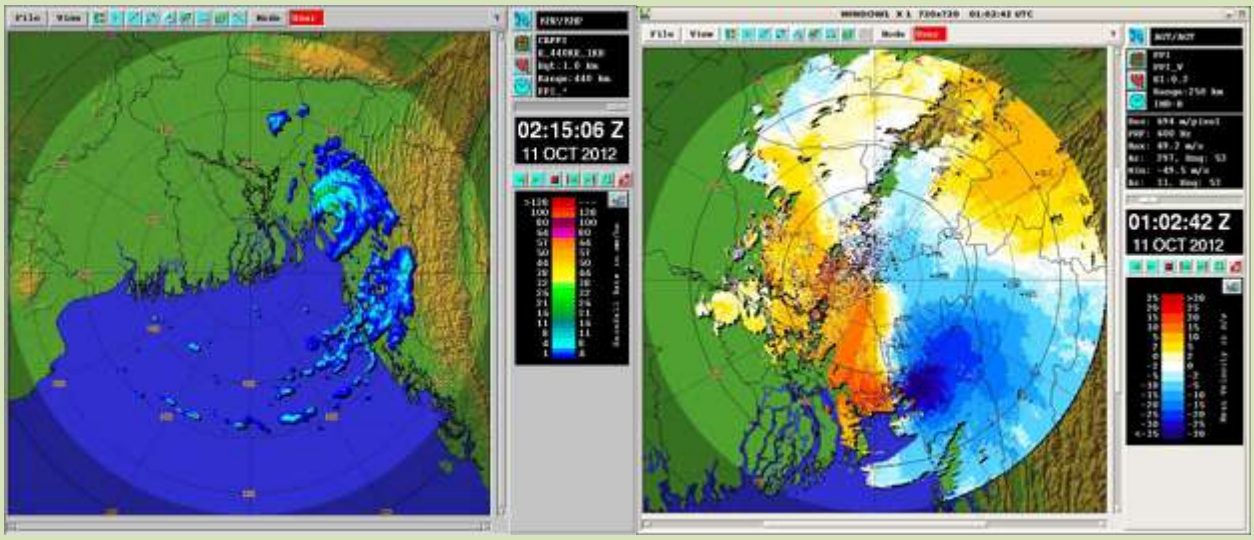
GOVERNMENT OF INDIA

MINISTRY OF EARTH SCIENCES

INDIA METEOROLOGICAL DEPARTMENT

Report on Deep Depression over the Bay of Bengal

10-11 October 2012



DWR imageries from DWR Khepupara and Agartala

CYCLONE WARNING DIVISION, NEW DELHI

OCTOBER 2012

Deep Depression over the Bay of Bengal (10-11 October, 2012)

1. Introduction

A deep depression formed over northeast Bay of Bengal in the evening of 10th October, 2012. It moved northward and crossed Bangladesh coast near Hatia during 11th morning and then moved northeastwards across Bangladesh. It weakened into a well marked low pressure area at 0600 UTC of 11th October, 2012 over Tripura and adjoining Bangladesh and Mizoram. It caused the death of about 43 persons and left several injured in southeastern part of Bangladesh. The salient features of this deep depression were as follows.

(i) It formed from a remnant from the south China Sea which moved across VietNam and Myanmar and emerged into the northeast and adjoining eastcentral Arabian Sea.

(ii) It was short lived with the life period of about 15 hrs

(iii) It intensified into a deep depression before landfall, though it was lying very close to coast.

2. Monitoring of depression

As the deep depression formed over northeast Bay of Bengal close to Bangladesh and Myanmar coasts, it could be monitored with INSAT imageries, microwave imageries from Polar Orbiting Satellites, Doppler Weather Radars (DWR) at Khepupara, Cox's Bazar (Bangladesh) and Agartala. The DWR imageries of Khepupara and Cox's- Bazar and coastal surface observations from Bangladesh were received from Bangladesh Meteorological Department. These products were very helpful for monitoring and prediction of this deep depression. Though the surface observations from Bangladesh could not be received on real time due to problem in Global Telecommunication System (GTS), these data were received through e-mail in late mode. These data were very helpful in reanalysis of the system.

3. Genesis, intensification and movement

A remnant of a tropical storm over south China Sea moved westwards across Vietnam and Myanmar emerged into northeast and adjoining east central Bay of Bengal as an upper air cyclonic circulation on 9th October 2012. It moved northwestwards and was seen as a low pressure area at 0300 UTC of 10th October, 2012. It concentrated into a depression and lay centred at 1200 UTC of 10th October, 2012 over northeast Bay of Bengal near latitude 21.0^0N and longitude 91.0^0E. Track of the system is shown in Fig.1.Sustained maximum surface wind speed was estimated to be about 25 knots gusting to 35 knots around system centre. The state of the sea was rough to very rough around the system centre. The estimated central pressure was about 1003 hPa with outer most closed isobar as 1006 hPa. The 24

hrs pressure tendency was negative and about 1 hPa along Bangladesh coast. The best track parameters are shown in Table 1

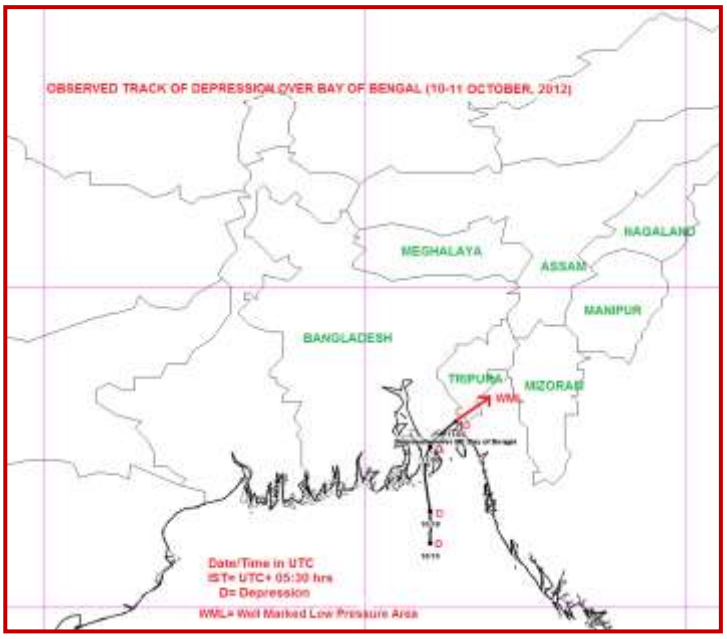


Fig.1.Track of the depression over Bay of Bengal (10-11 October, 2012)

Table 1 The best rack position and other parameters of deep depression over the Bay of Bengal during 10-11 October, 2012

Date	Time (UTC)	Centre lat.^{0} N/ long.^{0} E	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimated Pressure drop at the Centre (hPa)	Grade
10.10.2012	1200	21.0/91.0	1.5	1003	25	3	D
	1500	21.5/91.0	1.5	1003	25	4	D
	1800	22.0/91.0	2.0	1002	30	5	DD
11.10.2012	0000	22.5/91.3	2.0	1002	30	5	DD
	Deep Depression crossed near Hatia (Bangladesh) between 0000-0100 UTC						
	0300	23.0/91.5	1.5	1006	20	3	D
	0600	Weakened into a well marked low pressure area over Mizoram & neighbourhood					

In association with favourable environmental conditions like low to moderate wind shear, increase in convergence and vorticity in lower levels, increase in upper level divergence and its location near the upper tropospheric steering ridge, the

depression moved northward and intensified into a deep depression 1800 UTC of 10th October. It then moved north-northeastwards as the system lay close to the north of the upper tropospheric ridge. The deep depression crossed Bangladesh coast near Hatia between 0000-0100 UTC of 11th October, 2012. The associated sustained maximum wind speed at the time of landfall was about 30 knots.

After the landfall, the deep depression continued to move north-northeastwards, weakened into a depression and lay centred at 0300 UTC over Bangladesh and adjoining Tripura near latitude 23.0^{0}N and longitude 91.5^{0}E, about 100 km south of Agartala. It then continued to move northeastwards and further weakened into a well marked low pressure area over Tripura and adjoining Bangladesh and Mizoram at 0600 UTC of 11th October, 2012. It further weakened and moved away northeastwards towards Myanmar on 12th October, 2012 morning. There was rapid weakening of the system after the landfall, as it interacted with the hilly land surface and was cut-off from moisture alongwith feeding of cold and dry wind at middle tropospheric level over the northeast in association with the mid-latitude trough in westerlies over the region.

4. Synoptic features

The reanalyzed synoptic charts based on 1200, 1500, 1800 UTC of 10th and 0000, 0300 and 0600 UTC of 11th October are shown in Fig.2. It indicates that the lowest Estimated Central Pressure (ECP) was 1002 hPa during 1800 UTC of 10th to 0000 UTC of 11th October, 2012. The maximum pressure drop at the centre during this period was 5 hPa. The pressure gradient was more towards Bangladesh coast. Considering the 24 hr pressure changes in every three hourly interval, the maximum pressure fall of 3.6 hPa was reported by Hatia (Bangladesh) at 1800 UTC of 10th October with mean sea level pressure (MSLP) of 1004.8 hPa. Thereafter, the pressure increased over this station. The lowest pressure of 1002 hPa has been reported by Chittagong at 0000UTC of 11th October 2012, when the deep depression was lying west of this station. The pressure over Chittagong increased thereafter becoming 1006hPa at 0300 UTC of 11th, when the system weakened into a depression and lay to the north-northwest of Chittagong. Chittagong reported maximum wind

5. Features observed through satellite imageries

The system was monitored with Kalpana-1 imageries and products during 10th and 11th October 2012. The satellite Division of IMD assigned T1.0 as per Dvorak's classification to the vortex at 0300UTC of 10th October. As per reanalysis by Satellite Division of IMD, the vortex lat centred near lat. 19.5^{0}N and long. 91.5^{0}E at 0300 UTC, near 21.0^{0}N and long. 91.0^{0}E at 1200 UTC, near 21.5^{0}N and long. 91.0^{0}E at 1700 UTC, near 22.0^{0}N and long. 91.0^{0}E at 2100 UTC of 10th and near lat. 22.5^{0}N and long. 91.5E at 0000UTC of 11th October 2012. It lay centred over land near lat. 23.0^{0}N and long. 91.5^{0}E at 0300 UTC of 11th October. Hence, according to satellite imageries, the vortex initial moved northwestwards during 0300 to 0600 UTC of 10th

and then it moved northwards till 0000 UTC of 11th October. It then moved north-northeastwards. It continued as T1.0 till 0900UTC of 10th and was assigned as T1.5 at 1200 and 1500 UTC and T2.0 from 1800 UTC of 10th to 0000UTC of 11th October. As per satellite imageries, the convective clouds started disorganising at 0300UTC of 11th and further disorganization took place at 0300 and 0600UTC of 11th while moving north-northeastwards. According to satellite reanalysis, The T number was 1.5 at 0900 UTC and became 2.0 at 1500 UTC of 10th October. It continued the same till the landfall.

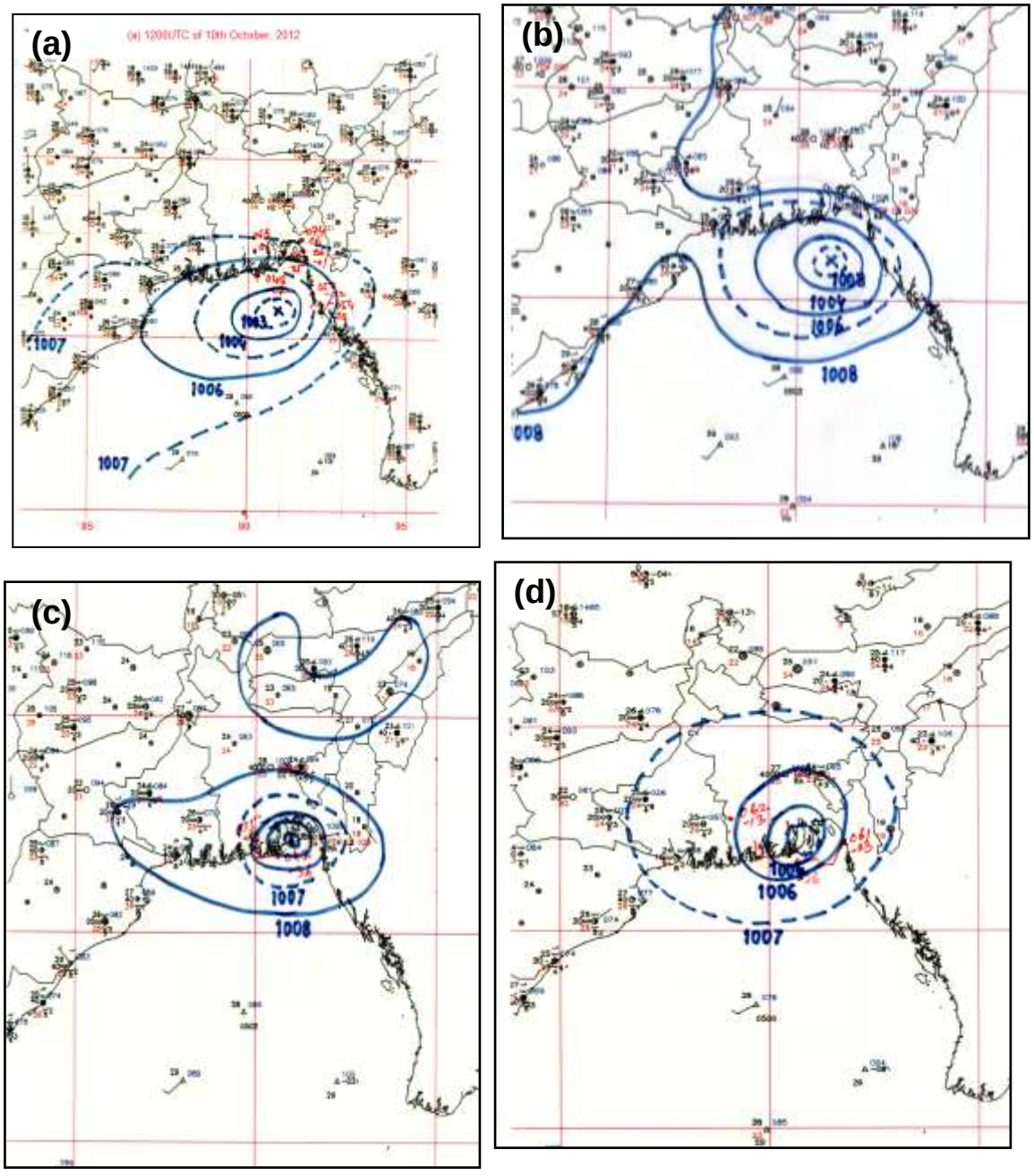


Fig.2 (a-d) Mean sea level pressure analyses of 10th October 2012 (a) 1200UTC, (b) 1500 UTC, (c) 1800 UTC and (d) 2100 UTC.

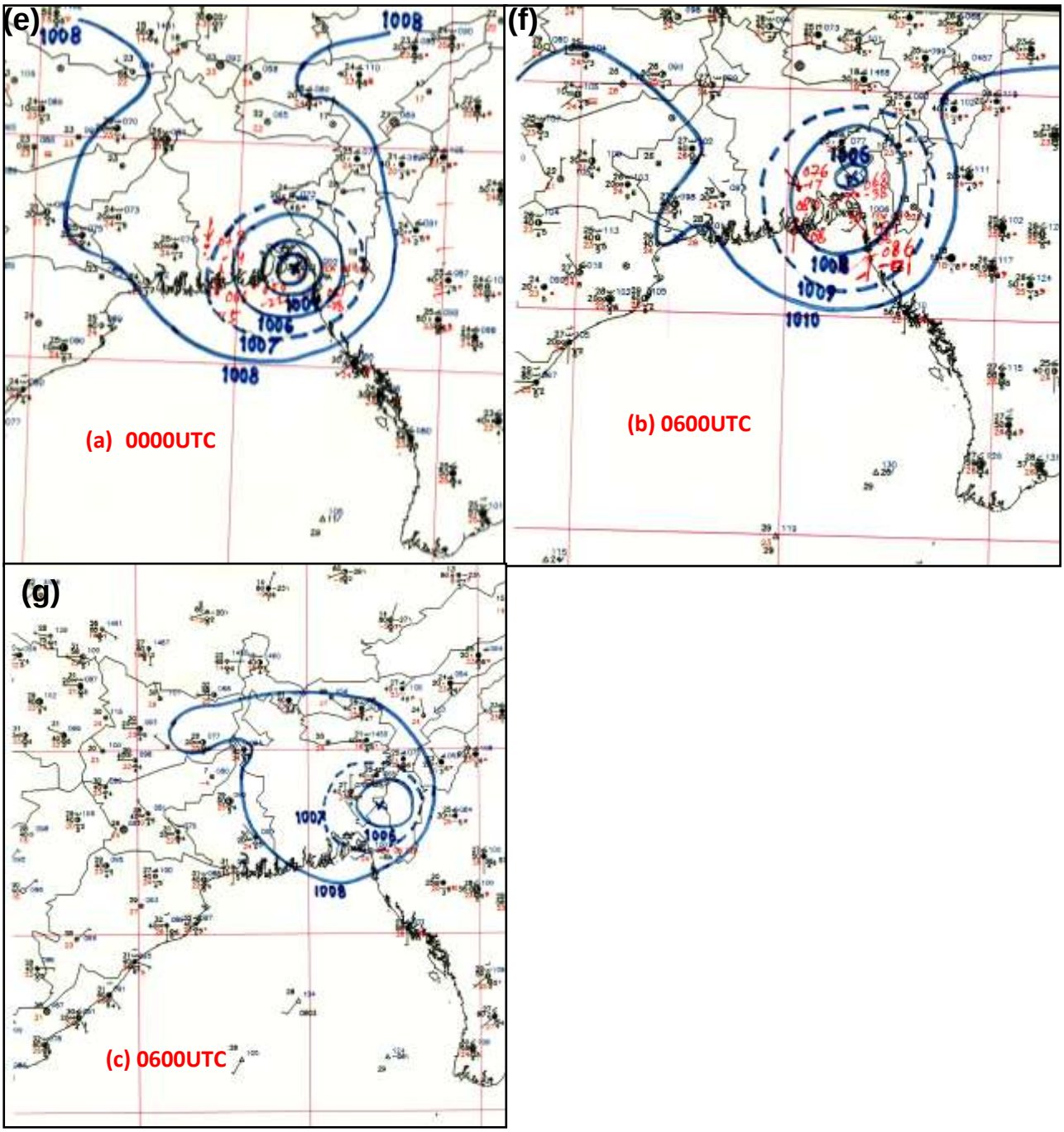


Fig.2 (e-g) Mean sea level pressure analyses of 10th October 2012 (e) 0000UTC, (f) 0300 UTC, (g) 0600 UTC.

The typical satellite imageries are shown in Fig.3 (a-b) during the life period of the deep depression. These imageries clearly indicated the convective cloud bands in association with the system. The lowest cloud top temperature (CTT) of about -80^{0}C was recorded during 10th night. However, it increased and was about -70^{0}C at 0000 UTC of 11th. As a result, the depth of convection was less during the landfall and thereafter which led to relatively less intense rainfall. The maximum amount of

rainfall was about 11 cm as shown on the realized weather section below. The IR imageries with CTTs during 10th and 11th October 2012 are shown in Fig.4.

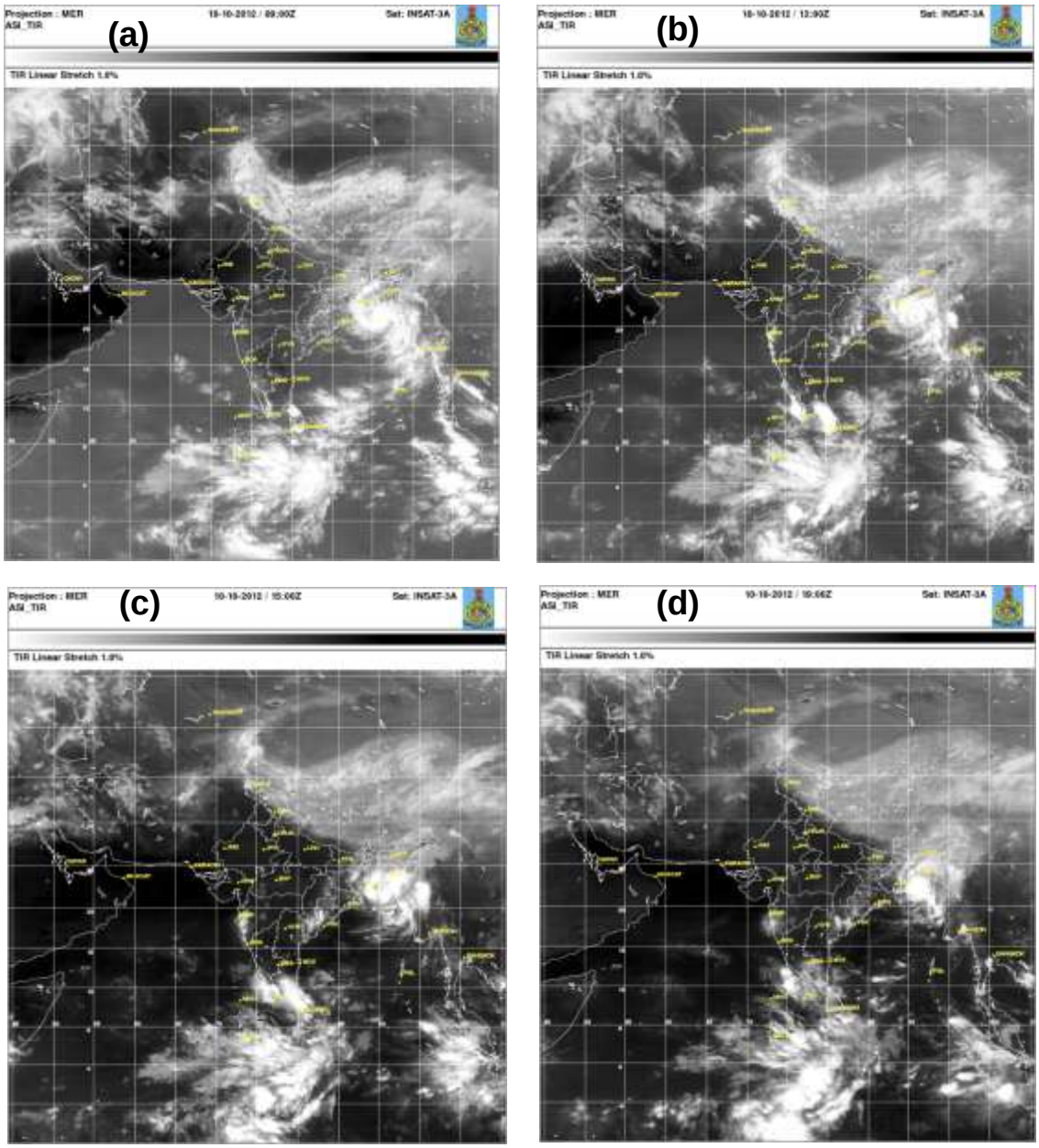


Fig.3(a-d): Satellite imageries of depression of (a) 06, (b) 09, (c) 12 & (d) 19 UTC of 10th October, 2012

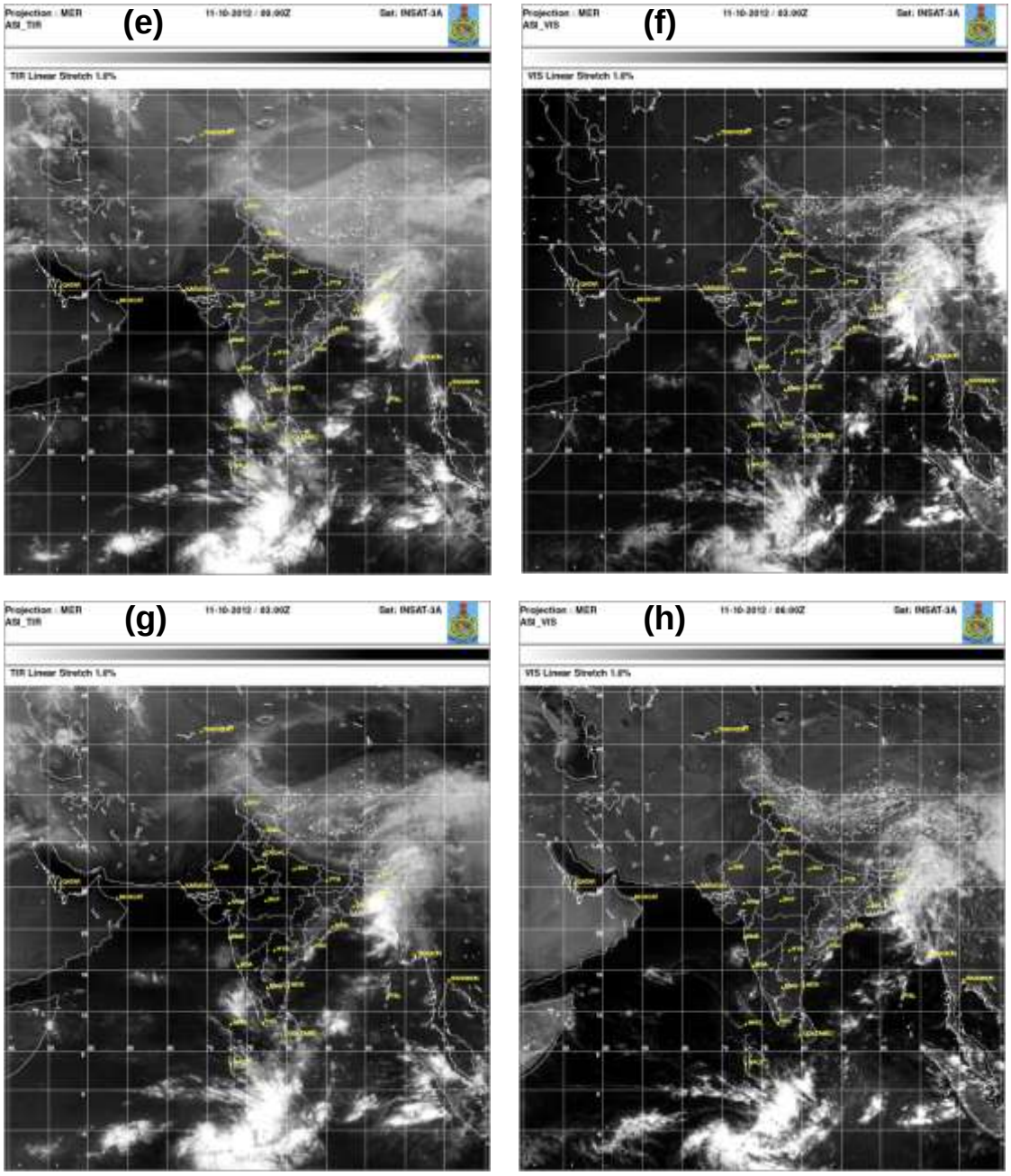


Fig.3(e-h): Satellite imageries (VIS. & IR) of depression of (e) 00, (f) 03(vis), (g) 03(IR) and (h) 06 UTC of 11th October, 2012

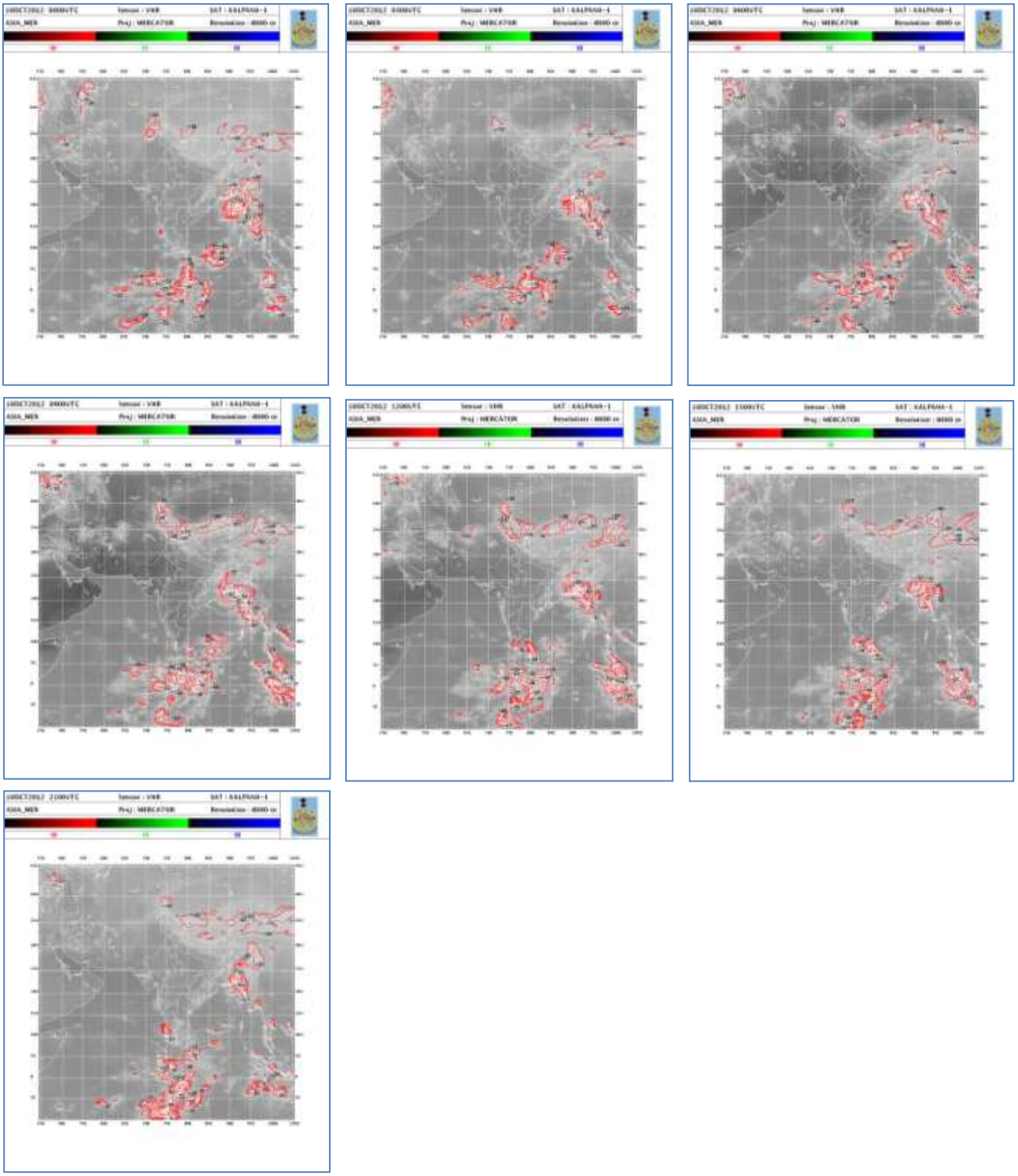


Fig.4(a).IR imageries with Cloud Top Temperature (CTT) at 0000, 0300, 0600, 0900, 1200, 1500 and 2100 UTC of 10th October, 2012

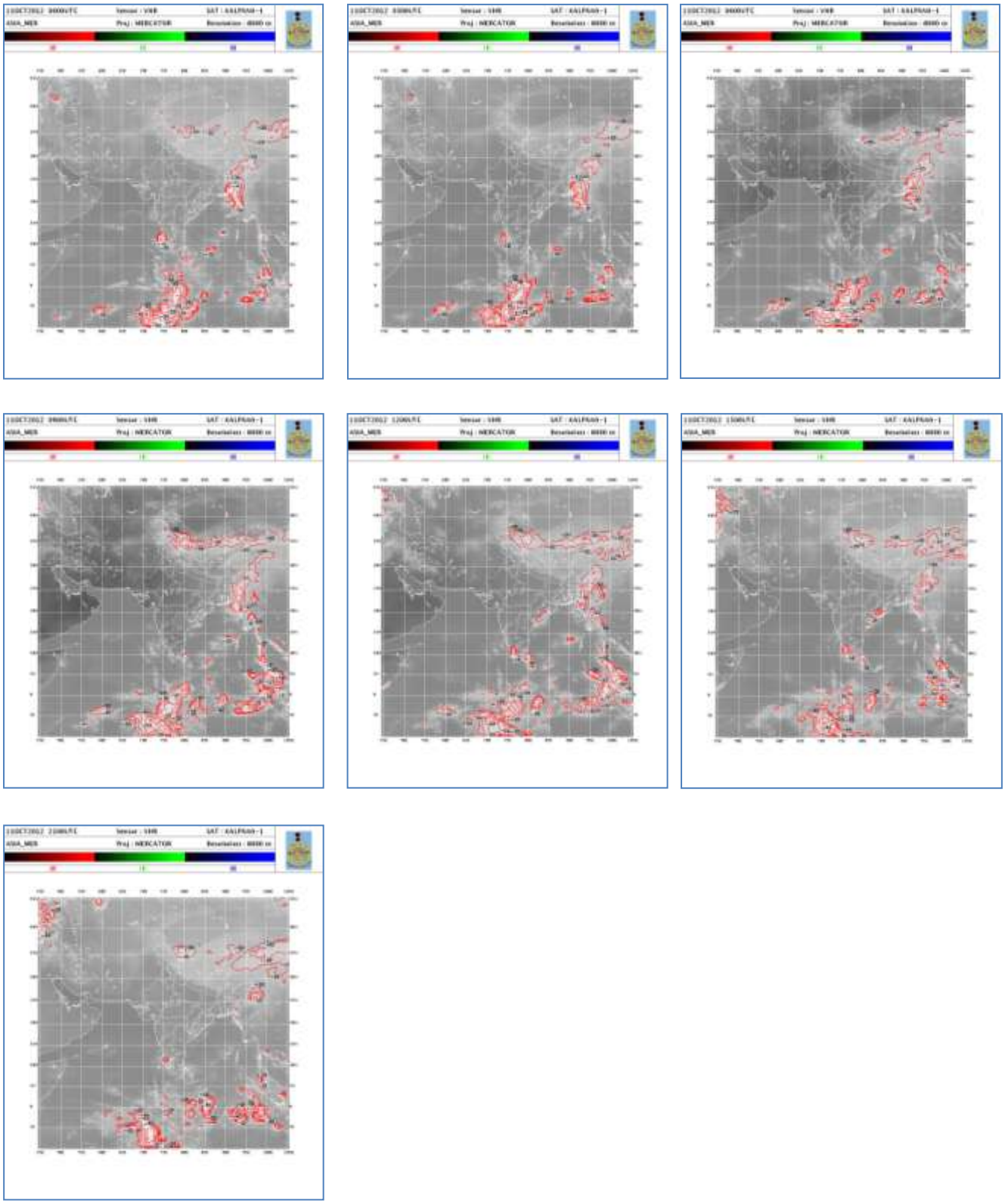


Fig.4(b). IR imageries of Cloud Top Temperature (CTT) for 0000, 0300, 0600, 0900, 1200, 1500 and 2100 UTC of 11th October, 2012

6. Features observed through DWR imageries

The deep depression was monitored with the DWR at Khepupara, Cox's Bazar and Agartala as mentioned earlier. The typical DWR imageries from these DWRs are shown in Fig.5. These imageries clearly indicated the convective cloud bands in association with the system.

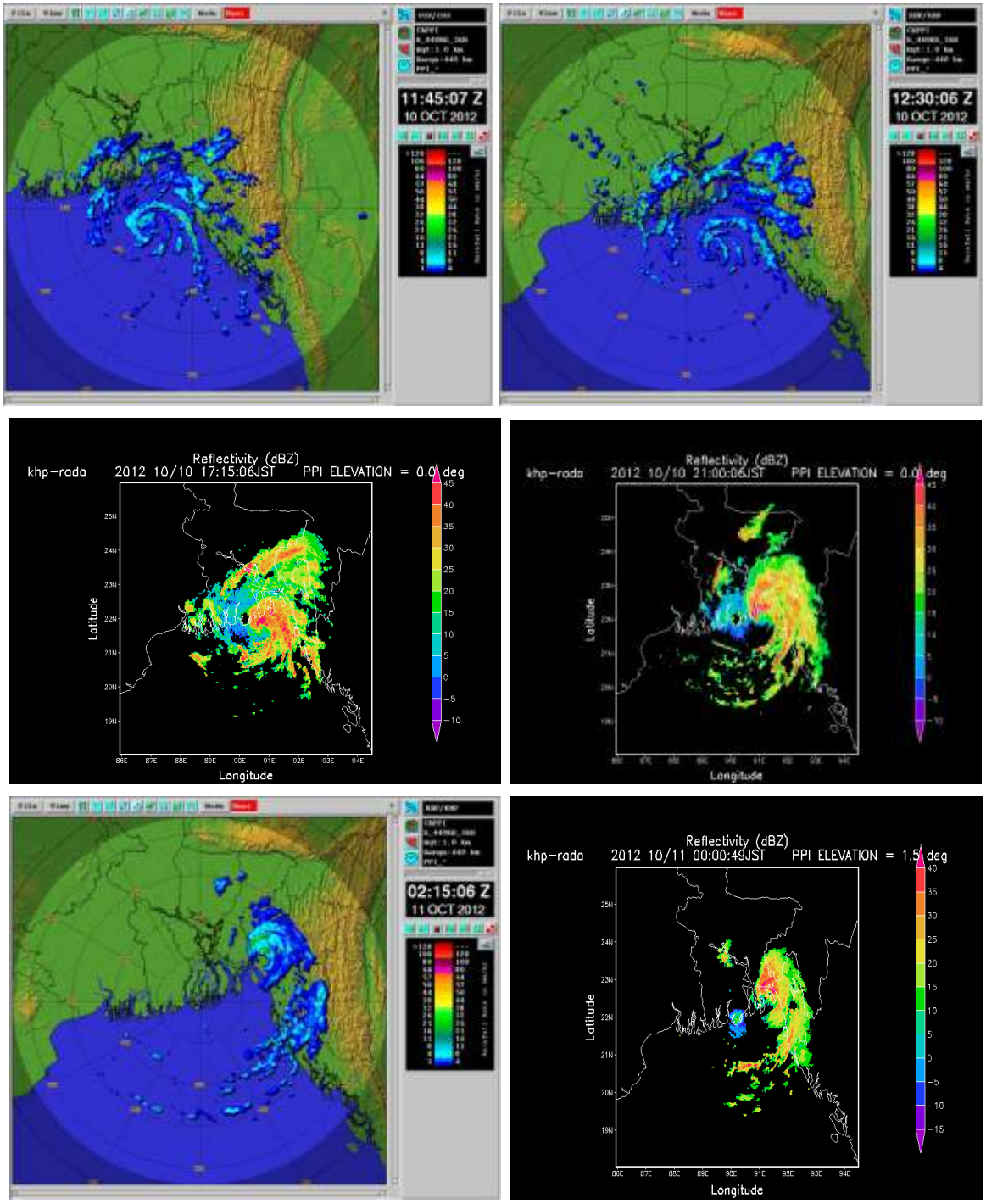


Fig.5(a): Radar imageries of deep depression over Bay of Bengal at 1145 UTC and 1230 UTC, 1715 JST, and 2100 JST of 10th October and 0000 JST and 0215 UTC of 11th October, 2012 from Cox's Bazar and Khepupara respectively

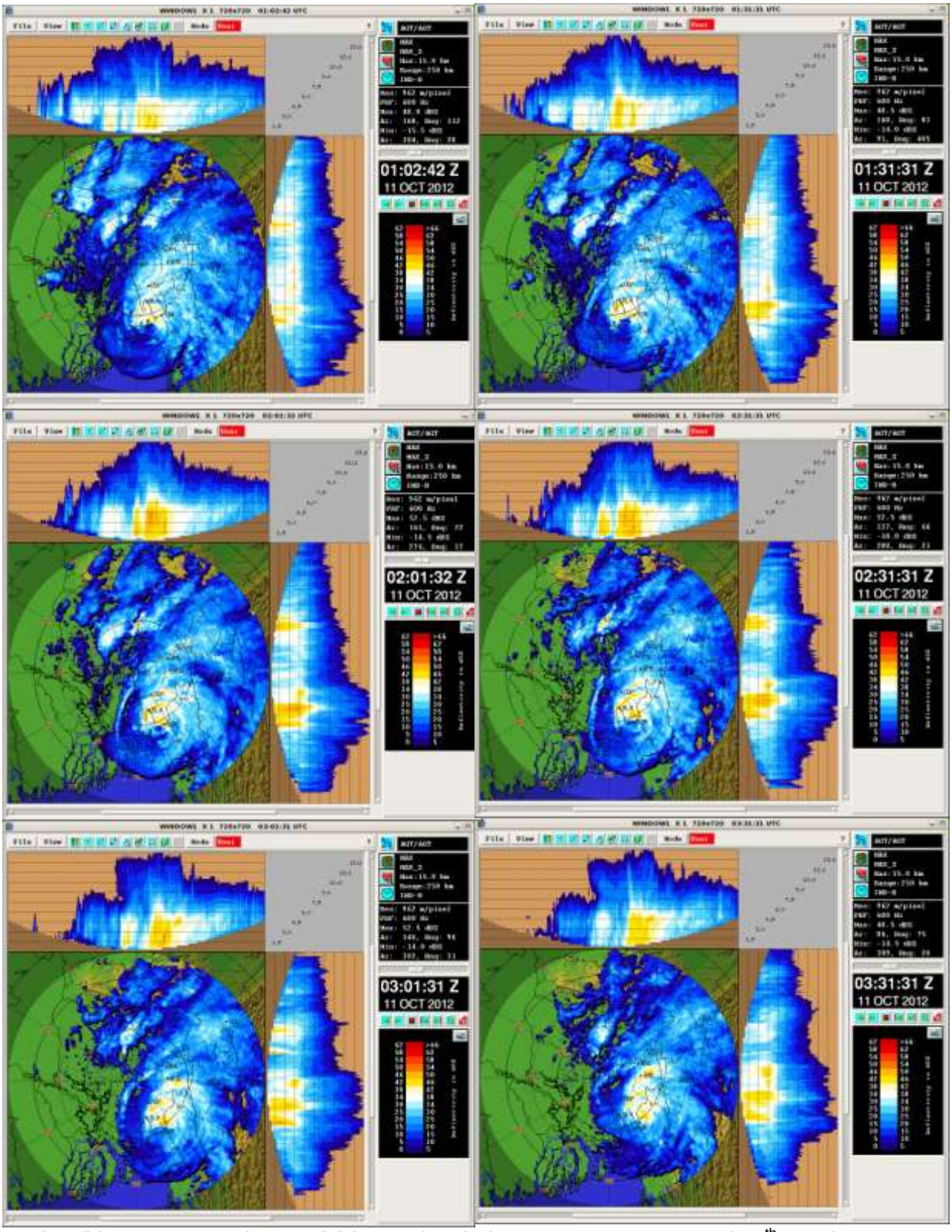


Fig.5(b) DWR, Agartala MAX(Z) imageries during 0100 to 0330 UTC of 11th October, 2012

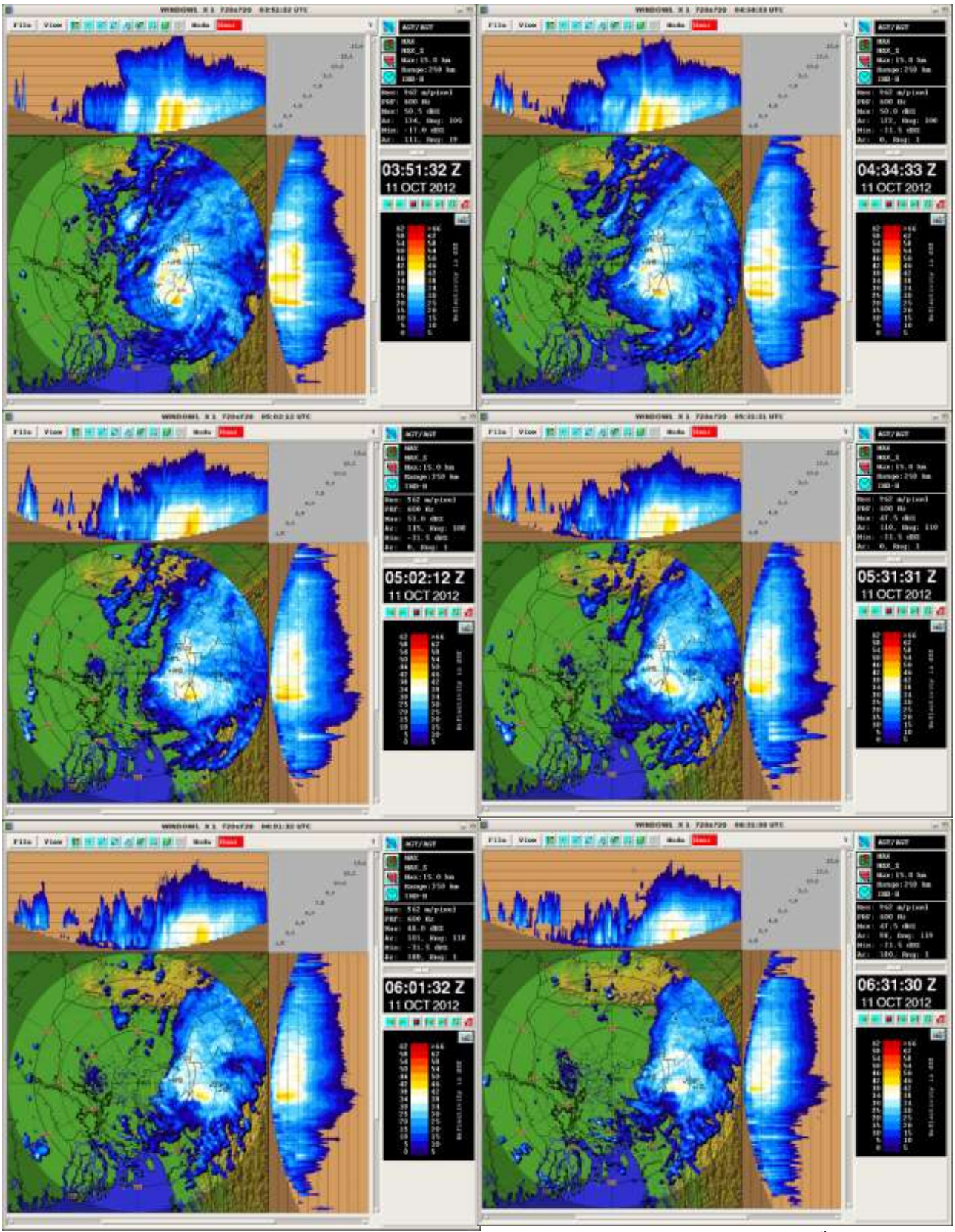


Fig.5(b)(Contd)DWR, Agartala MAX(Z) imageries during 0350 to 0630 UTC of 11th October.

However, as per DWR imageries, the reflectivity of the convective clouds was relatively less (50DB). As a result, the intensity of rainfall due to the system was limited to about 10 cm per hours. The centred determined by DWR imageries are in agreement with the centres mentioned in the best track (Table 1).

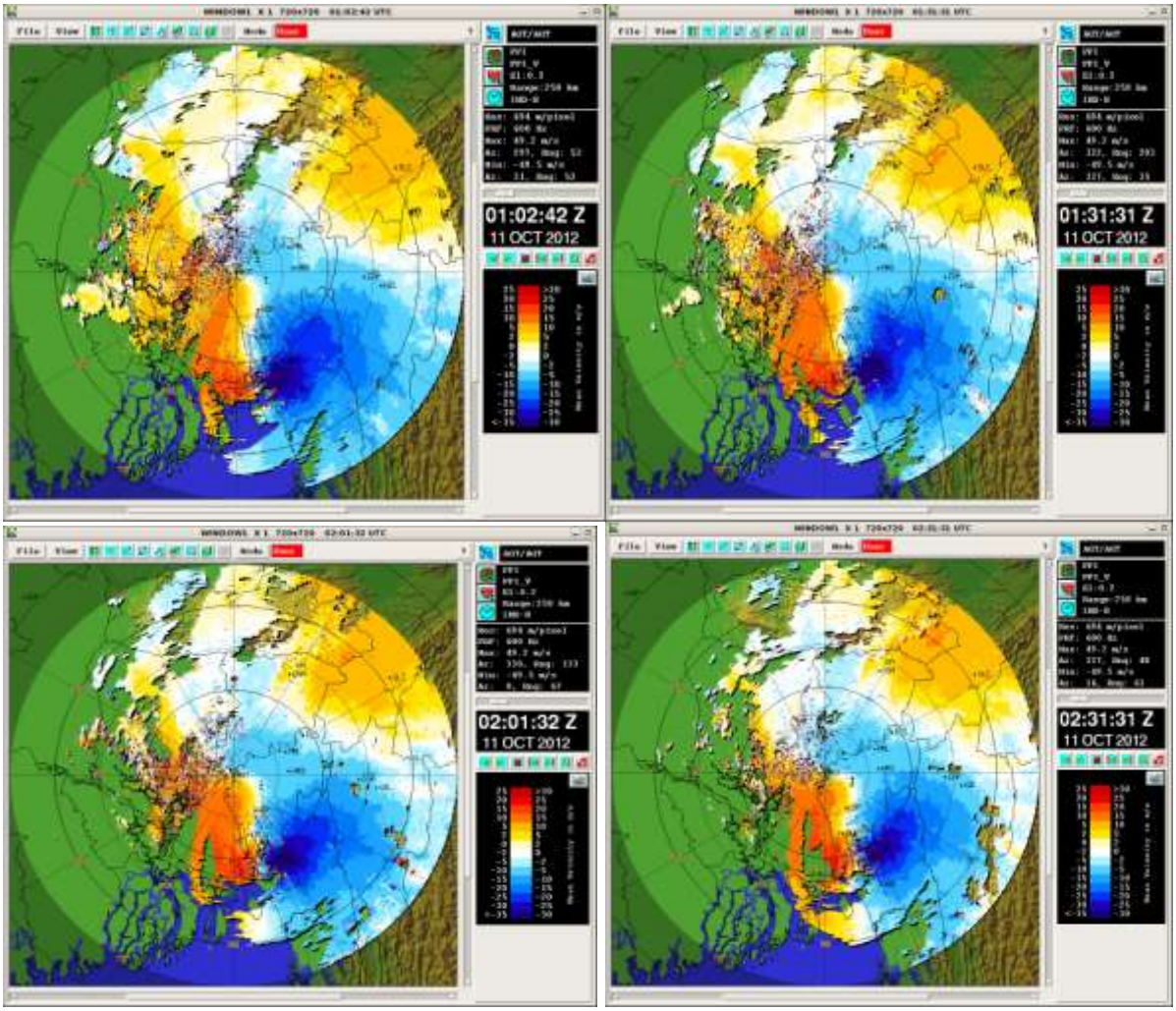


Fig.6. DWR, Agartala PPI-V imageries at elevation of 0.2^0 during 0100 to 0230 UTC of 11^{th} October 2012.

The PPI-V imageries from DWR, Agartala are shown in Fig.6 for the period of 0100 to 0230 UTC at the interval of half an hour. It indicates that the wind speed was higher in the southeastern quadrant of the deep depression at the time of landfall. The wind speed gradually decreased as the deep depression moved over land surface in the north-northeast direction. The radial wind of about 25-30 meter per second (48=58 knots) has been report by DWR, Agartala in the southeast direction at a distance of about 130 km and with an elevation angle of 0.2^0. As there is no conversion formula available in the literature for conversion of radial wind measured by a DWR at a certain elevation to the surface wind, the conversion method used for conversion of flight level wind of reconnaissance aircraft to the surface wind (James

Franklin, 2000) has been used to calculate the surface wind. As per this method, the radial wind speed of 25-30 meter per second at a height of 1 km is equivalent to 36-44 knots at surface level.

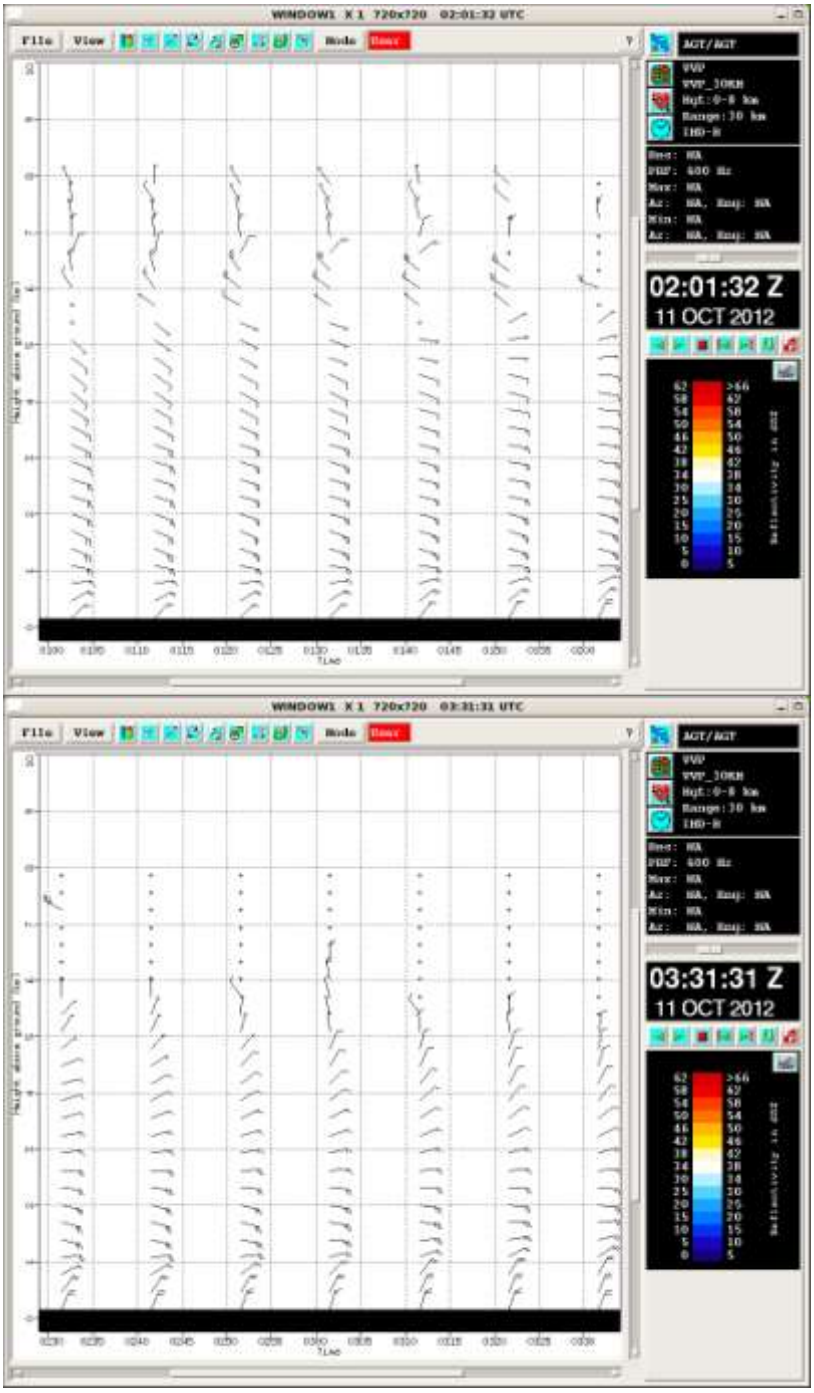


Fig.7. Wind observed over Agartala as per DWR, Agartala during 0100 to 0330 UTC of 11th October 2012.

The wind reported over Agartala as observed through DWR, Agartala is shown in in Fig.7. It indicates that Agartala experienced 15-20 knots wind at the surface level during 0100-0300 UTC. The wind backed over time indicating north-

northeastward movement of the system. The wind speed gradually decreased and became about 5 knots around 0600 UTC.

7. Dynamical features

The low level convergence as well as upper level divergence and lower level relative vorticity had increased on 10th October. The vertical wind shear between 200 and 850 hpa levels was low to moderate (10-20 knots) around system centre. However, it increased towards Bangladesh coast. The upper tropospheric ridge lay along 20^0 N and hence close to system centre. This ridge moved northward alongwith the movement of the system. Helce, it helped in northward movement of the system. However, at 0000 UTC of 11th the system lay close to the north of the system centre. Further, a trough in mid-tropospheric westerlies roughly ran along 80^0E to the north of 18^0N. Under these conditions, the system moved north-northeastwards and weakened over the land surface.

The Meteosat-7 satellite based derived products, viz., middle and upper tropospheric water vapour derived wind vectors, lower level cloud motion vectors, vertical wind shear of horizontal wind, lower level convergence and relative vorticity and upper level divergence at 1200 UTC of 10th October 2012 are shown in Fig.8 to illustrate the above facts.

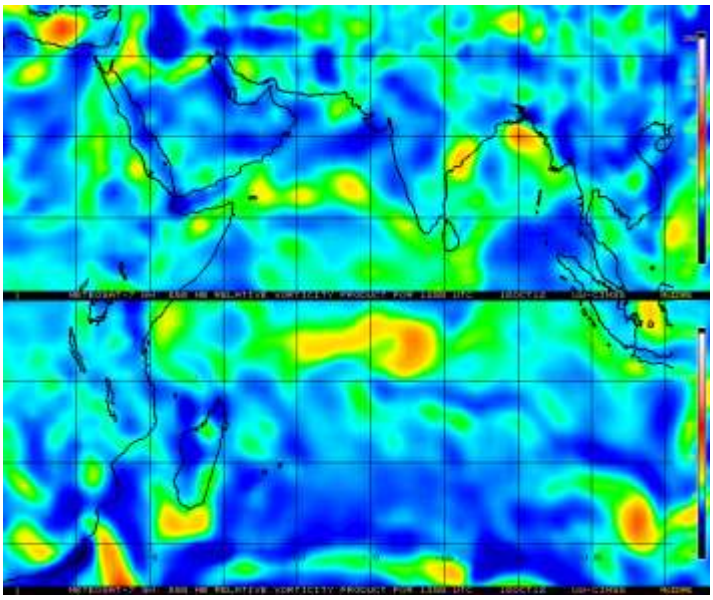


Fig.8(a). Meteosat-7 satellite based lower level relative vorticity at 1200 UTC of 10th Oct. 2012

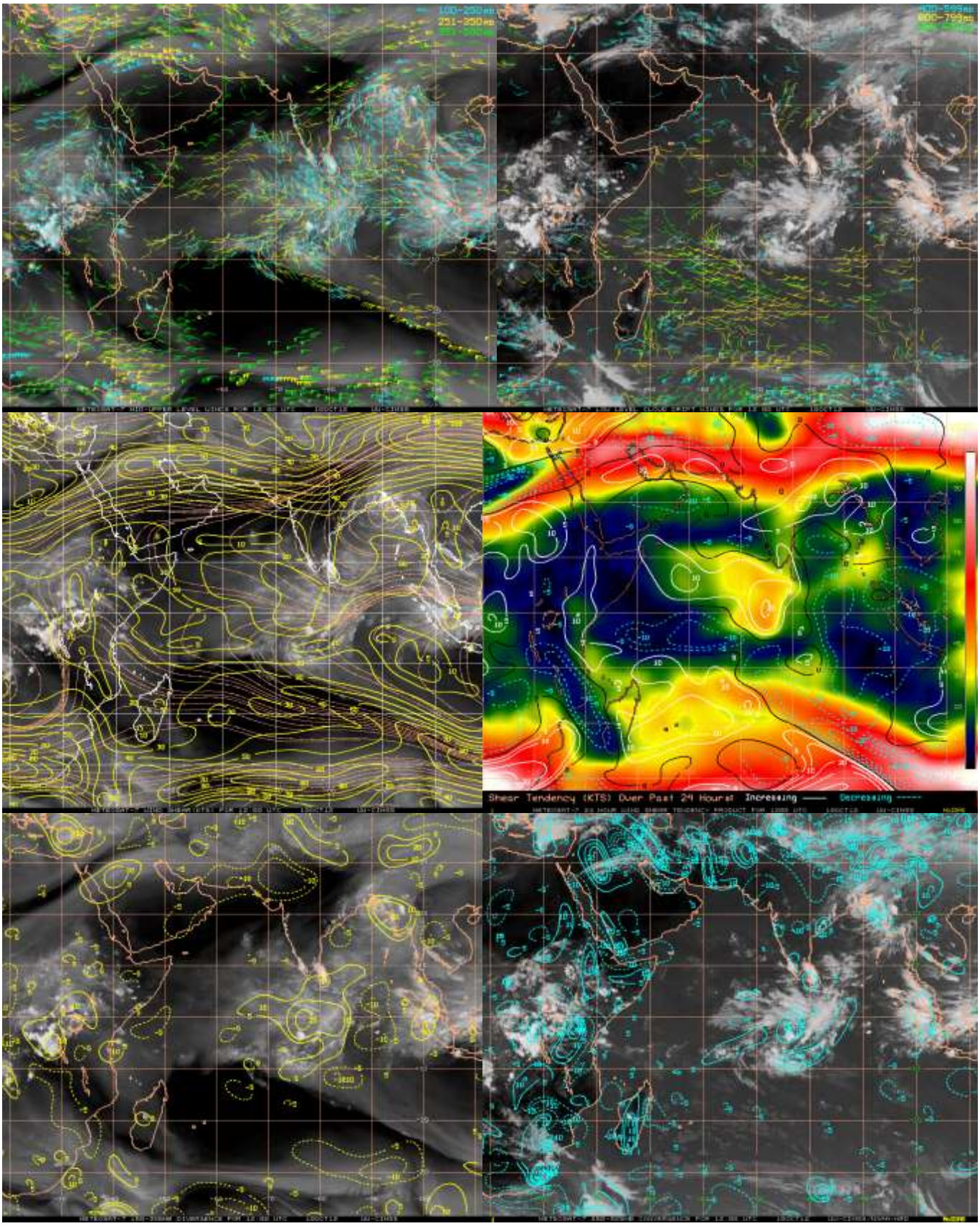


Fig.8(b-g). Meteosat-7 satellite based derived products (b) middle and upper tropospheric water vapour derived wind vectors, (c) lower level cloud motion vectors, (d) vertical wind shear of horizontal wind, (e) 24 hr tendency of vertical wind shear (f)

lower level convergence and (g) upper level divergence at 1200 UTC of 10th October 2012.

8. Large scale features

Considering the environmental features, the Madden Julian Oscillation Index lay over phase 6 with amplitude of 1 on 10th October, 2012. As per statistical and NWP model predictions, it was expected to lie in phase 7 during next 2-3 days with decrease in amplitude. Hence it was not favourable for intensification. The sea surface temperature was about 29-30^{0}C over north Bay of Bengal. The ocean thermal energy was 50 - 60 KJ/cm^2 around the system centre. It decreased towards Bangladesh coast. Hence it was also not favourable for further intensification into cyclonic storm. The deep depression did not intensify further as it lay over the area with less Ocean thermal energy and increased vertical wind shear near Bangladesh coast. The interaction with land also did not favour further intensification.

9. NWP Guidance

The NWP guidance from global models kike IMD GFS, NCEP GFS, ECMWF, NCMRWF Unified model, UKMO, mesoscale models like IMD WRF model and ensemble forecast system like NCMRWF global ensemble forecast system (GEFS) were utilised for monitoring and prediction of track and intensity of deep depression. In the analysis field, the ECMWF model, Unofied model and Meteo-France model could detect the genesis in their analysis fields of both pressure and wind. However, the maximum intensity of the system was depression as per these models. IMD GFS and NCMRWF-GEFS could not detect the system. However, these models showed maximum intensity of a low pressure area.

Considering the NWP model guidance, the genesis of the depression could be predicted by ECMWF, Meteo-France and Unified models based on the initial conditions of 1200 UTC of 9th October and 0000 UTC of 10th October, 2012. IMD GFS and WRF models predicted a low pressure area based on these initial conditions. Above mentioned global models did not suggest further intensification of the system limiting the maximum intensification upto depression stage. Most of the models suggested northward movement and landfall over Bangladesh coast near 91^0 E by 11th October morning and further northeastward movement.

The IMDGFS, ECMWF, NCMRWF Unified Model and GEFS analysis and forecast products for 24 & 48 hr forecast period based on initial conditions of 0000 and 1200 UTC of 10th and 11th October, 2012 are shown in Fig.9-14.

To summarise the performance of the NWP models, though the track could be predicted well by most of the NWP models, the genesis and intensity of the system could not be well predicted by many models. The intensity remained under-predicted by all the models with ECMWF and unified model being closer to realized intensity of the system.

The analysis and forecast fields based on initial conditions of 0000 and 1200 UTC of 10th and 11th October 2012 in respect of IMD GFS, ECMWF, Unified Model of NCMRWF are shown in the Figures.

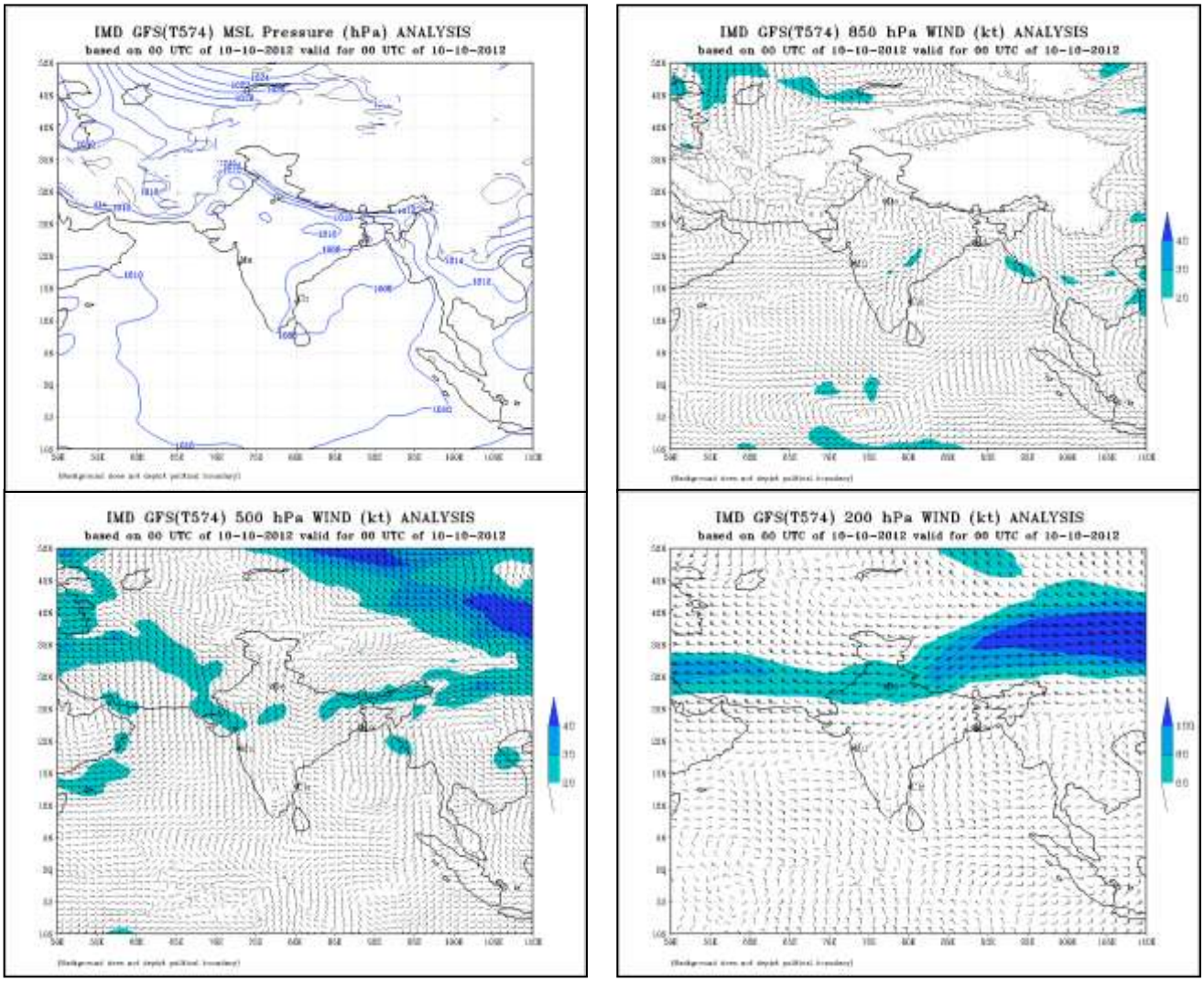


Fig. 9(a) IMD GFS pressure and wind analysis (850, 500 & 200 hPa) based on 0000 UTC of 10th October, 2012.

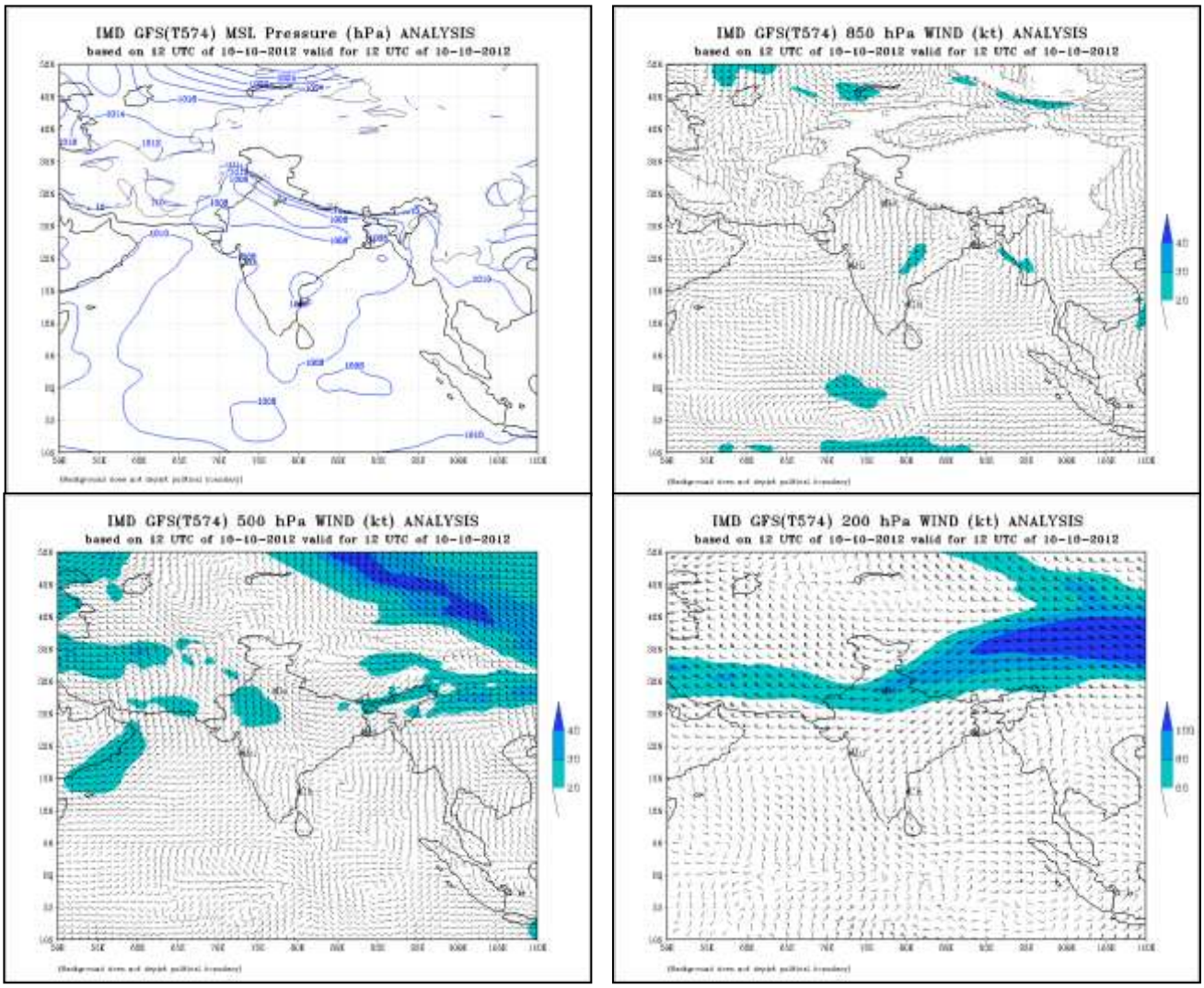


Fig. 9(b) IMD GFS pressure and wind analysis (850, 500 & 200 hPa) based on 1200 UTC of 10th October, 2012.

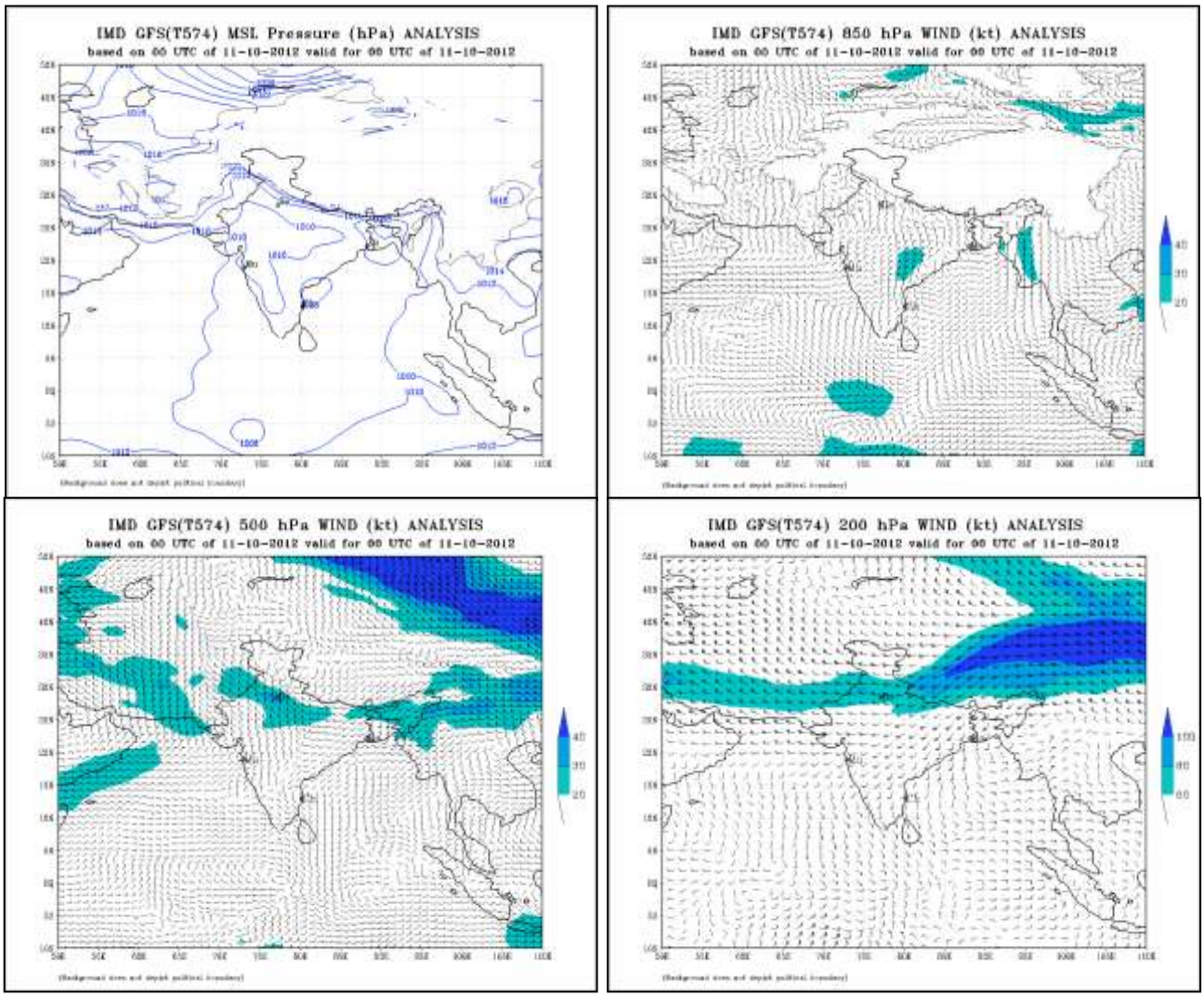


Fig.9(c) IMD GFS pressure and wind analysis (850, 500 & 200 hPa) based on 0000 UTC of 11th October, 2012.

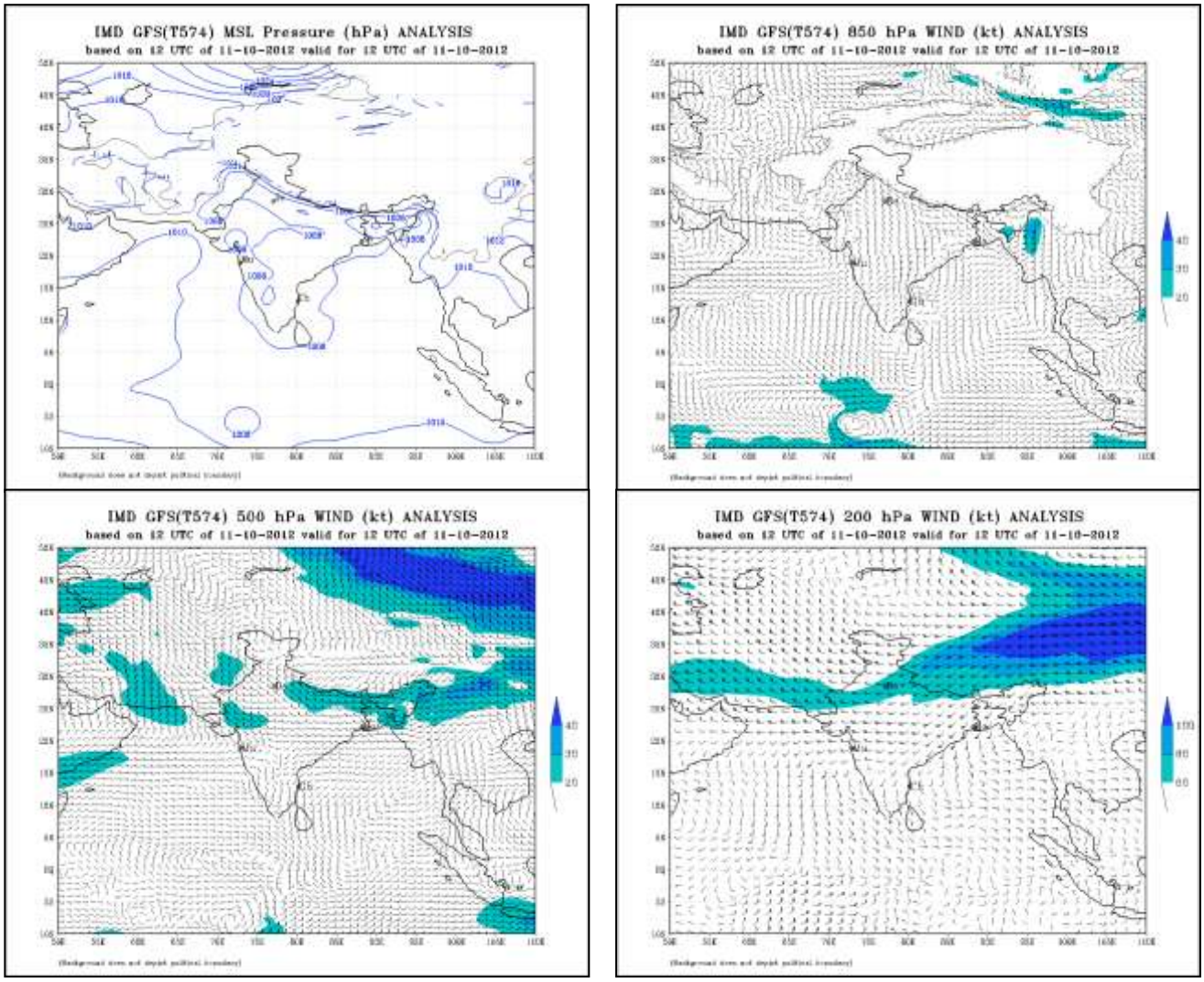


Fig. 9(d) IMD GFS pressure and wind analysis (850, 500 & 200 hPa) based on 1200 UTC of 11th October, 2012.

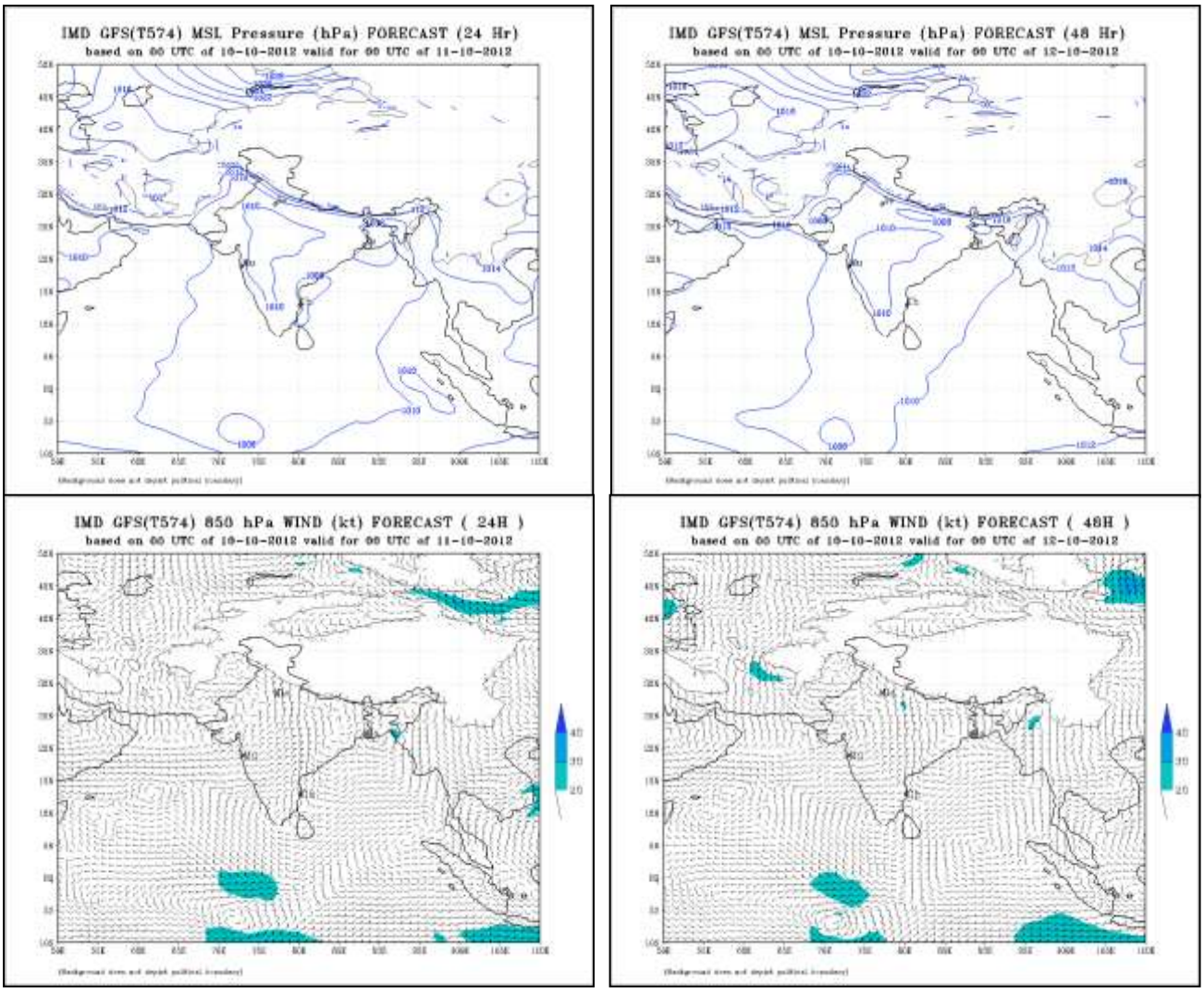


Fig. 10(a) IMD GFS pressure forecast for 24and 48 hr period based on 0000 UTC of 10th October, 2012.

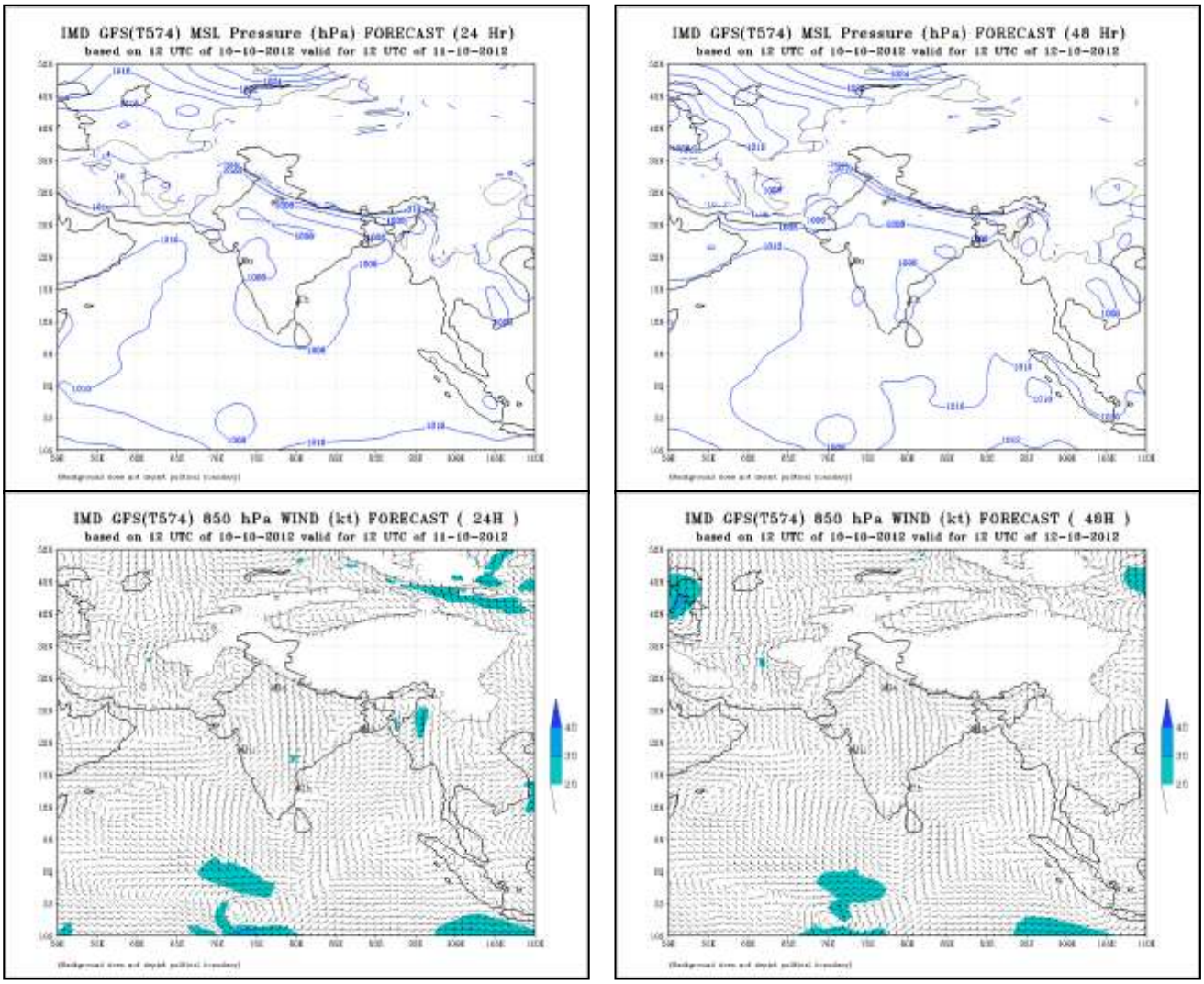


Fig.10(b) IMD GFS pressure and 850 hPa wind forecast for 24and 48 hr period based on 1200 UTC of 10th October, 2012.

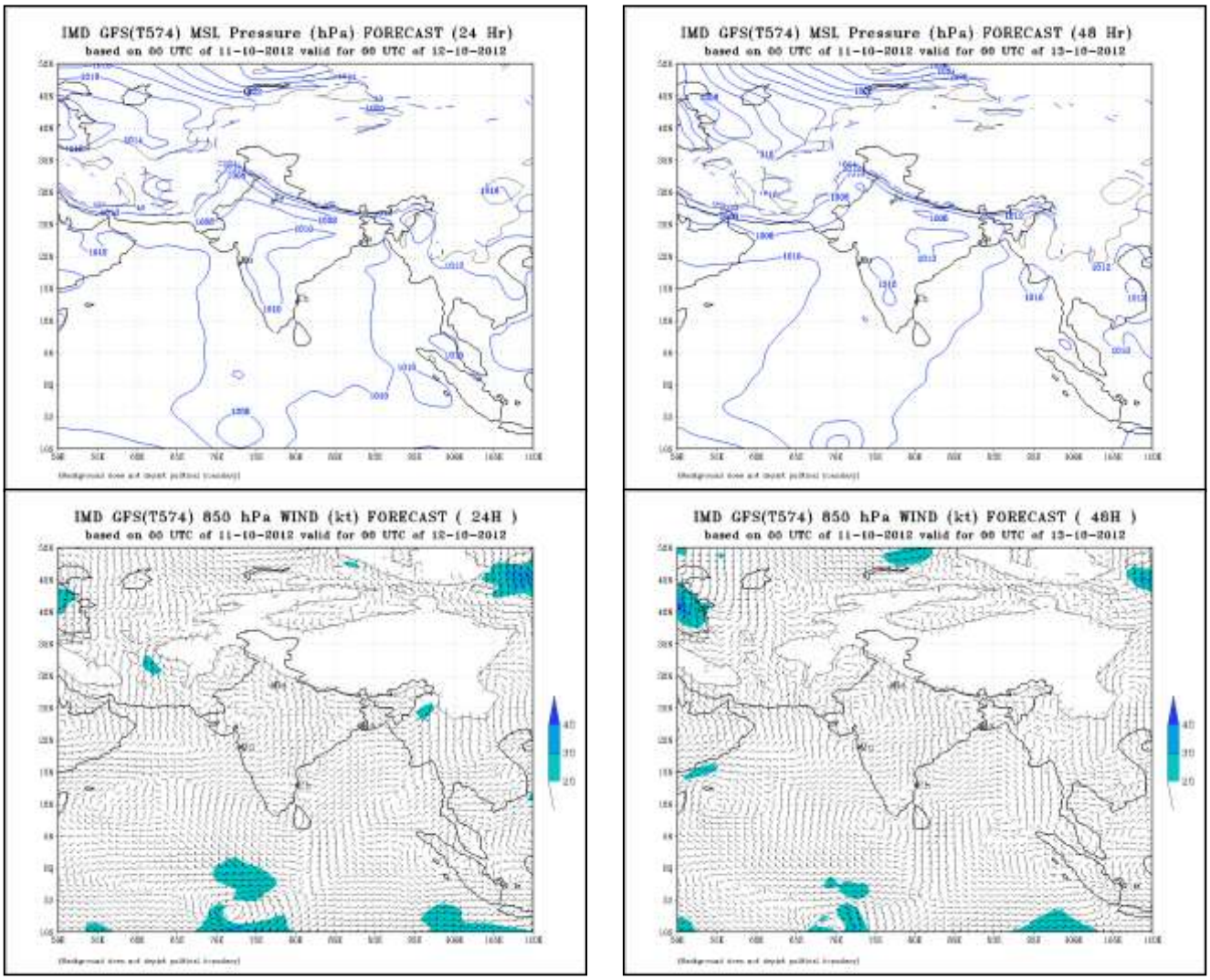


Fig. 10(c) IMD GFS pressure and wind (850 hPa) forecast for 24and 48 hr period based on 0000 UTC of 11th October, 2012.

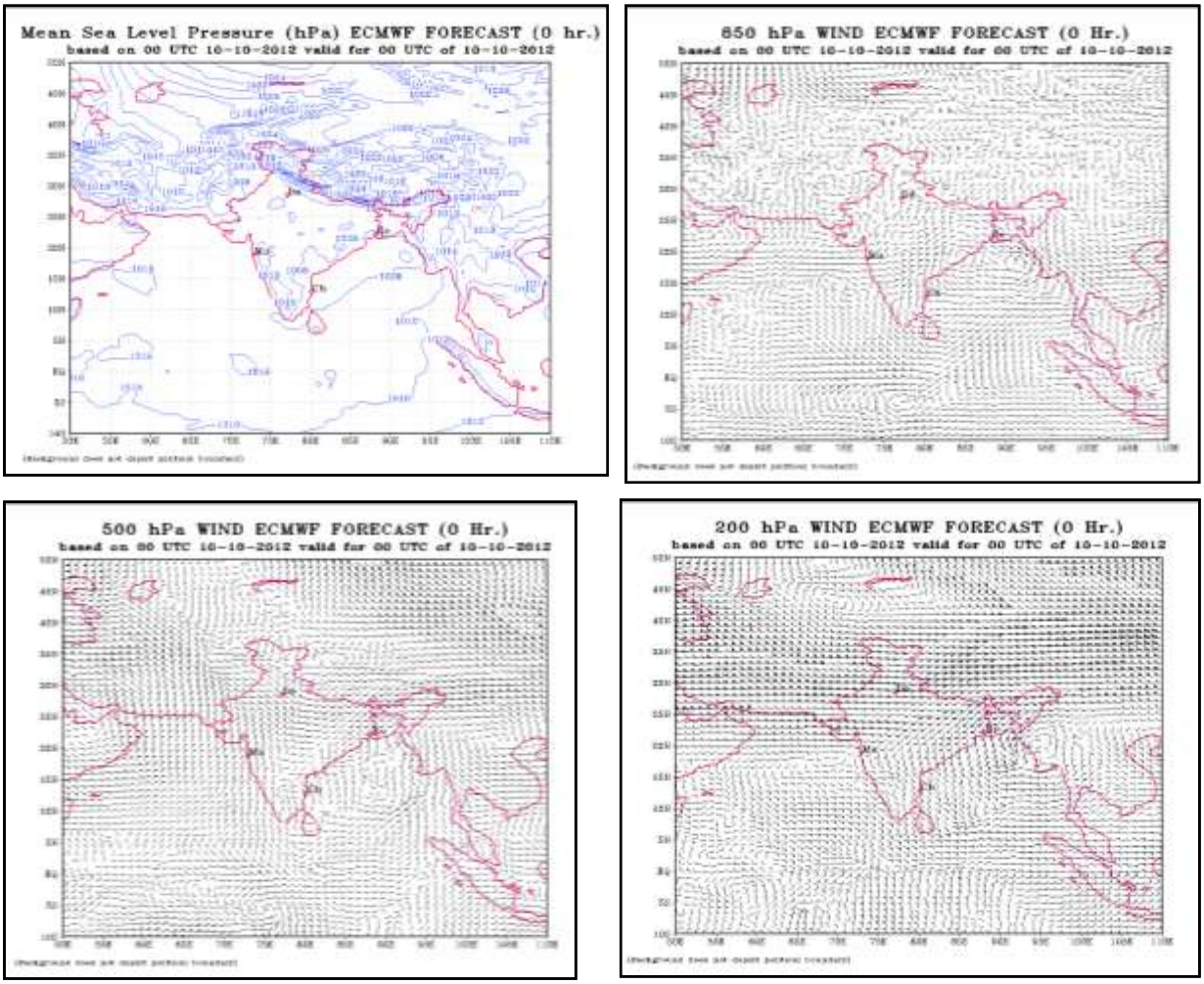


Fig.11(a).ECMWF analysis of MSLP and Winds at 850, 500 & 200 hPa levels based on 0000 UTC of 10th October, 2012

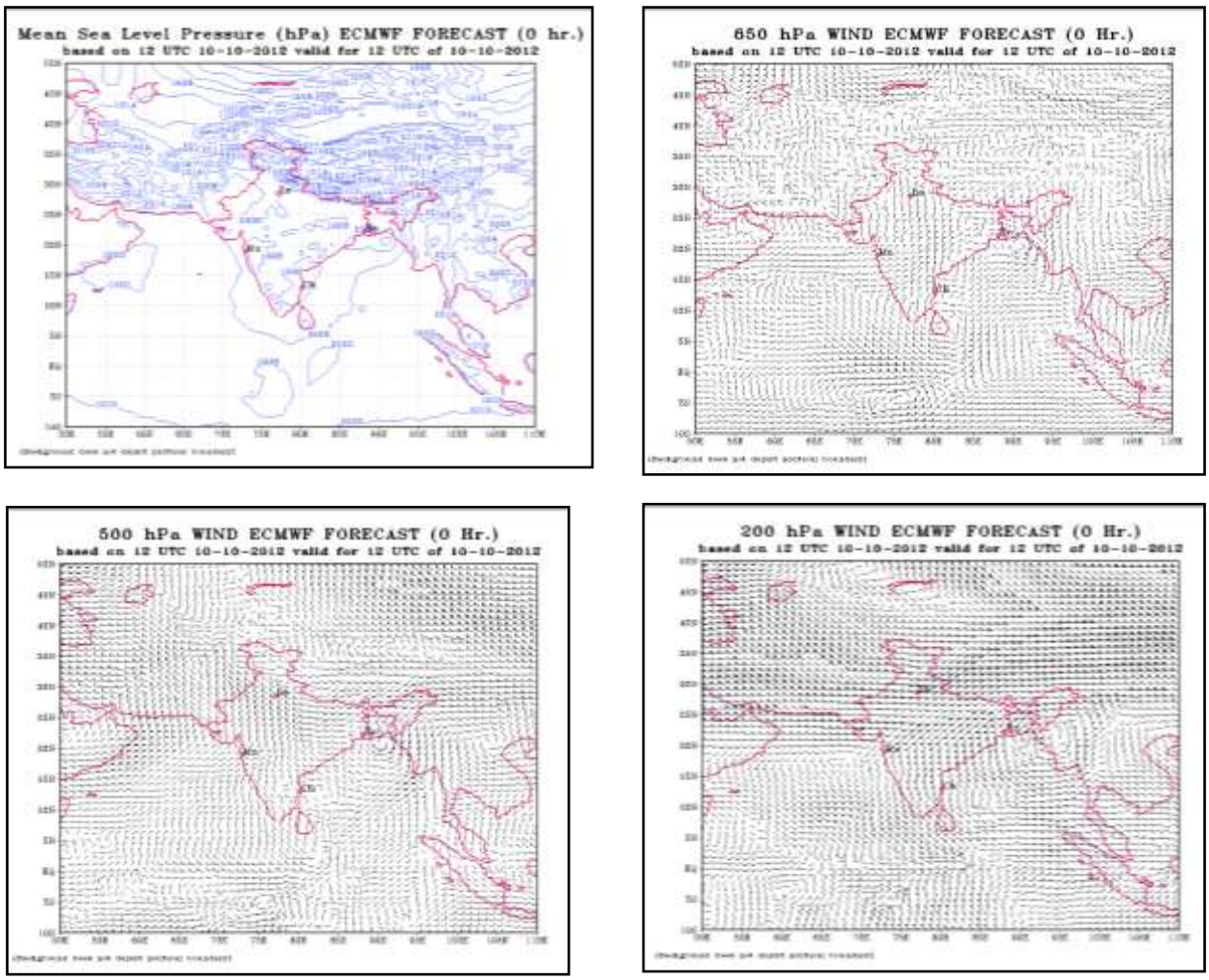


Fig.11(b).ECMWF analysis of MSLP and Winds at 850, 500 & 200 hPa levels based on 1200 UTC of 10th October, 2012

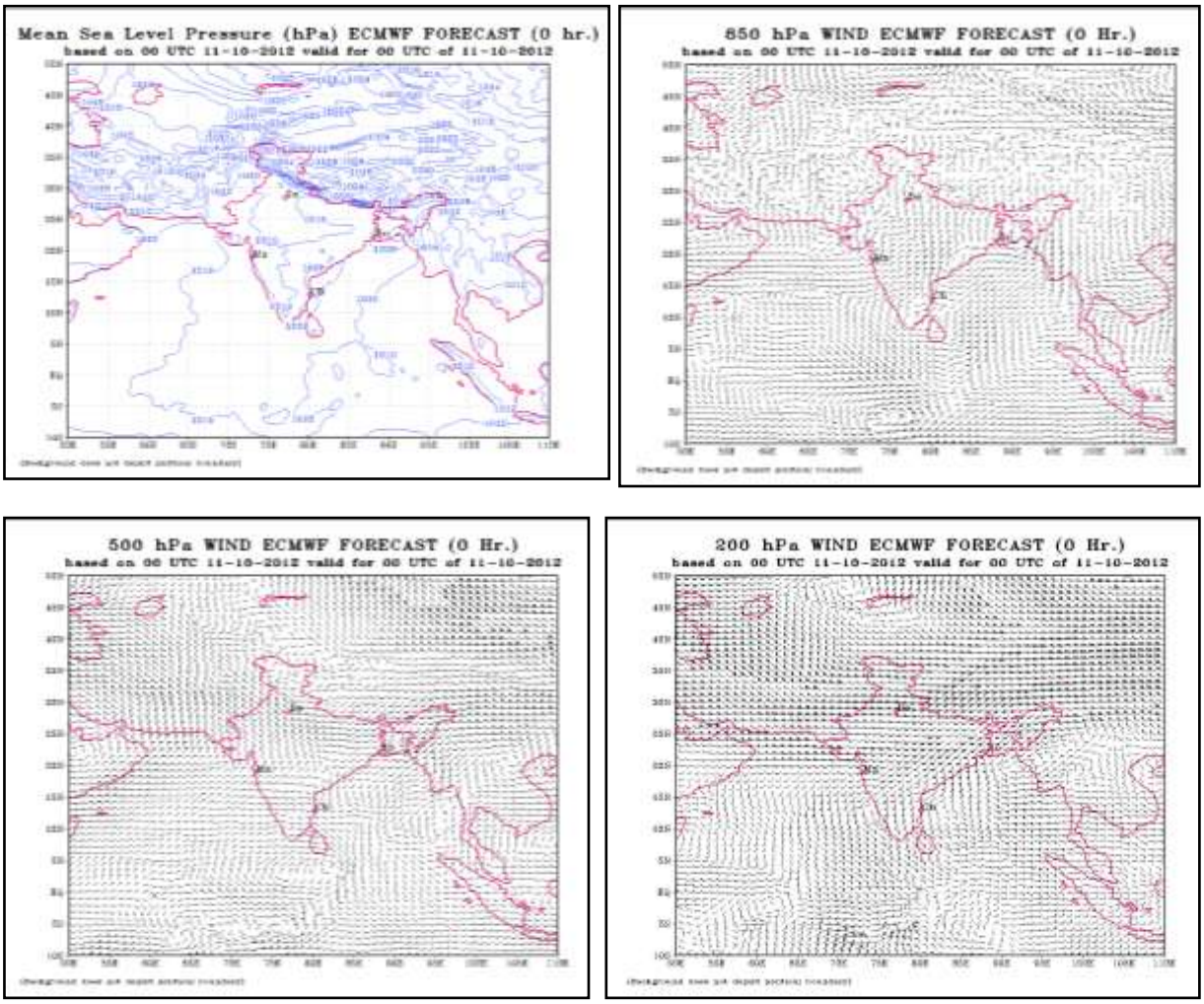


Fig.11(c).ECMWF analysis of MSLP and Winds at 850, 500 & 200 hPa levels based on 0000 UTC of 11th October, 2012

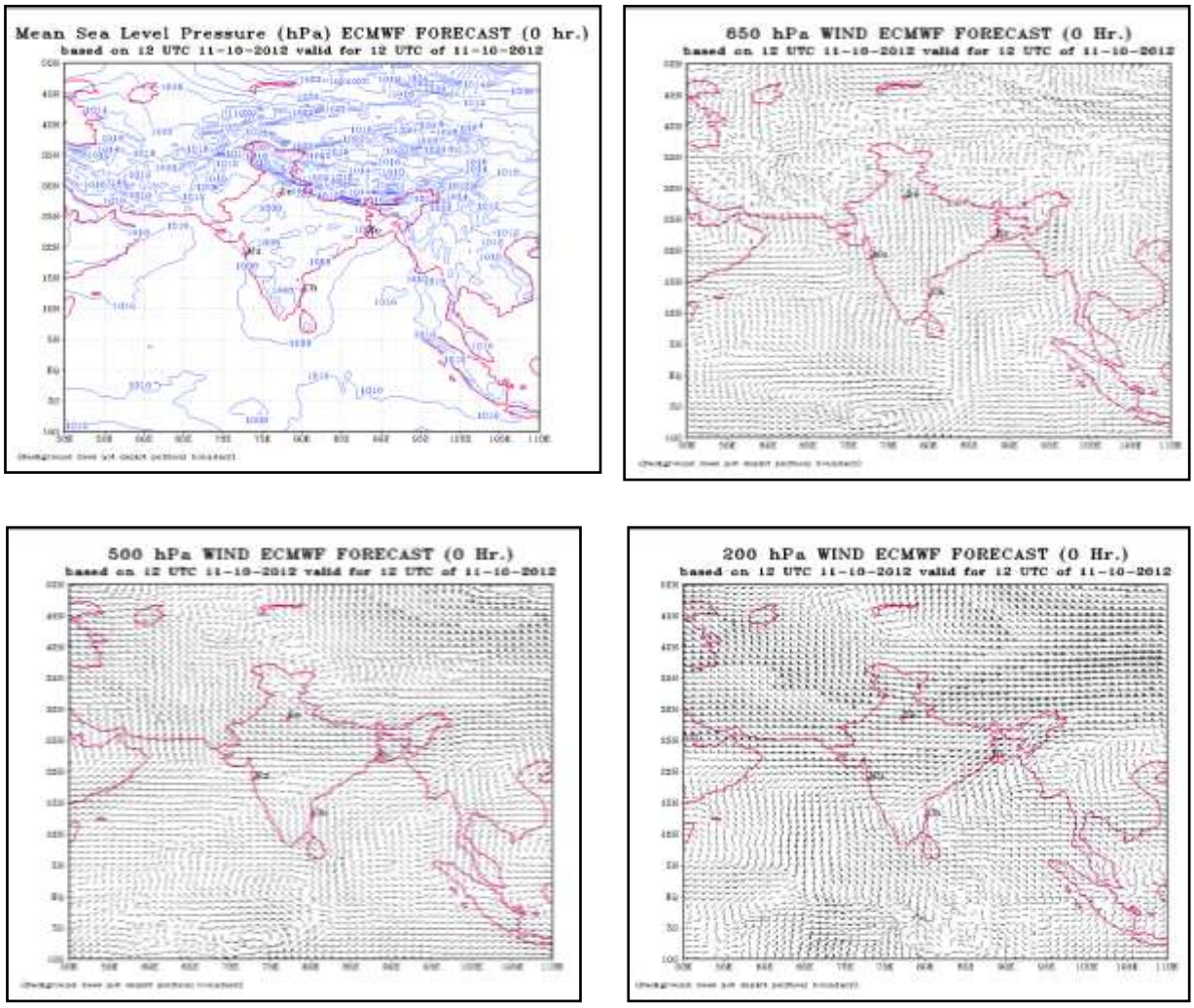
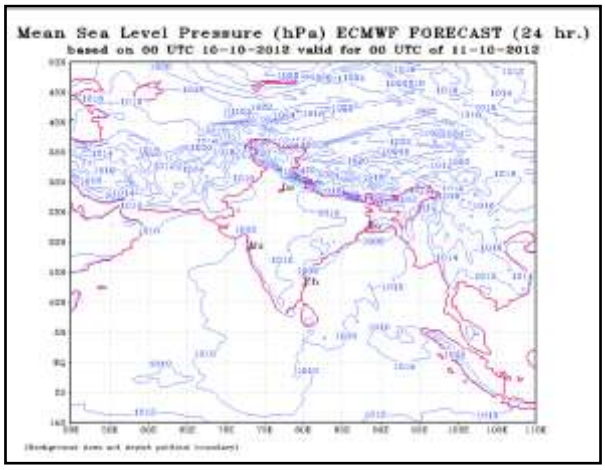


Fig.11(d).ECMWF analysis of MSLP and Winds at 850, 500 & 200 hPa levels based on 1200 UTC of 11th October, 2012



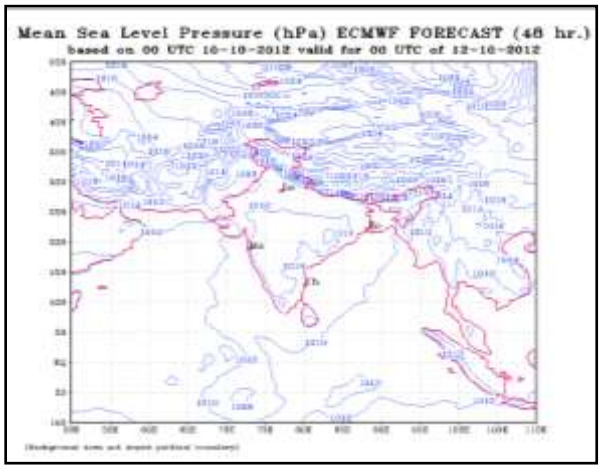
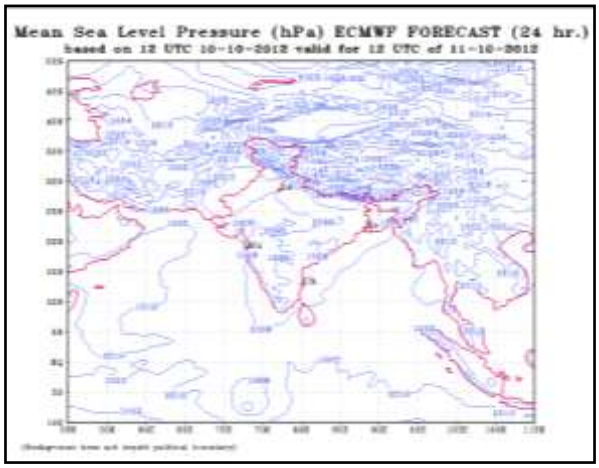


Fig.12(a). ECMWF forecast for 24 & 48 hr forecast period based on initial conditions of 0000 UTC of 10th October, 2012.



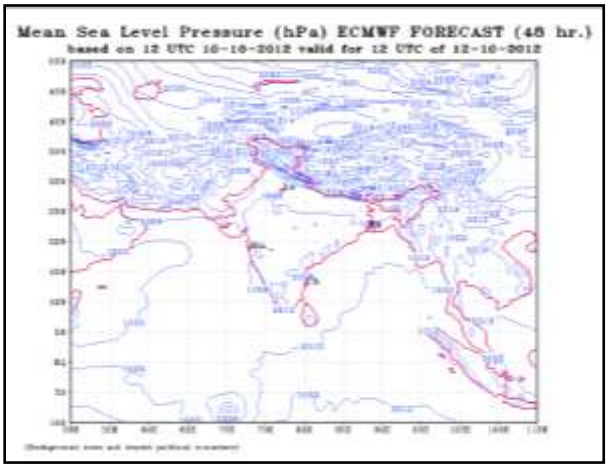
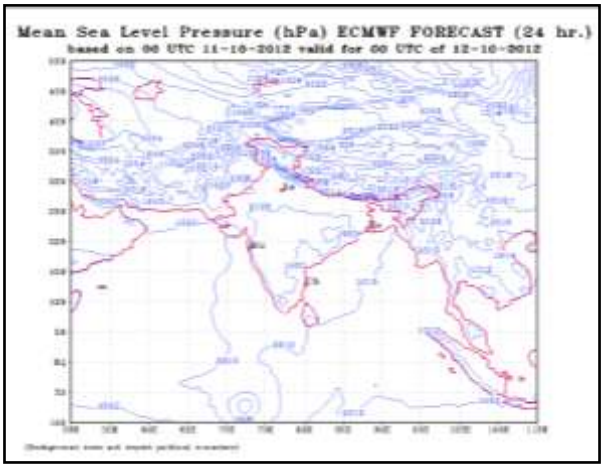


Fig.12(b). ECMWF forecast for 24 & 48 hr forecast period based on initial conditions of 1200 UTC of 10th October, 2012.



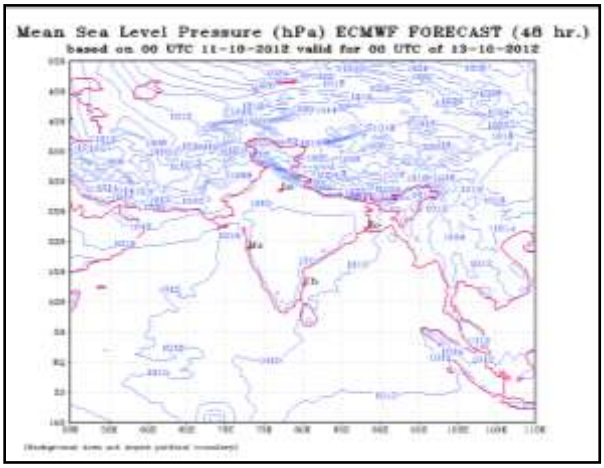
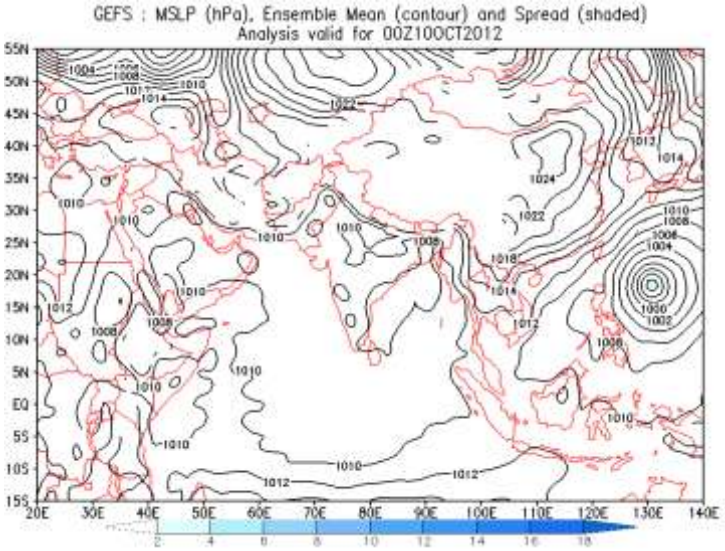


Fig.12(c). ECMWF forecast for 24 & 48 hr forecast period based on initial conditions of 0000 UTC of 11th October, 2012.



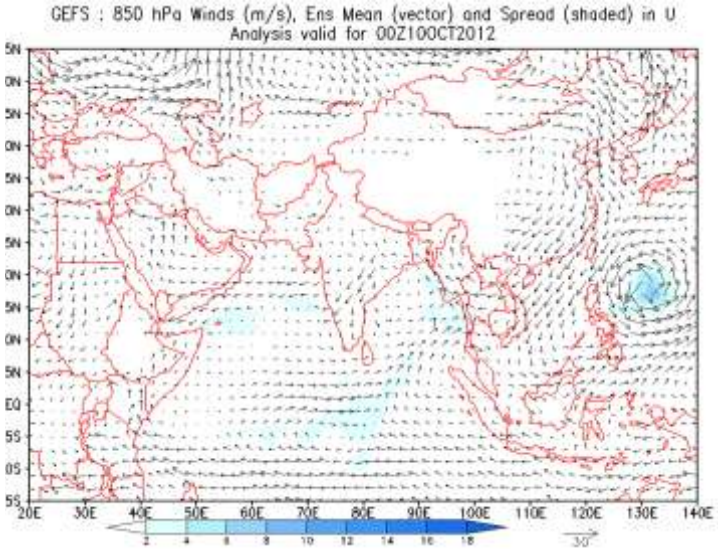
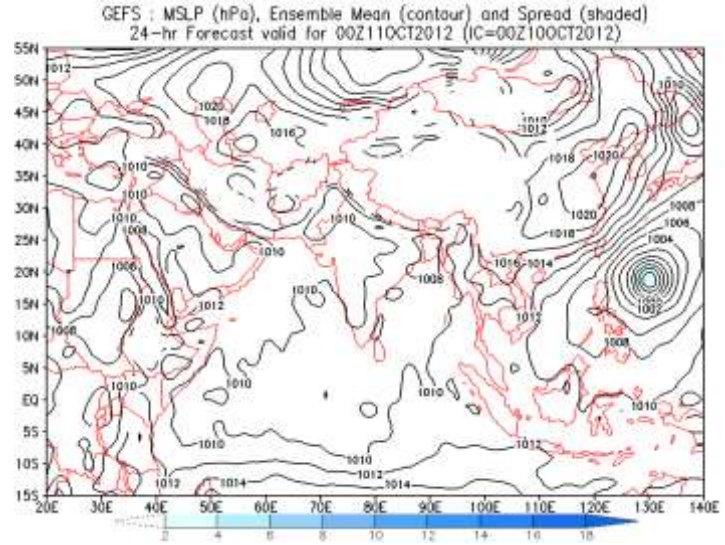
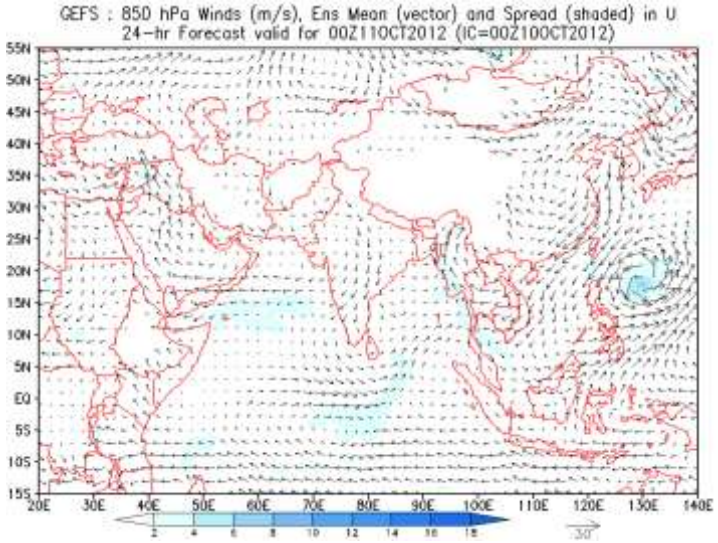
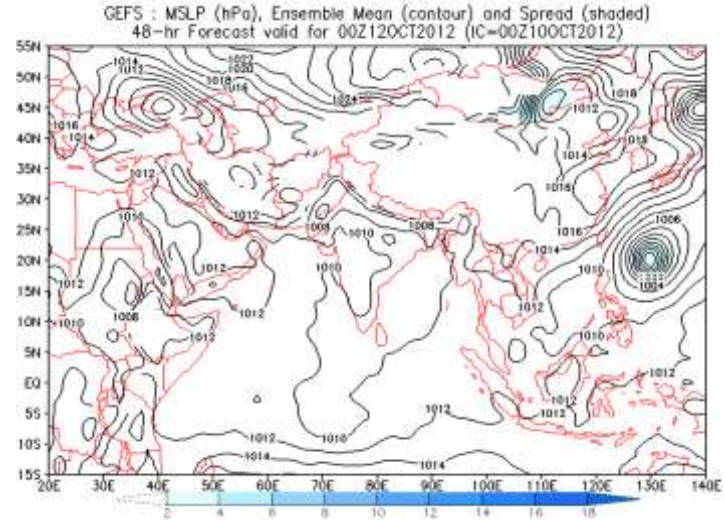
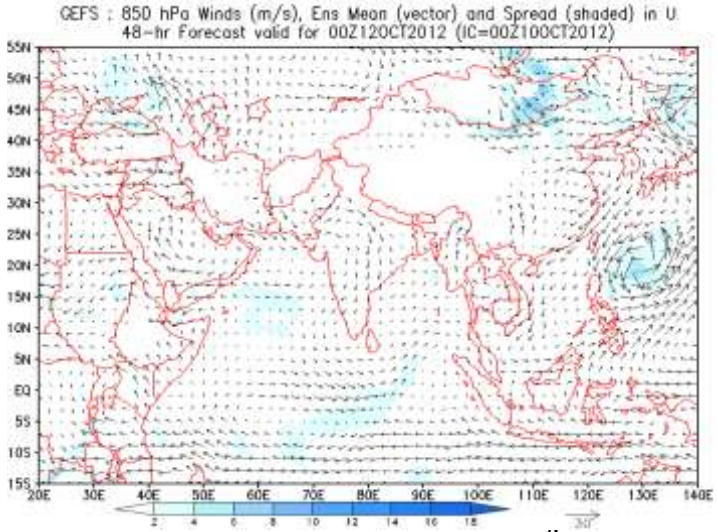


Fig.13(a). NCMRWF Global Ensemble Forecast System (GEFS) mean MSLP and









850 hPa wind analysis and 24 & 48 hr forecasts based on 0000 UTC of 10th October 2012

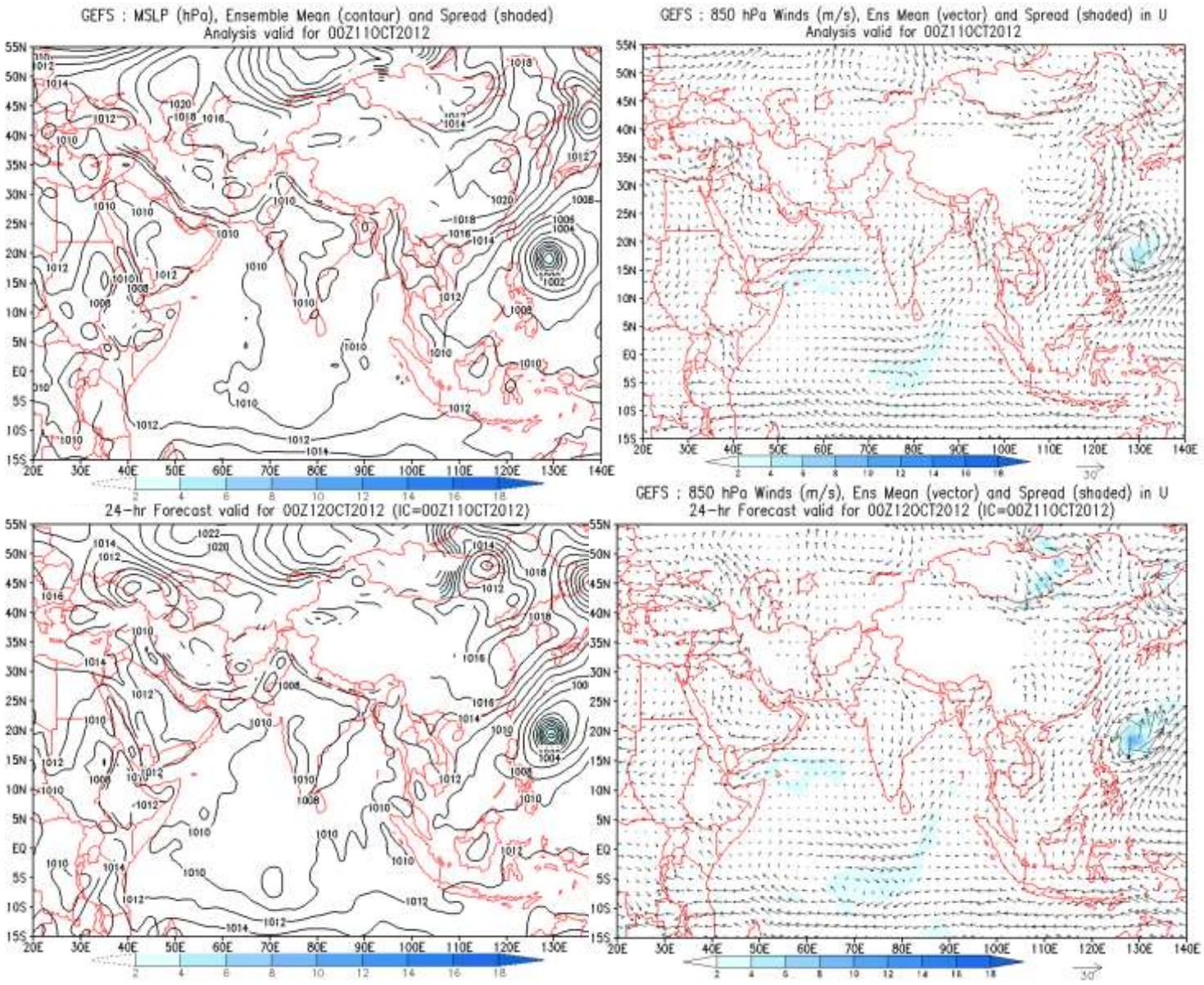


Fig.13(b). NCMRWF Global Ensemble Forecast System (GEFS) mean MSLP and 850 hPa wind analysis and 24 hr forecasts based on 0000 UTC of 11th October 2012

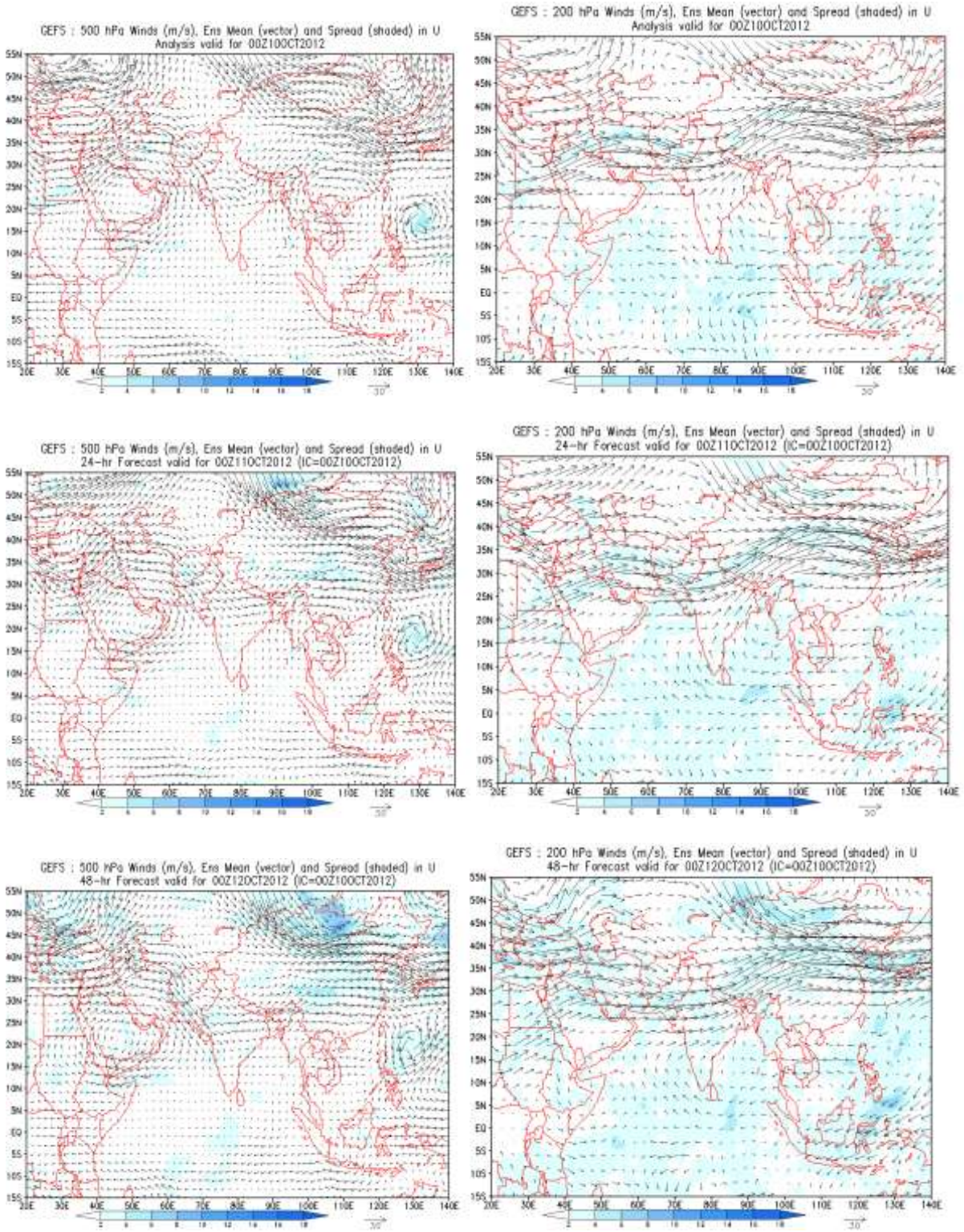
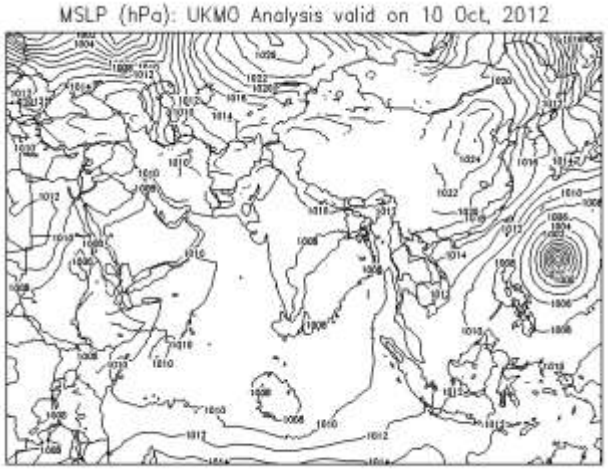
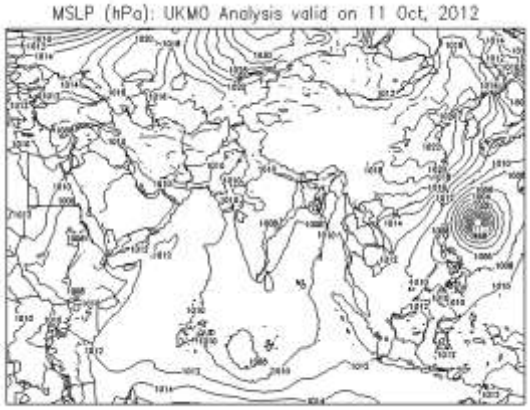
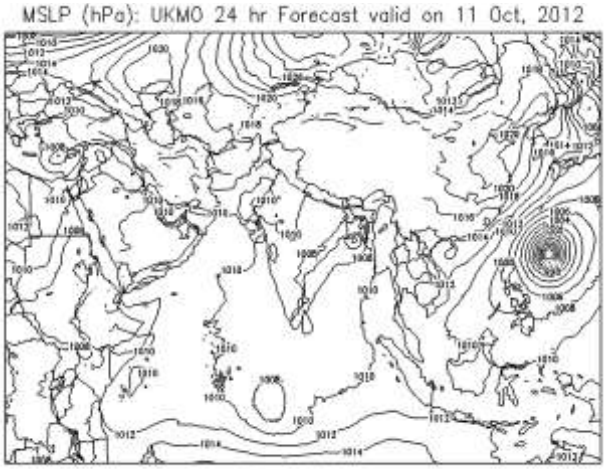
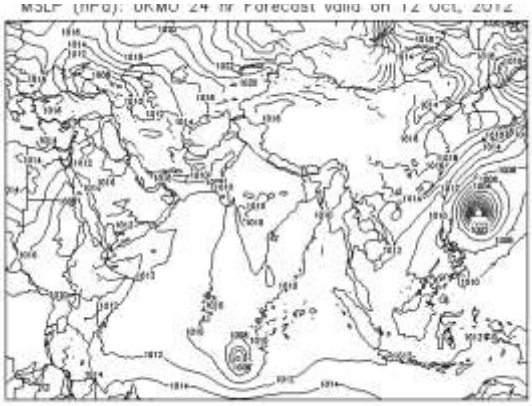


Fig.13(c). NCMRWF Global Ensemble Forecast System (GEFS) mean 500 and 200 hPa wind analysis and 24/48 hr forecasts based on 0000 UTC of 10th October 2012









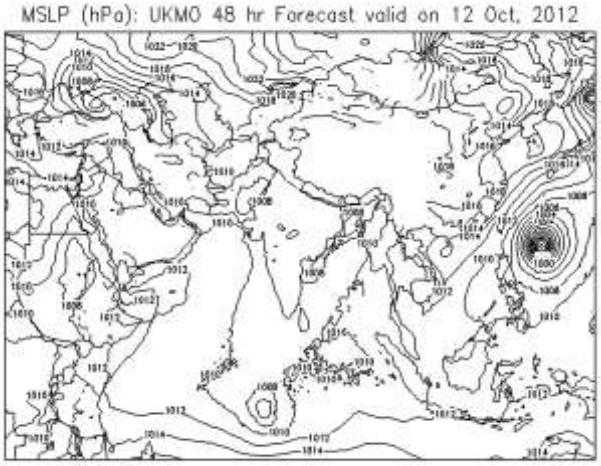


Fig.14(a). NCMRWF Unified Model (Global) MSLP analysis and 24 & 48 hr forecasts based on 0000 UTC of 10th October 2012

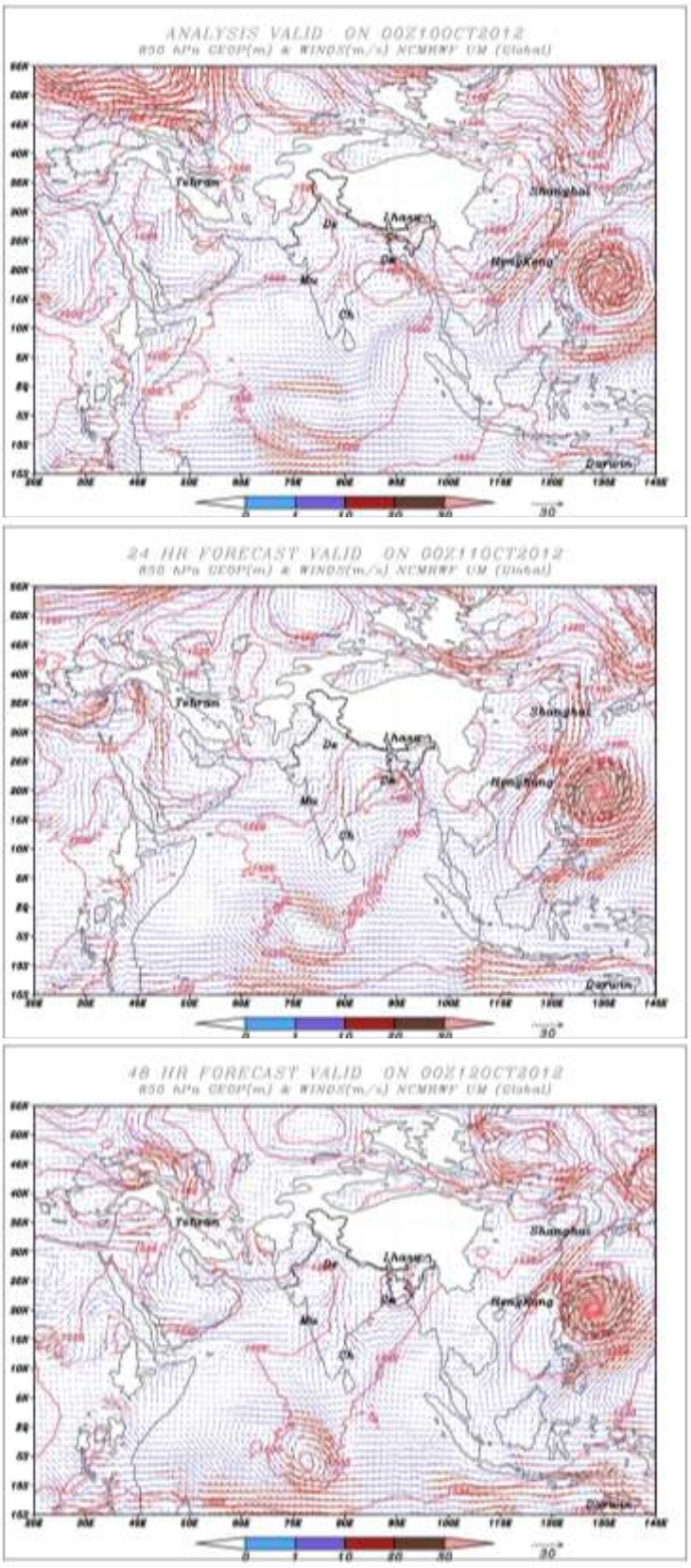


Fig.14(b). NCMRWF Unified Model (Global) 850 hPa wind and contour analysis and 24 & 48 hr forecasts based on 0000 UTC of 10th October 2012

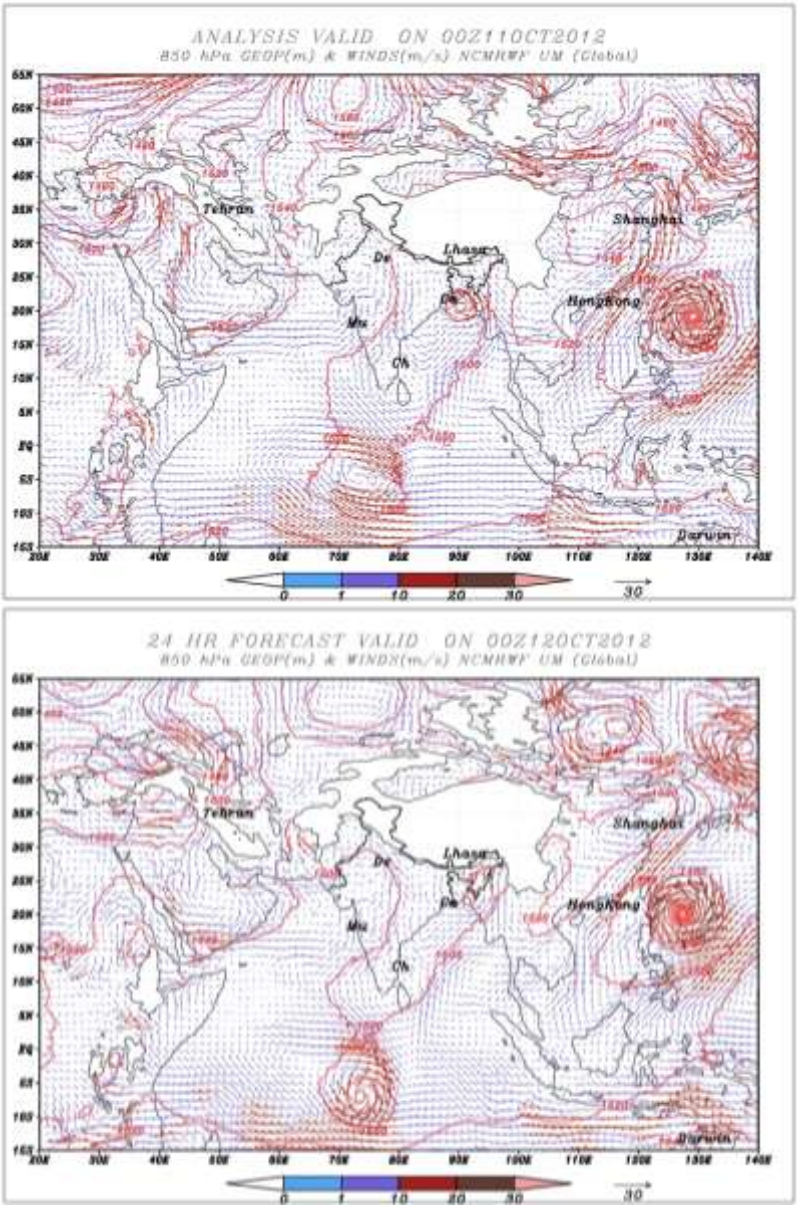


Fig.14(c). NCMRWF Unified Model (Global) 850 hPa wind and contour analysis and 24 hr forecasts based on 0000 UTC of 11th October 2012

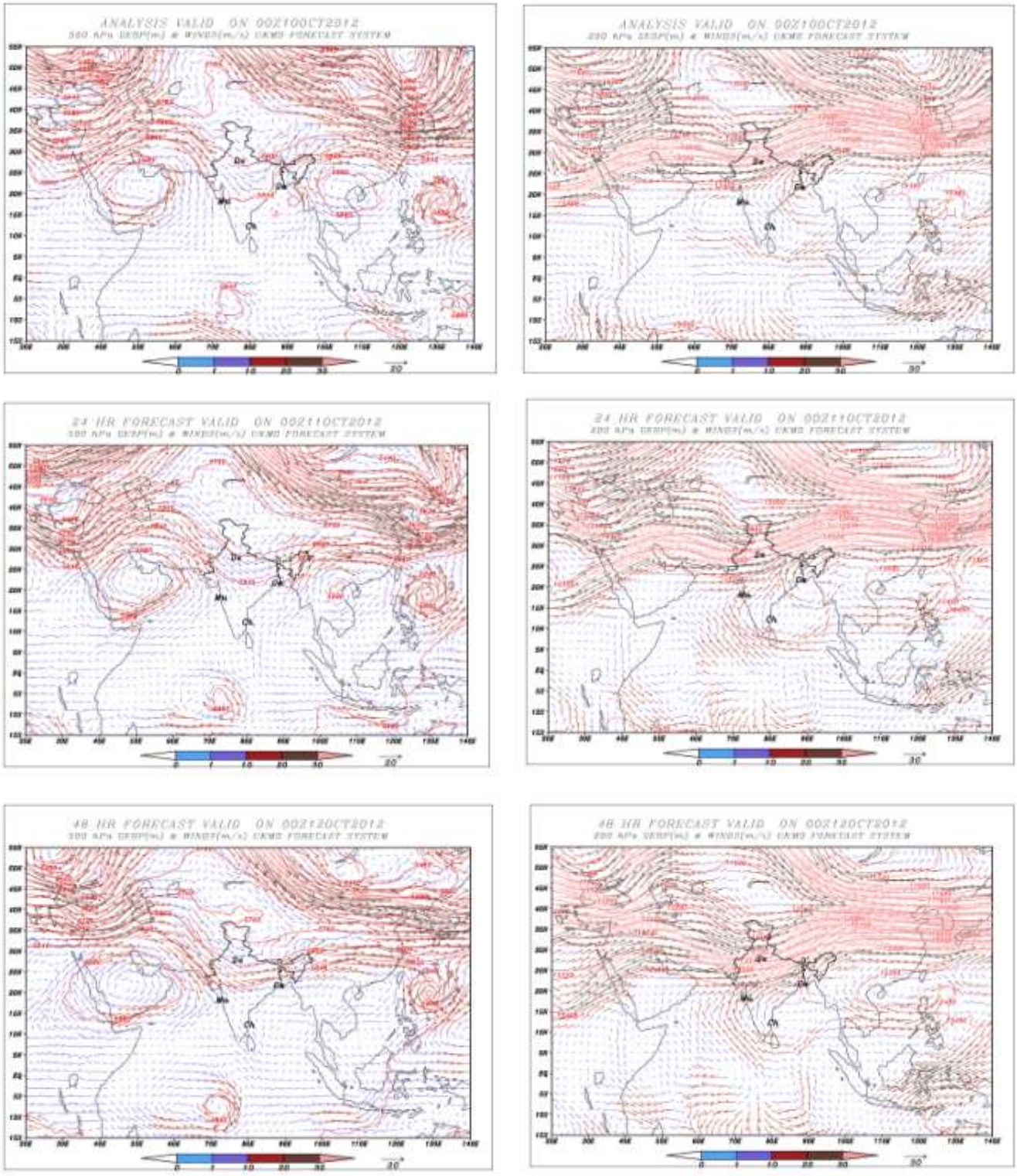


Fig.14(d). NCMRWF Unified Model (Global) 500 and 200 hPa wind and contour analysis and 24 hr forecasts based on 0000 UTC of 10th October 2012

10. Realised Weather

India:

Fairly widespread rainfall with isolated heavy falls occurred over Nagaland, Manipur, Mizoram and Tripura on 10th and 11th October, 2012. Fairly widespread rainfall also occurred over Assam, Meghalaya and Arunachal Pradesh on 10th and 11th October, 2012. Chief amounts of 24 hrs cumulative rainfall (≥ 5 cm) ending at 0300 UTC of 11th and 12th October, 2012 are given below :-

11.10.2012 : Meghalaya: Cherrapunjee, Barapani-5 cm each.

Assam: Chouldhowaghat and Jia Bharali N T Road Xing-5 cm each.

Tripura: Belonia-9 cm, Bagafa-7 cm and Amarpur-6 cm.

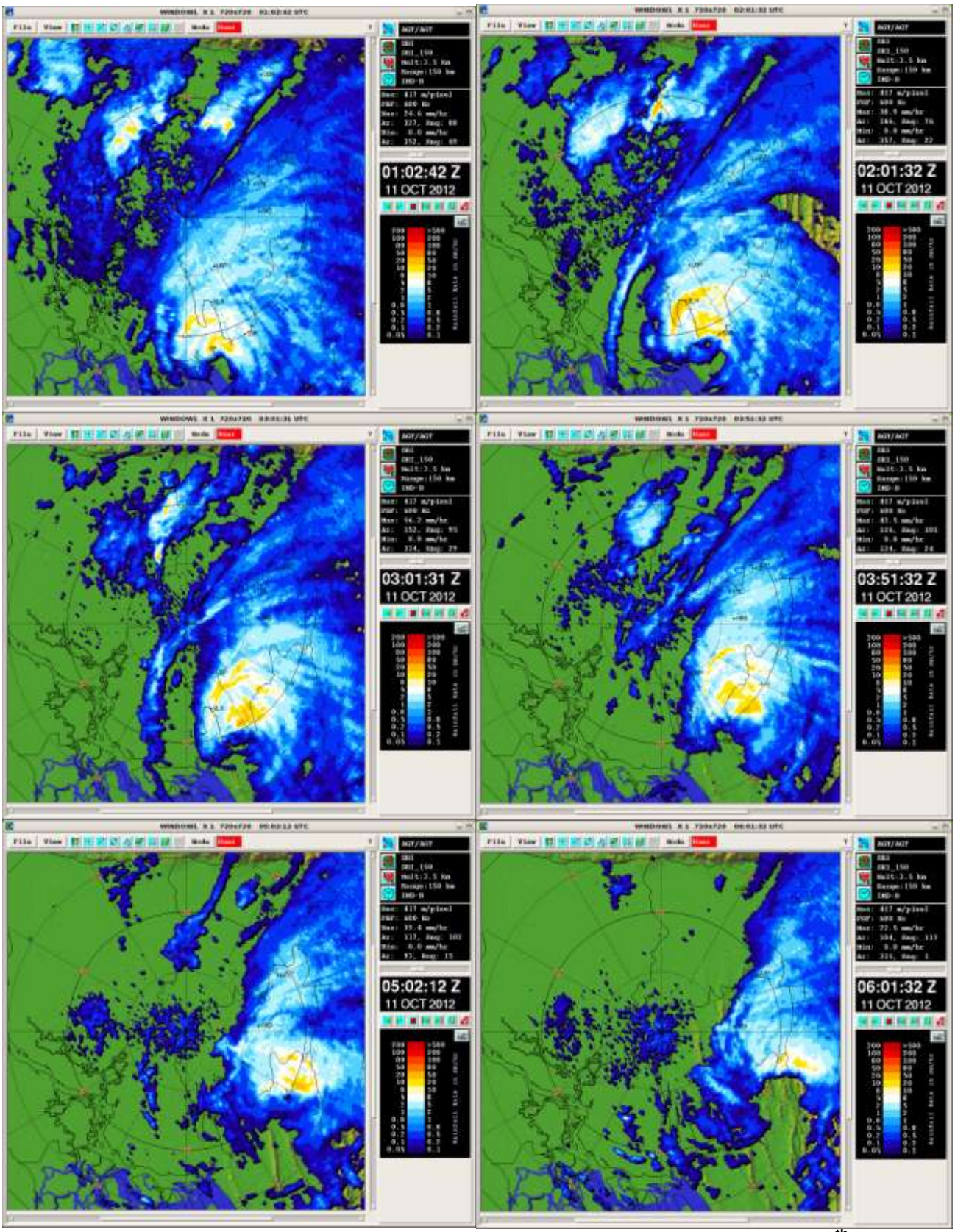


Fig.15. DWR, Agartala based hourly rainfall rate during 0100 to 0600 UTC of 11th Oct.

12.10.2012

Mizoram: Lengpui -9 cm and Llowngtlai – 5 cm

Manipur: Imphal – 6 cm and Thoubal – 5 cm

Assam: Matizuri- 9 cm, Kajalgaon (AWS) – 7 cm and Badarpurghat – 6 cm

Bangladesh:

Bangladesh reported sustained maximum surface wind of 22 knots over Hatia, 25 kts over Sandip and 32 knots over Chittagong at the time of landfall. Widespread rainfall occurred over Bangladesh on 10th and 11th October, 2012. Chief amounts of 24 hrs cumulative rainfall (≥ 5 cm) ending at 0300 UTC of 11th October, 2012 are given below:

Hatia- 9 cm, Sandip- 6.5 cm, Kutubdia- 10 cm, Cox's Bazar- 10.6 cm, Rangamati- 6 cm and Chittagong- 6 cm.

Hourly rainfall rates as observed through DWR, Agartala during 0100 to 0600 UTC of 11th October 2012 are shown in Fig.15. It indicated that the maximum rainfall rate was observed around 0200 UTC and it decreased gradually thereafter.

11. Forecast Performance

11.1 Bulletin issued by IMD

The depression was continuously monitored and bulletins were issued by Cyclone Warning Division, IMD, New Delhi in regular intervals to national and international agencies from 1500 UTC of 10th October, 2012. Following is the statistics of Bulletins issued to various disaster management agencies in the country and to World Meteorological Organisation (WMO)/ Economic and Social Co-operation for Asia and the Pacific (ESCAP) Panel countries including Bangladesh.

No. of Bulletins issued to National Disaster Management agencies and Chief Secretaries of northeastern States: :4

No. of Special Tropical Weather Outlook Bulletins issued to WMO/ESCAP Panel member countries including Bangladesh :4

Two Special advisory messages were also issued to Storm Warning Centre, Bangladesh before the genesis of depression on 10th October, 2012. There was also telephonic conversation between the forecasters of IMD and Bangladesh during the period. The bulletins were also issued by Area Cyclone Warning Centre of IMD at Kolkata for sea areas. Regional Meteorological Centre at Guwahati and Meteorological Centre at Agartala issued the corresponding warning bulletins to Assam, Arunachal Pradesh, Meghalaya, Tripura, Mizoram, Manipur and Nagaland Governments.

11.2 Forecast Verification

Parameter	Base Date/Time (UTC)	Forecast	Actual
Track, intensity & landfall	10.10.2012/ 1500	Depression likely to intensify further, move northward and cross Bangladesh coast near Hatia in the morning of 11th October.	Depression moved northward, intensified into a deep depression and crossed Bangladesh coast near Hatia between 0000-0100 UTC (0530-0630 hrs IST) of 11th October.
Rainfall	10.10.2012/1500	Fairly widespread and isolated heavy rainfall during next 48 hrs over Assam, Meghalaya, Nagaland, Manipur, Mizoram and Tripura	Fairly widespread rainfall with isolated heavy falls (Sec.5)
Surface Wind	10.10.2012/1500	25 knots gusting to 35 knots.	Chittagong- 32 kts in gustiness at 2330 UTC, Hatia-22kts at 2045 UTC and Sandip-25 kts at 2250 UTC of 10th October.

12. Damage

The storm brought high winds and heavy rains to much of Bangladesh, causing extensive damage. 43 people were killed and dozens injured when powerful storms lashed several upzillas of Noakhali, Bhola, Chittagong and Feni districts early yesterday. Over 200 thatched cottages in Hatia were damaged. Scores of trees along the subarnachar and Hatia were uprooted, several fishermen with their fishing trawlers remained missing. Squalls destroyed mosques and educational institutions. Afew damage photographs are shown in Fig.16.

Fig.16. Photographs showing damage in coastal areas of Bangladesh

Acknowledgement :

We are thankful to Bangladesh Meteorological Department (BMD) for providing all the surface and radar observations for the reanalysis of the system and preparation of the report. Our special thanks go to Dr Shamsuddin Mohmadd, Assistant Director, BMD for his support and inputs through e-mail and phone for preparation of this report. We also thank Satellite Division and NWP Division of IMD, New Delhi, Regional Meteorological Centre, Guwahati and Meteorological Centre, Agartala for providing the inputs for preparation of this report.