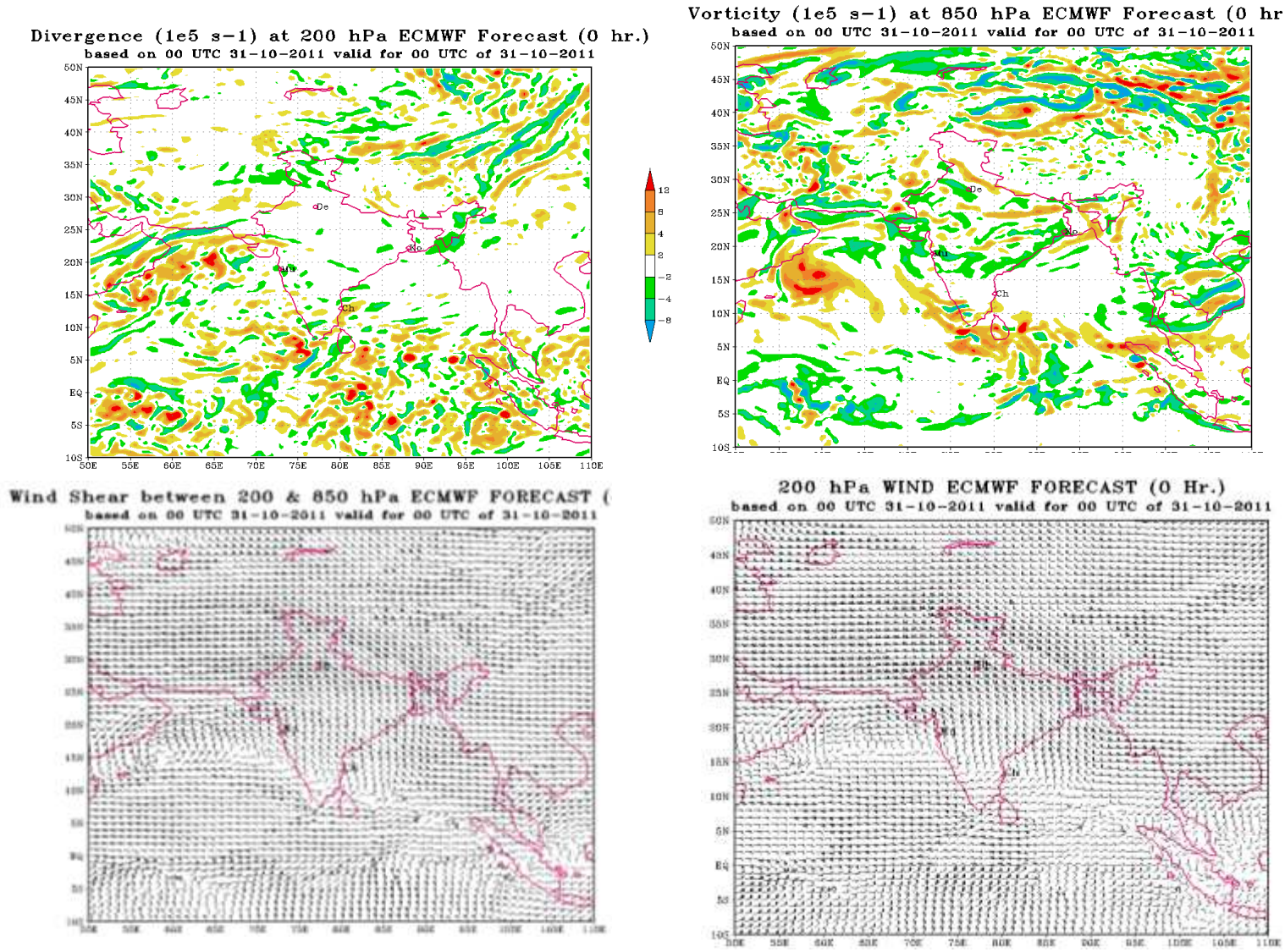


Fig. 7.3 (d) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) vertical wind shear of horizontal wind between 200 and 850 hPa level (iv) wind at 200 hPa level based on the ECMWF model analysis of 0000 UTC of 31st October, 2011.

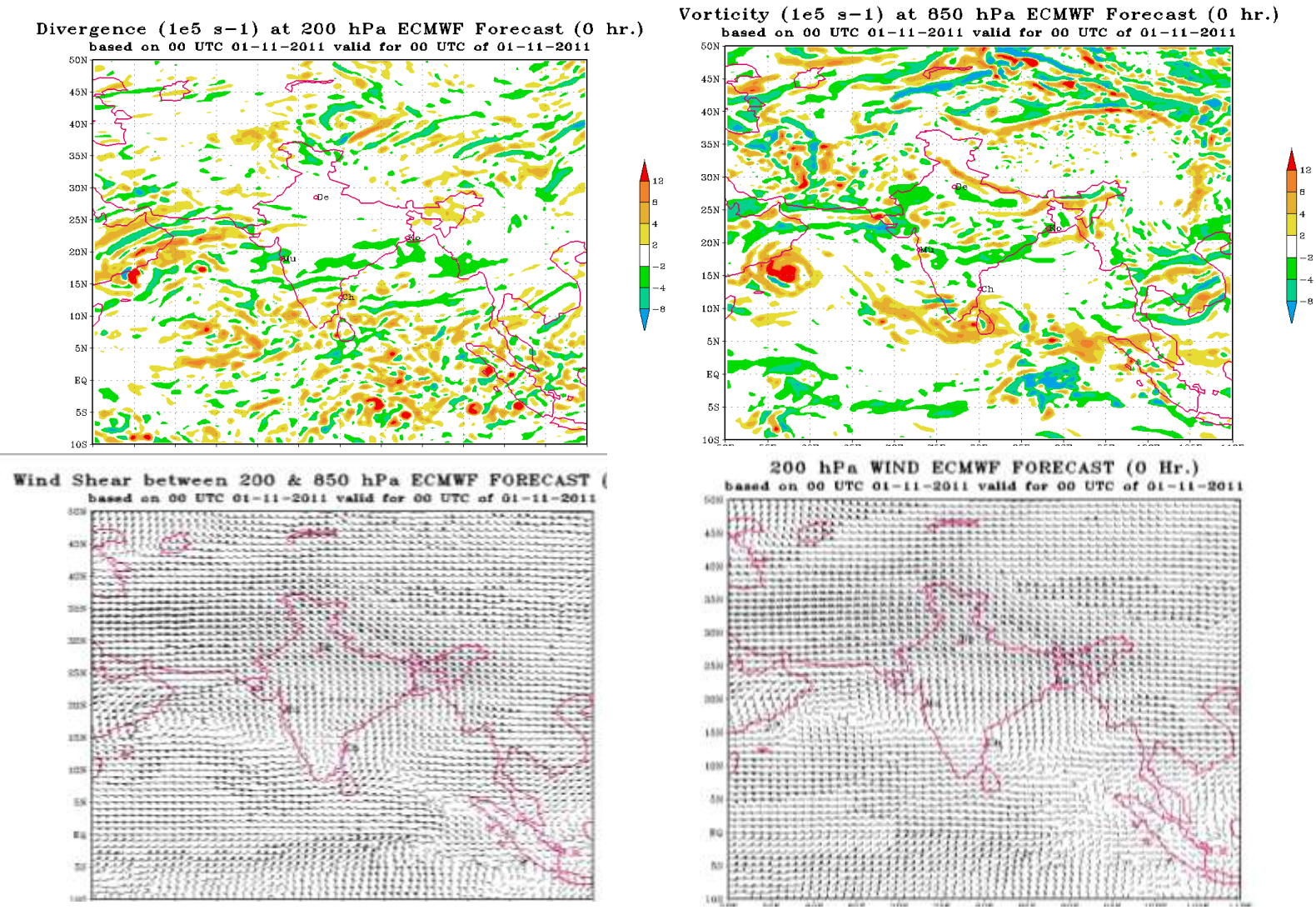


Fig. 7.3 (e) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) vertical wind shear of horizontal wind between 200 and 850 hPa level (iv) wind at 200 hPa level based on the ECMWF model analysis of 0000 UTC of 01st November, 2011.

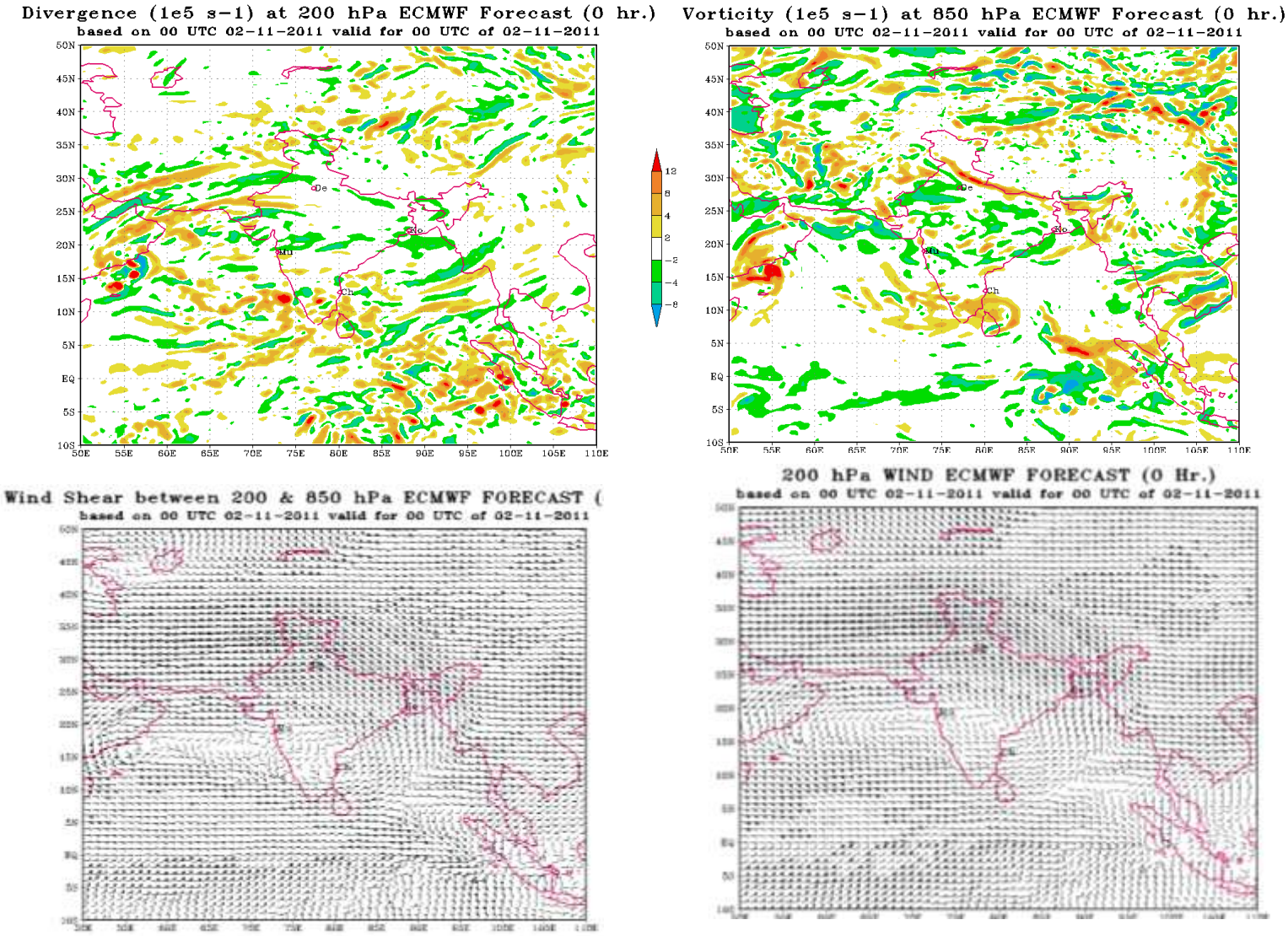
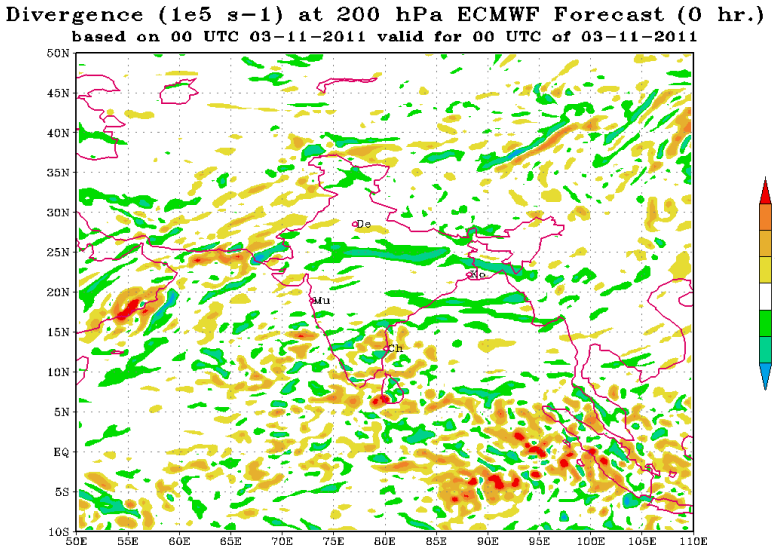
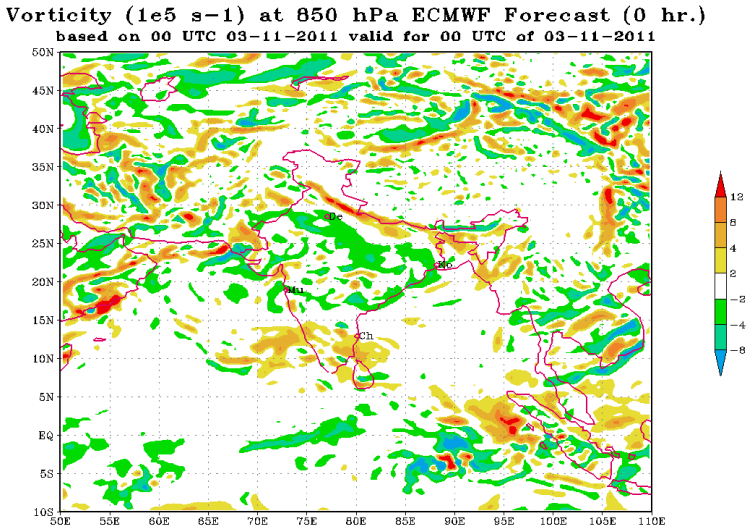
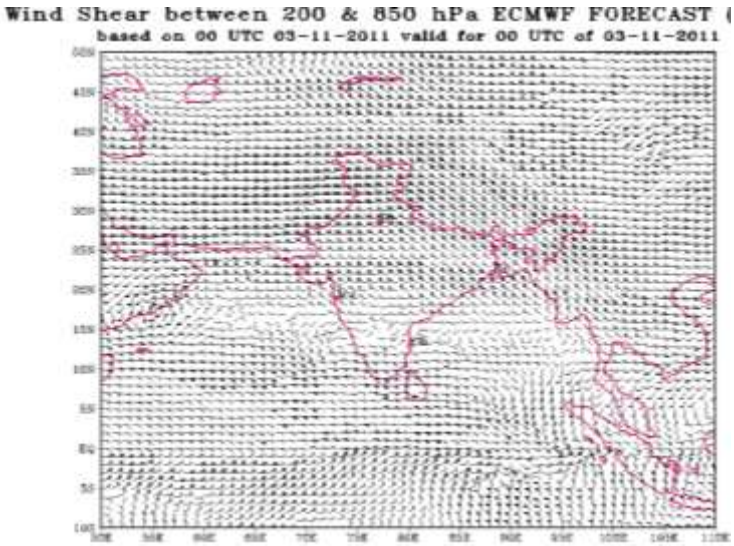


Fig. 7.3 (f) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) vertical wind shear of horizontal wind between 200 and 850 hPa level (iv) wind at 200 hPa level based on the ECMWF model analysis of 0000 UTC of 02nd November, 2011.







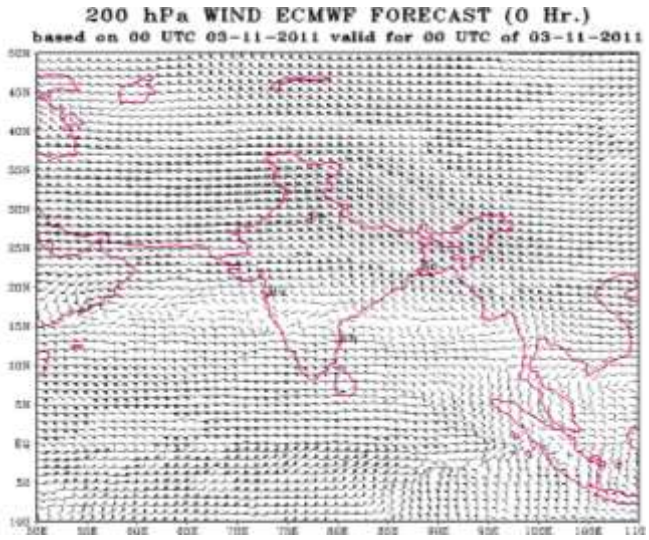


Fig. 7.3 (g) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) vertical wind shear of horizontal wind between 200 and 850 hPa level (iv) wind at 200 hPa level based on the ECMWF model analysis of 0000 UTC of 03rd November, 2011.

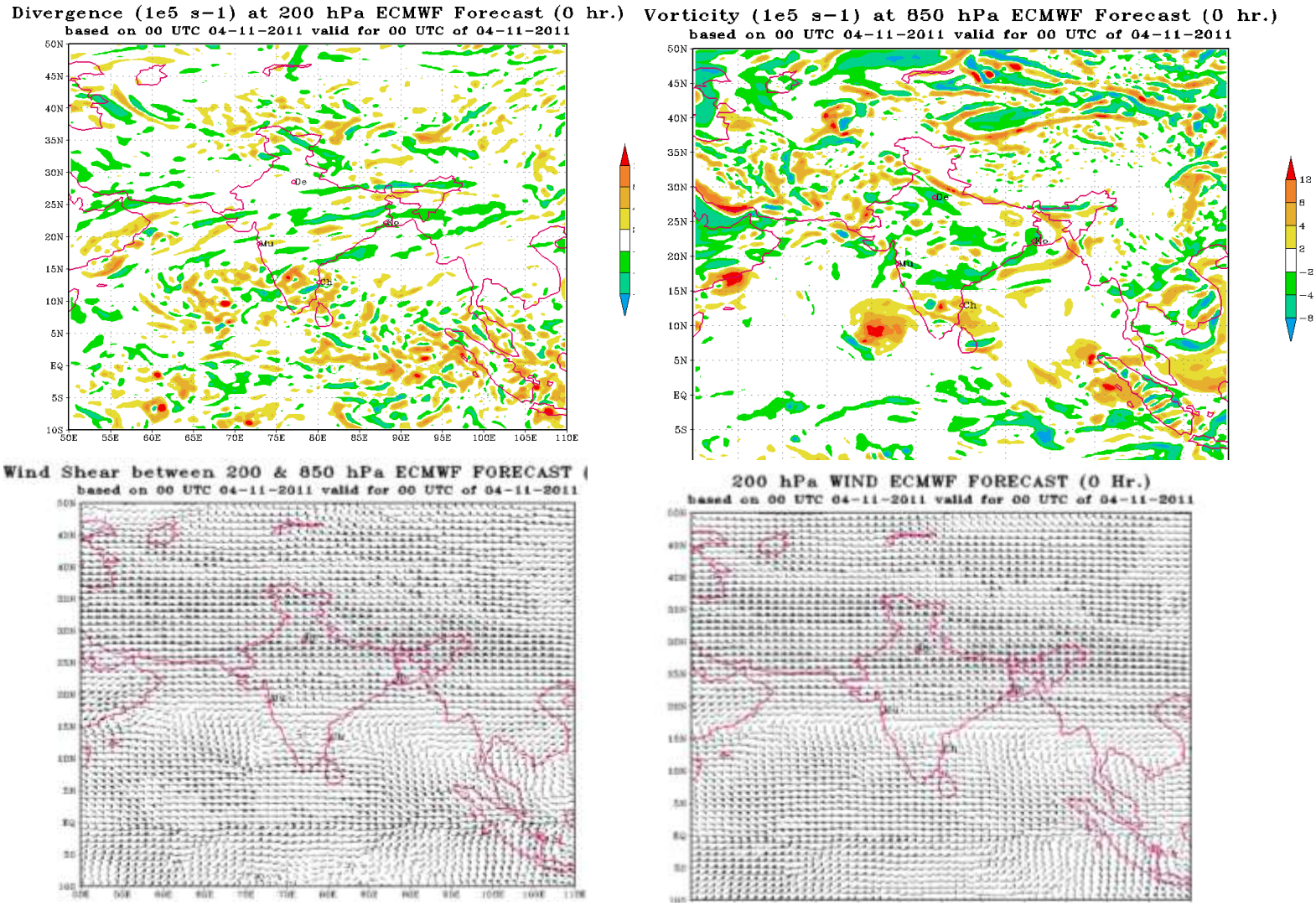


Fig. 7.3 (h) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) vertical wind shear of horizontal wind between 200 and 850 hPa level (iv) wind at 200 hPa level based on the ECMWF model analysis of 0000 UTC of 04th November, 2011.

7.7 Forecast performance:

7.7.1 Track and Intensity Forecast The verification of intensity and track forecast issued by IMD is discussed in table 7.7.1

Table 7.7.1 Average Track & Intensity Forecast Error Cyclonic Storm KEILA

Lead period (hrs)	Average track forecast error (kms)	Average intensity Forecast error (kts)
12	89 (4)	5 (4)
24	177 (4)	7 (4)
36	260 (3)	9 (4)
48	397 (3)	7 (3)
60	336 (1)	10 (1)

The numbers written inside the brackets are the number of forecast verified.

7.7.2 Landfall forecast The landfall forecast error for the system is given in Table 7.7.2

Table 7.7.2 Verification for landfall forecast

Lead Time(hrs)	Landfall point error(Km) (Forecast point - actual point)	Landfall time error (hrs) (Forecast - actual time of landfall)
24	00	-2
36	00	-16
48	00	-16.5