Diagnostic Study of Deep Depression over Northwest Bay of Bengal in June 2011: A Case Study

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ABSTRACT

A Deep Depression (DD) was formed over North-West Bay of Bengal during (16-22) June 2011 and its gradual movement caused the Southwest monsoon 2011 to cover most parts of the country outside western parts of Rajasthan and north Gujarat state. The unique feature associated with this DD was that the life of the system was longer and movement was slow. Various diagnostic features associated with life period and movement has been analysed and discussed. This study highlights that the system has given heavy to very heavy rainfall together with some exceptionally heavy rainfall along its path. As a result of this, the rainfall distribution of June 2011 along its path has been excess. The analysis of the synoptic condition revealed that the absolute vorticity for the system was very strong. After the landfall the continuous supply of moisture initially from the Bay of Bengal and after that the strong moisture incursion from the Arabian Sea has been responsible for the longer life of the system upto Madhya Pradesh. Moreover, after landfall it comes under the influence of mid & upper tropospheric westerly wind which may be responsible for slow movement of the system.

Key words: *Deep Depression, Rainfall Distribution, Absolute Vorticity*

1. Introduction

Low Pressure system (LPS) formed over the Bay of Bengal plays a significant role in distribution of rainfall during summer monsoon season (June-September) over India. The onset of southwest monsoon over eastern India and its further progress largely depends on the formation of LPS and its movement. The existence of a closed low pressure area formed due to low, depression and cyclonic storm is termed as an LPS.Many researcher like, Pisharoty and Asnani (1957), Lal (1958), Raghavan (1965), Sikka (1977) and Joseph (1981) have extensively studied the influence of cyclonic storm/depression on the performance of monsoon rainfall in India.Moolay and Shukla (1989) analyzing the long period data(1888-1983) have found significant direct relation between LPS days over Indian region including Bay of Bengal and Arabian Sea and central Indian rainfall during monsoon season.Mohapatra (2008) has studied relation between LPS over Bay of Bengal and monsoon rainfall over India during 1982-1999 and concluded that frequent development and persistence of LPS over North West Bay are responsible for higher seasonal monsoon rainfall over east central India whereas the frequent development and persistence of LPS over West Central Bay are responsible for higher seasonal monsoon rainfall over peninsular India excluding west coast. Weather satellites since

1960 have provided a vital tool for observing tropical convection. India established its own geostationary satellite program, known as INSAT, in early 1980's which has enabled operational forecasters to continuously monitor development of hazardous weather. Satellite information (visible, infrared and water vapour imageries) and precipitation estimates provided by Tropical Rainfall Measuring Mission (TRMM) satellite have provided a wealth of new data to understand tropical convection (Houze *et al*. 2007). In India INSAT data have been extensively used in research studies on tropical storms and monsoon depression. Recently, Pradhan and De (2012) has established that DWR is very useful for prediction of short term cyclonic storm, its direction of movement and heavy rainfall associated with the system.

The 2011 southwest monsoon set over Kerala on 28th May three days ahead of its normal onset date whereas it set in over South Andaman Sea on 29th May 2011 after delay of about 9 days. With the association of formation of LOW over NE Bay of Bengal on 13th June 2011,its intensification into a deep depression (DD) on 16th June and its gradual movement towards central parts of the country caused the monsoon to cover the most part of the country outside western Rajasthan and north Gujarat state. The life of the DD was longer and movement was slow. Therefore, in this paper an attempt has been made to analyse the salient features associated with the DD and possible reason for its slow movement and longer life period.

2. Data and Methodology

The system was first seen as Low pressure area formed over North West Bay of Bengal on 13th June and it intensified into a depression on 0300UTC/16th and crossed West Bengal-Bangladesh as DD on 16th afternoon and moved slowly west northwesterly direction weakened into a Well Mark Low (WML) on 23rd over MP.Fig.1 gives the track of the DD.

The onset date of southwest monsoon 2011 and sub divisional rainfall distribution of June 2011 has been collected from IMD-Weather in India (2012).The realized rainfall data during 16-23 June 2011 associated with this DD has been collected from Synergie workstation install at ACWC Kolkata. Daily Satellite picture from KALPANA1 with superimposition of DVORAK (-90° C/+60° C) cloud top temperature (CTT) during the period (16-23) June 2011 has been analysed.

The Radar picture for the event has been obtained from Doppler Weather Radar (DWR) installed at Kolkata during 16-18th June 2011 as after 18th the system went out of DWR Kolkata range. Though the picture of the system has been obtained at every 10 minutes interval, however for the present study radar pictures at 6 hrly interval are taken on 16th June 2011 from 00 UTC to 1800 UTC and then after at every three hourly interval. The absolute vorticity, upper air wind at different levels have been obtained from ARP 1.5 model (French model) for analysis for the period under study.

3. Results and Discussion

3.1 Rainfall analysis associated with Deep Depression

Day to day rainfall associated with the system during 16th-23rd June 2011 has been shown in Fig.3 (a-h). The system has given heavy to very heavy rainfall along its track starting from Gangetic West Bengal (GWB), Jharkhand, Bihar, Uttar Pradesh (UP) and Madhya Pradesh (MP). GWB received heavy to very heavy rainfall during 16th to 18th June

.Similarly, Jharkhand and Bihar experienced heavy to very heavy rainfall on 18th and 19th June .MP has got heavy to very heavy along with exceptional heavy rainfall during 20th June to 22nd June .As a results of such higher contribution of the system the sub divisional rainfall activity of June 2011 along the path of the DD was excess(Fig-2).

3.2 Features as seen in satellite images

Daily picture (0300 UTC) of KALPANA1 cloud imageries along with superimposition of DVORAK (-90° C/+60° C) cloud top temperature (CTT) during the period (16-23) June 2011 has been analysed.It has been observed from the Fig.4(a-h) that CTT around the centre was of the range -71° C to -80 ° C (very intense convection) during 16-23 June except on 21st June where it was on the range of -60° C to -70° C (intense convection).It has also been observed that two/three bands cloud mass on 16th June 2011 merges as a single cloud mass after its landfall (fig-4(a and b)). A circular cloud mass has been seen over the area in association with the system. The intense cloudiness is seen mainly over southwest quadrant of the DD as in case of monsoon depression. By 23rd June afternoon the cloud organization has weaken considerably.

3.3 Features as seen in Doppler Weather Radar

Doppler weather radar installed at Kolkata recorded the images of depression at an interval of 10 minutes. However, in the present study, pictures at 6 hrly interval are taken on 16th June 2011 from 00 UTC to 1800 UTC and then after at every three hourly interval because initial development and movement of the system was quite slow and after 1800 UTC, the development became very fast. Fig 5 (a) is the maximum reflectivity (Max_Z) image of the clouds associated with the low pressure system at 00 UTC on 16th June ,when the system was under development stage. It shows the distribution of the clouds in the form of an arc approaching from Bay of Bengal to the south of the Kolkata confirming a cyclonic circulation. This is quite similar to the satellite image at 0300 UTC image of 16th June (Fig.4 a) which shows the convection to the southern part of Kolkata. As the resolution of DWR image is of the order of 0.5 km, the clouds are clearly seen with vertical extent reaching 8-9 km with reflectivity lying in the range of 47.6-50.7 dBz. Fig.5 (b) shows the Max_Z image at 0600 UTC of 16th June in which not much significant change is observed whereas in Fig.5(c) spiral bands are clearly visible. Fig.5(d) shows a dense cloud mass on the SE sector of Kolkata with better organized spiral bands. The reflectivity in the cloud lies in the range of 50.7-53.7 dBZ which is quite high and indicates the possibility of moderate to heavy rainfall over that area.

Fig.5(e) & Fig.5(f) indicate north westerly movement of the system with better organization having a central part surrounded by the spiral bands. Fig.5(g) is the picture at 03 UTC/17.06.2011 showing a well developed system with over Kolkata and neighborhood and further north westerly movement. This picture resembles the satellite picture (Fig.4b) of the same time. Fig.5(h) at 0600 UTC/17.06.2011 clearly depicts a “depression” with its centre just over Kolkata and further northwesterly movement of the depression. Fig5(i-n) shows the consequent north westerly movement of the system which again confirm the synoptic observations and actual movement of the system.

3.4 Absolute vorticity analysis

Absolute vorticity (AV) indicates the measurement of rotation of the air parcel.Changes in absolute vorticity following horizontal motion is associated with convergence or divergence. Increasing absolute vorticity at a particular level indicates the strong cyclonic circulation/convergence and decreasing absolute vorticity indicates weaker cyclonic circulation/divergence at that level. Daily picture of absolute vorticity of 850 hPa at 0000 UTC from (16-23) June 2011 associated with the Deep Depression has been obtained from ARP 1.5 model. The analysis of AV at 850 hPa level associated with the Deep Depression (Fig-6) indicates that the AV for the system has been in increasing trends from 16th June to 19th June (Fig 6(a-d)) which increased from 26 AV on 16th to 30 AV upto 19th June then started decreasing to 26 AV on 20th (fig 6(e))/ 21st June (fig 6(f)) and further decreased to 22 AV on 22nd and 23rd June (fig 6) and finally weakened gradually.

3.5 Upper air chart analysis

On examining the wind at different levels obtained from ARP 1.5 model shows that the cyclonic circulation associated with the deep depression has been extended upto MTL tilting southwestward with height. After landfall over Bangladesh-GWB in afternoon of 16th June continuous supply of moisture initially from Bay of Bengal and after that the strong moisture incursion from Arabian Sea in lower level due to lack of any significant synoptic situation over the western coast and Arabian Sea has been responsible for the intensity of the system upto Madhya Pradesh as shown in the fig.6 ((a-h)) which represents the wind at 850 hPa during the period under consideration.

Moreover, after examining the wind at mid & upper tropospheric level (Fig 8(a-h)) it has been observed that northerly/northwesterly wind prevails at 300 hPa over the area along its path during 16-19 June (Fig 8(a-h)). The slow movement of the system may be due to the fact after landfall it has comes under the influence of northerly/northwesterly wind in mid & upper tropospheric level which prohibits its movement.

4. Conclusions

The following conclusions may be drawn from this study

1. With the movement of Deep Depression (16-22 June 2011) Southwest Monsoon covered most part of India outside west Rajasthan and north Gujarat.
2. The Deep Depression contributed significantly to the rainfall activity of June 2011. The sub-divisional rainfall distribution of June 2011 along its path has been excess.
3. The Absolute vorticity associated with this DD has been very strong and steady during the period.
4. After landfall over Bangladesh-GWB in the afternoon of 16th June, continuous supply of moisture initially from the Bay of Bengal and after that the strong moisture incursion from the Arabian Sea in the lower level has been responsible for the intensity of the system upto Madhya Pradesh.
5. The slow movement of the system may be due to the fact that after the landfall it came under the influence of strong westerly wind in mid tropospheric level and upper troposphere which prohibited its movement.

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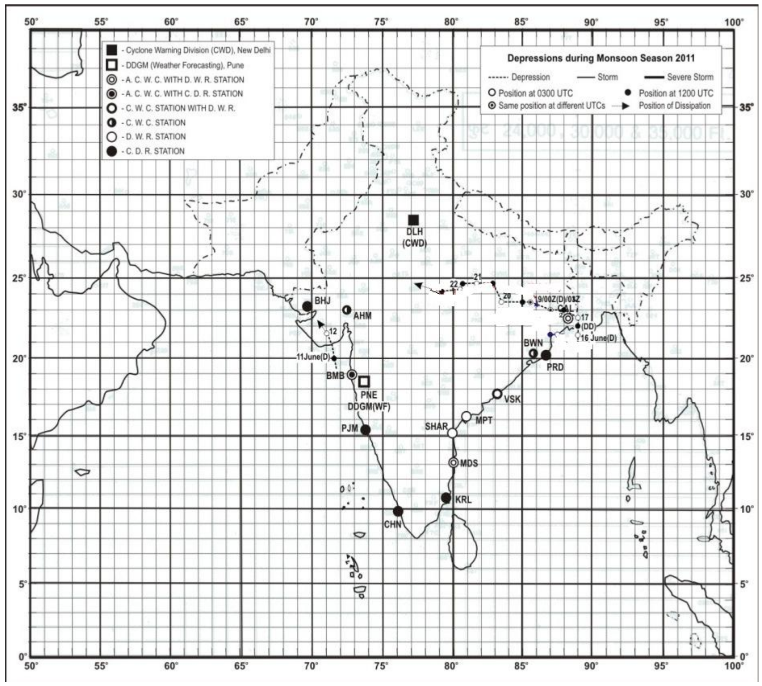


Fig.1: Track of Deep Depression

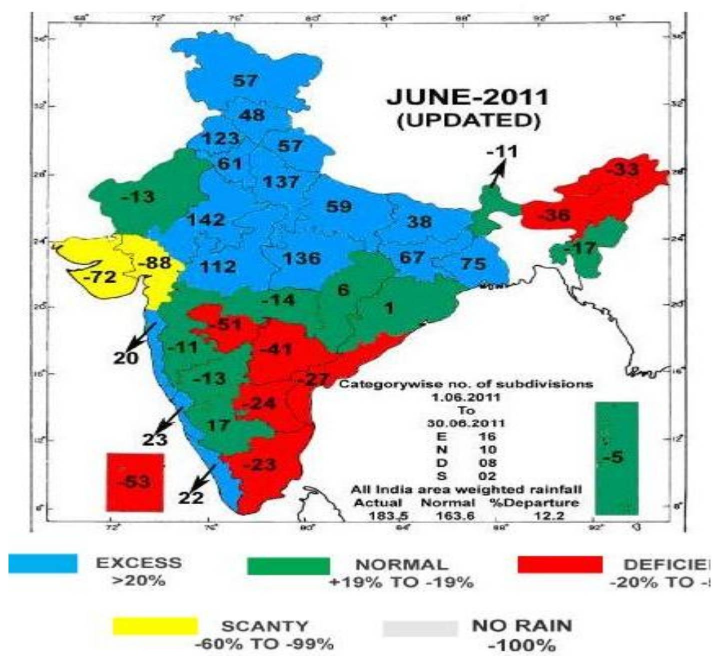


Fig.2: Subdivisional monthly rainfall distribution over India during June 2011

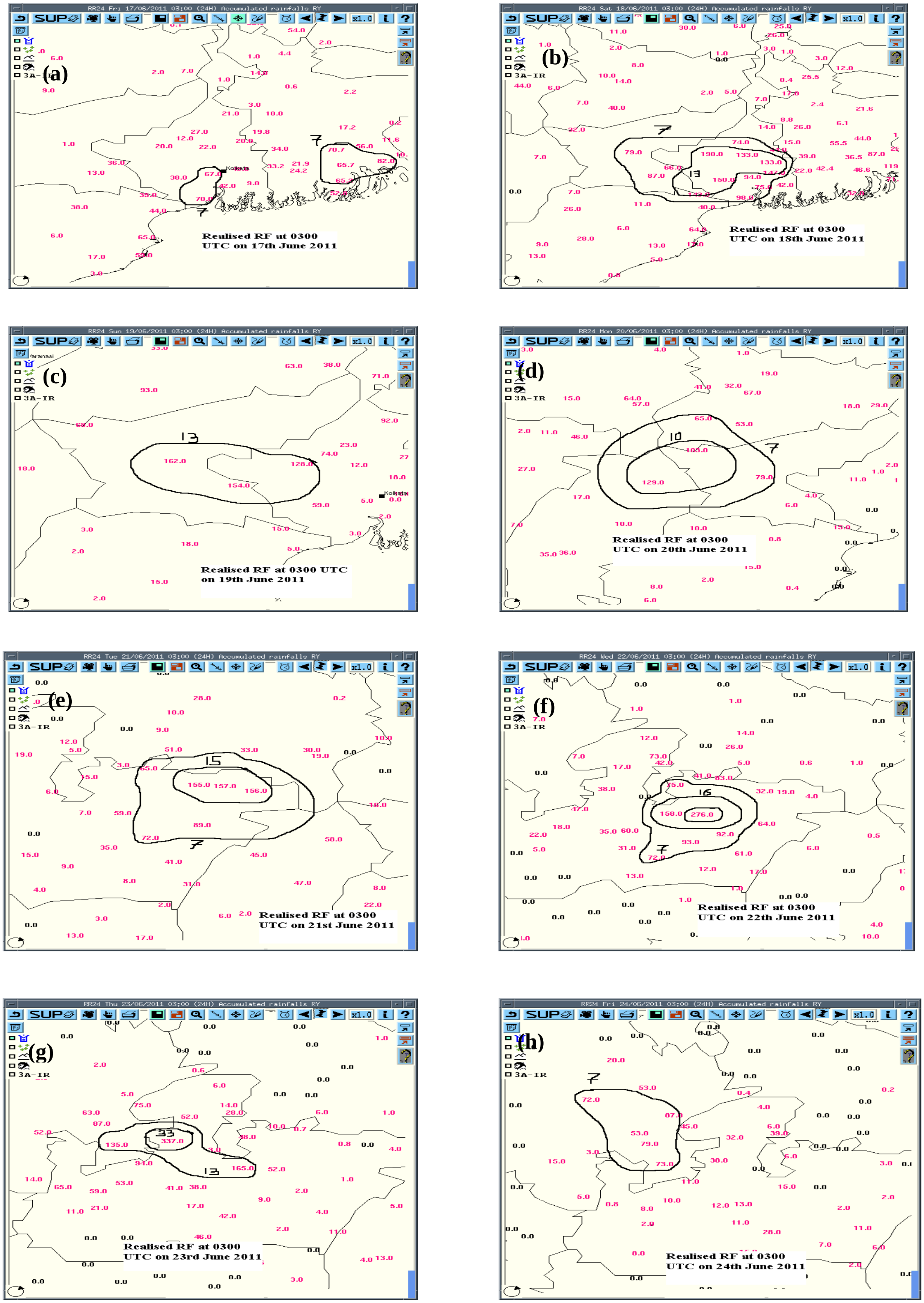


Fig.3 (a-h): Analysis of Rainfall

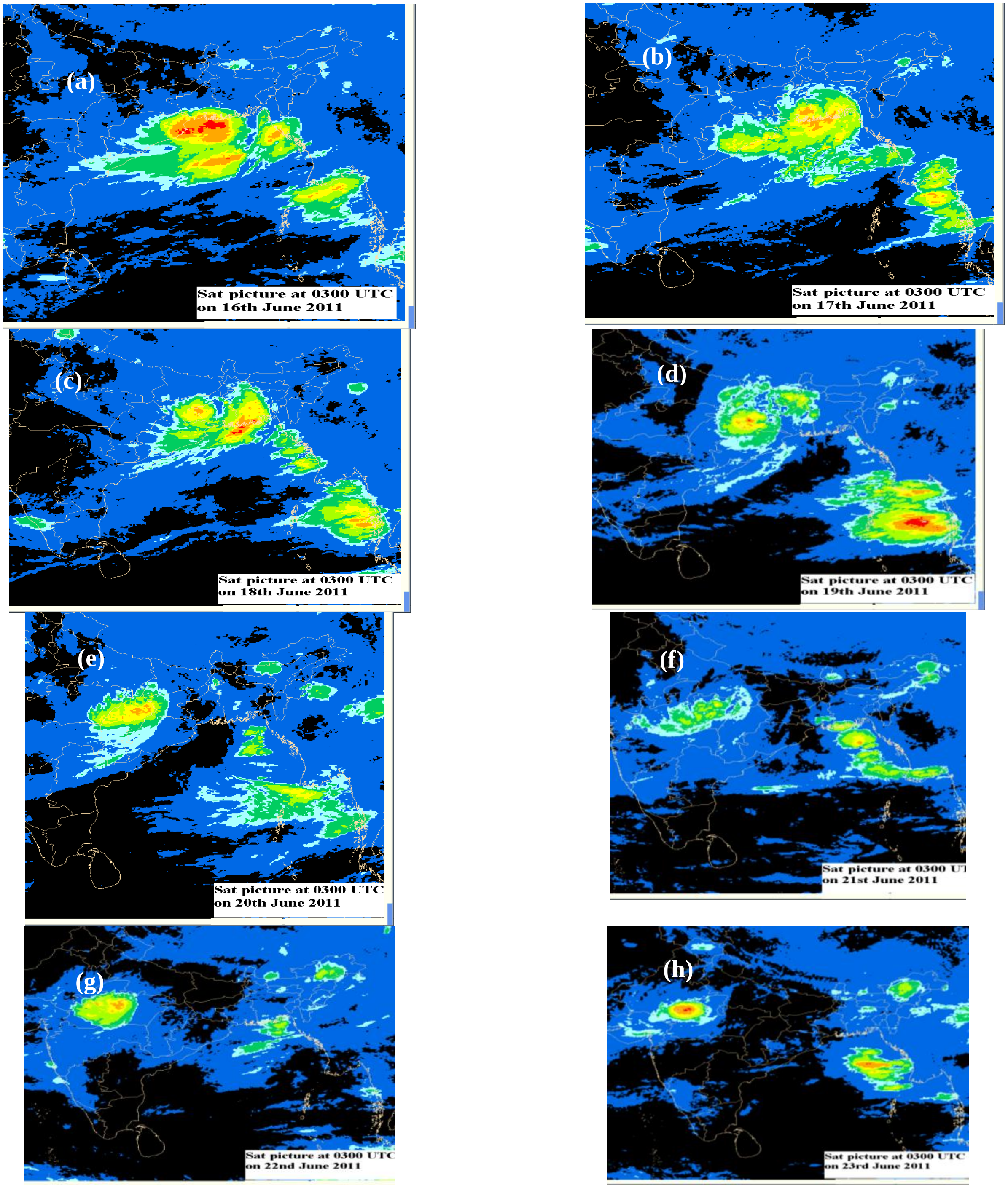
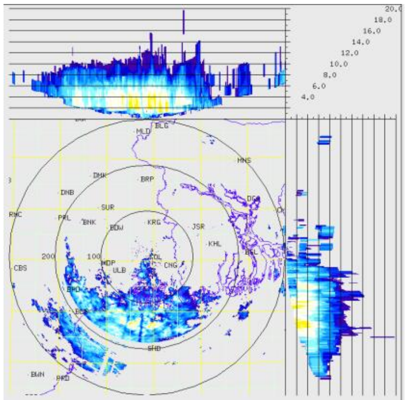


Fig.4(a-h) : Analysis of satellite picture



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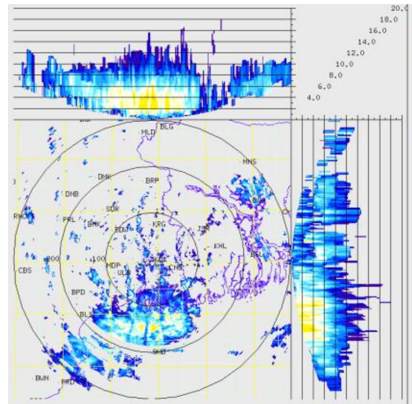

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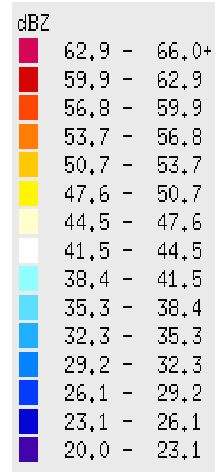

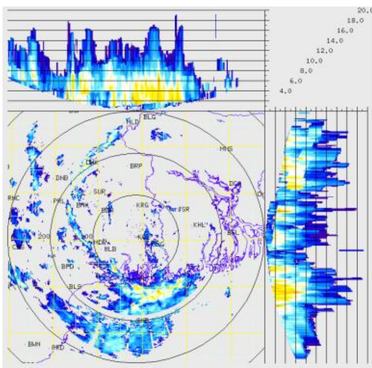

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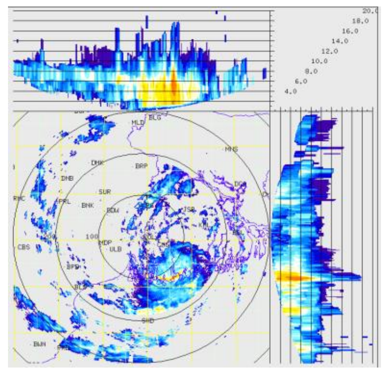

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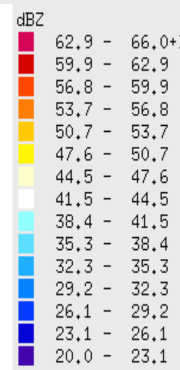

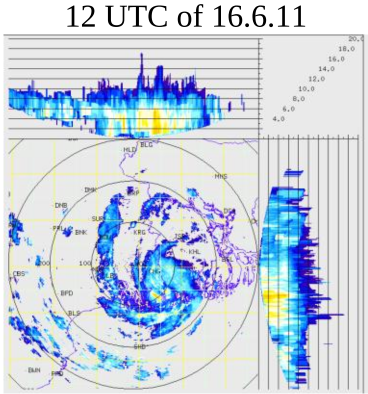

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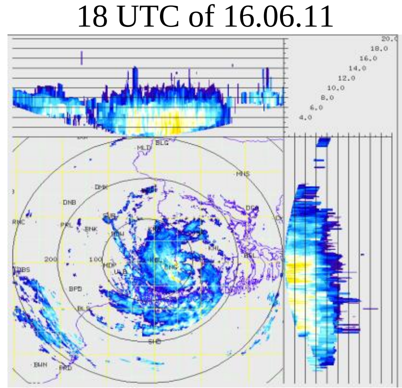

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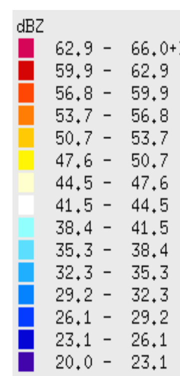

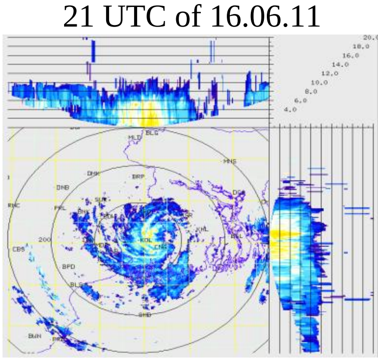

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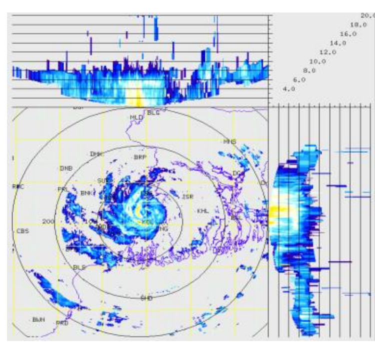

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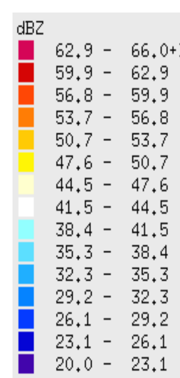

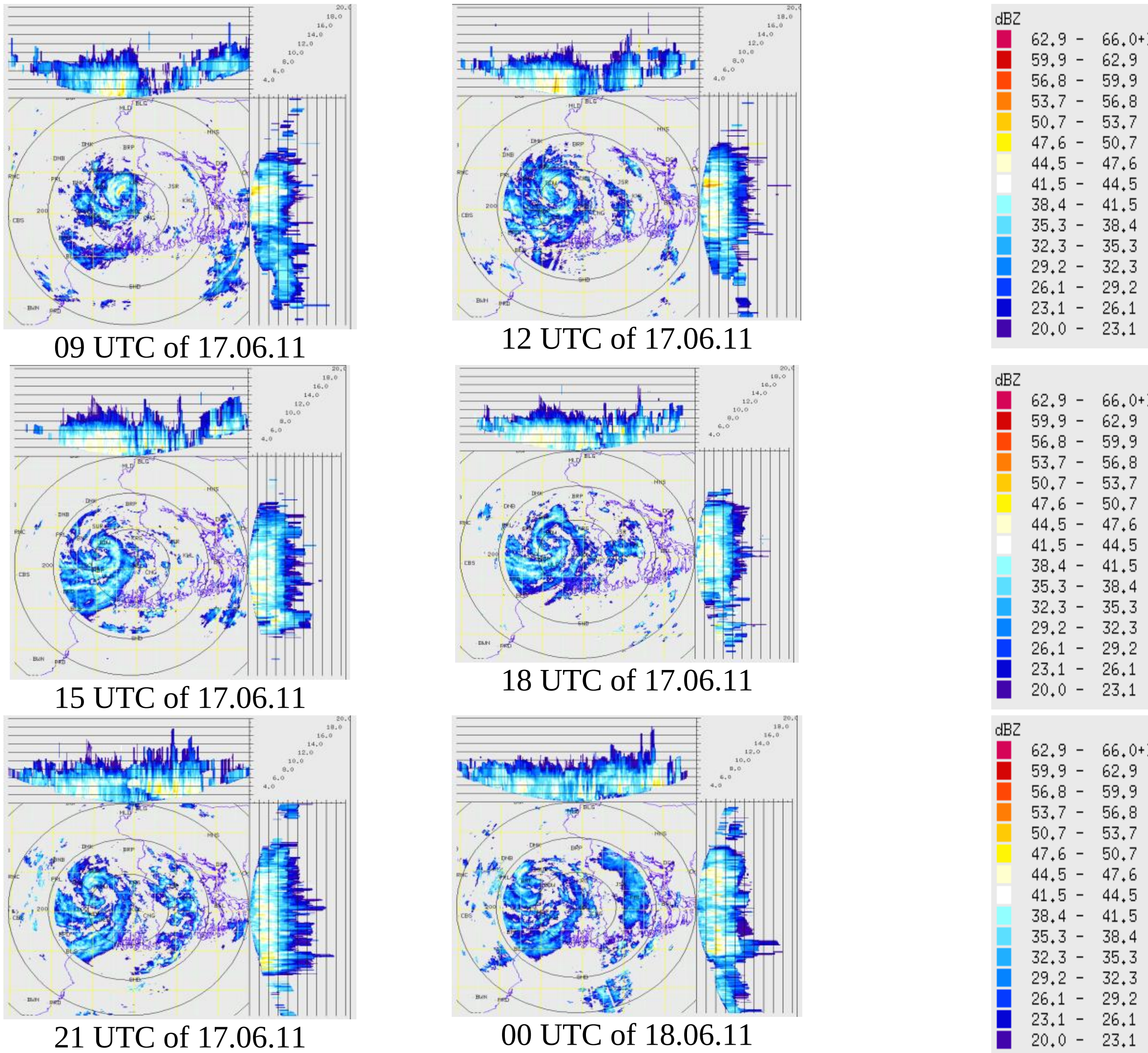

Fig.5: DWR images of the Depression during 16-18 June 2011

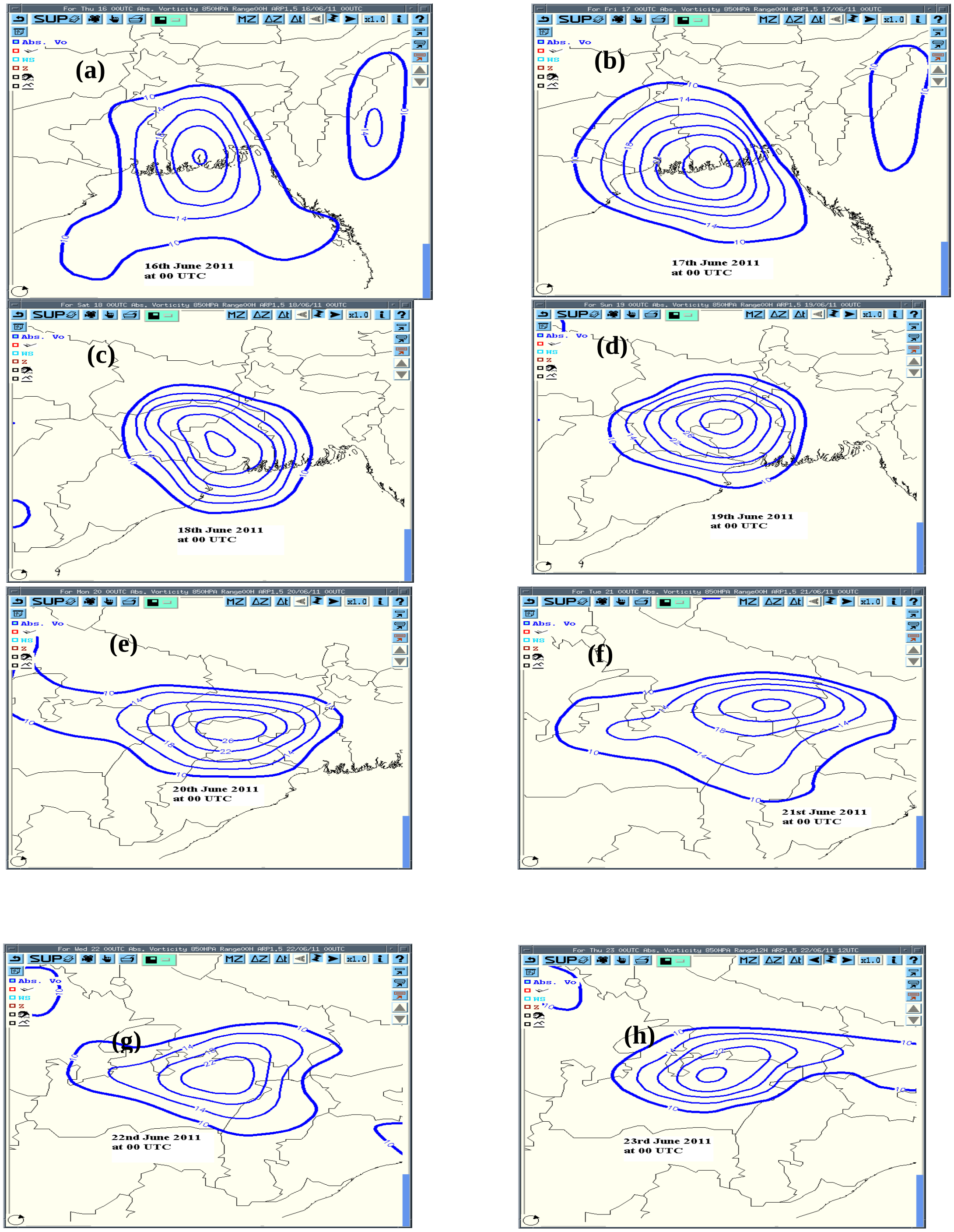

Fig.6 (a-h): Analysis of Absolute Vorticity

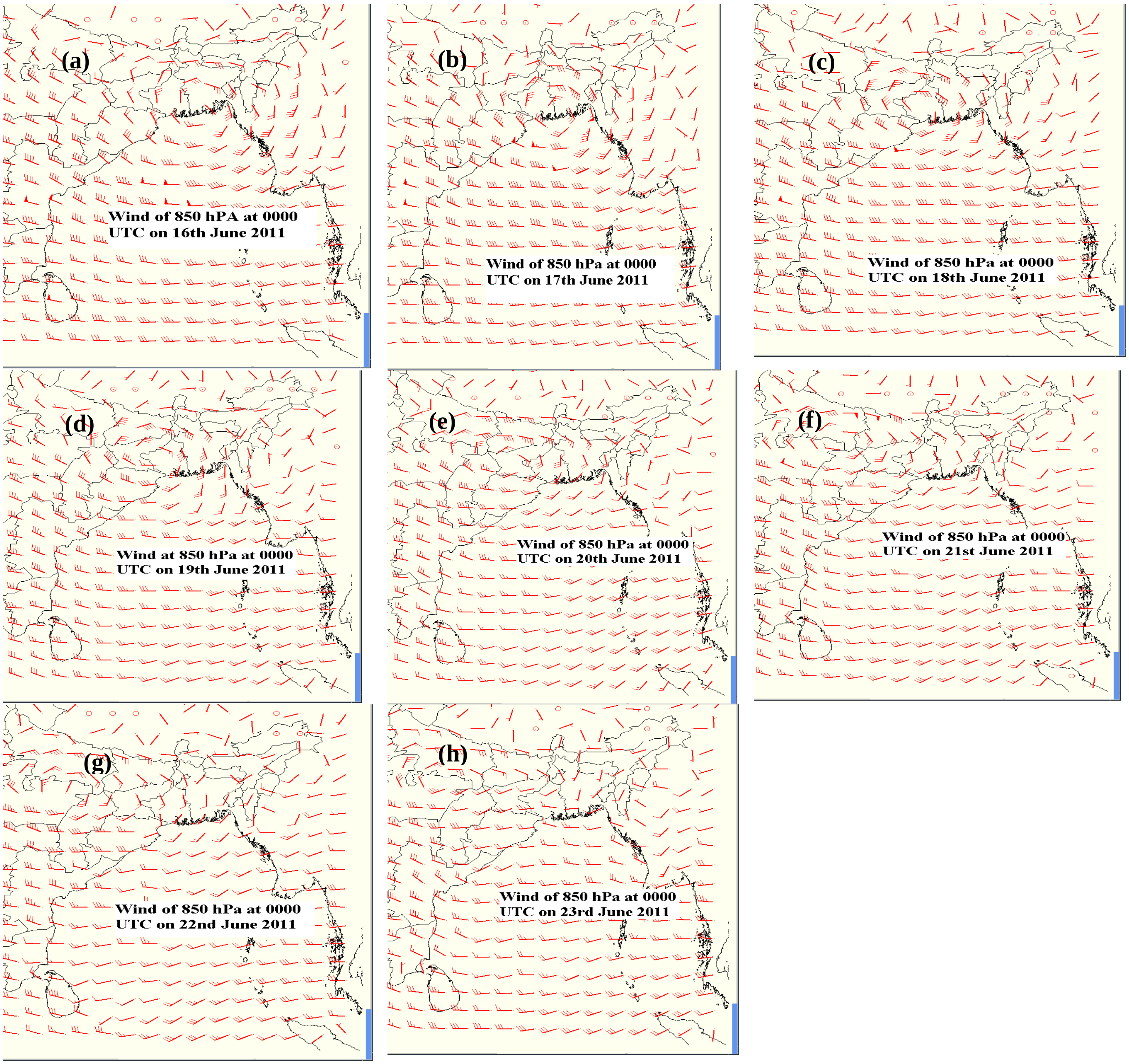

Fig.7 : Analysis of Wind at 850 hPa

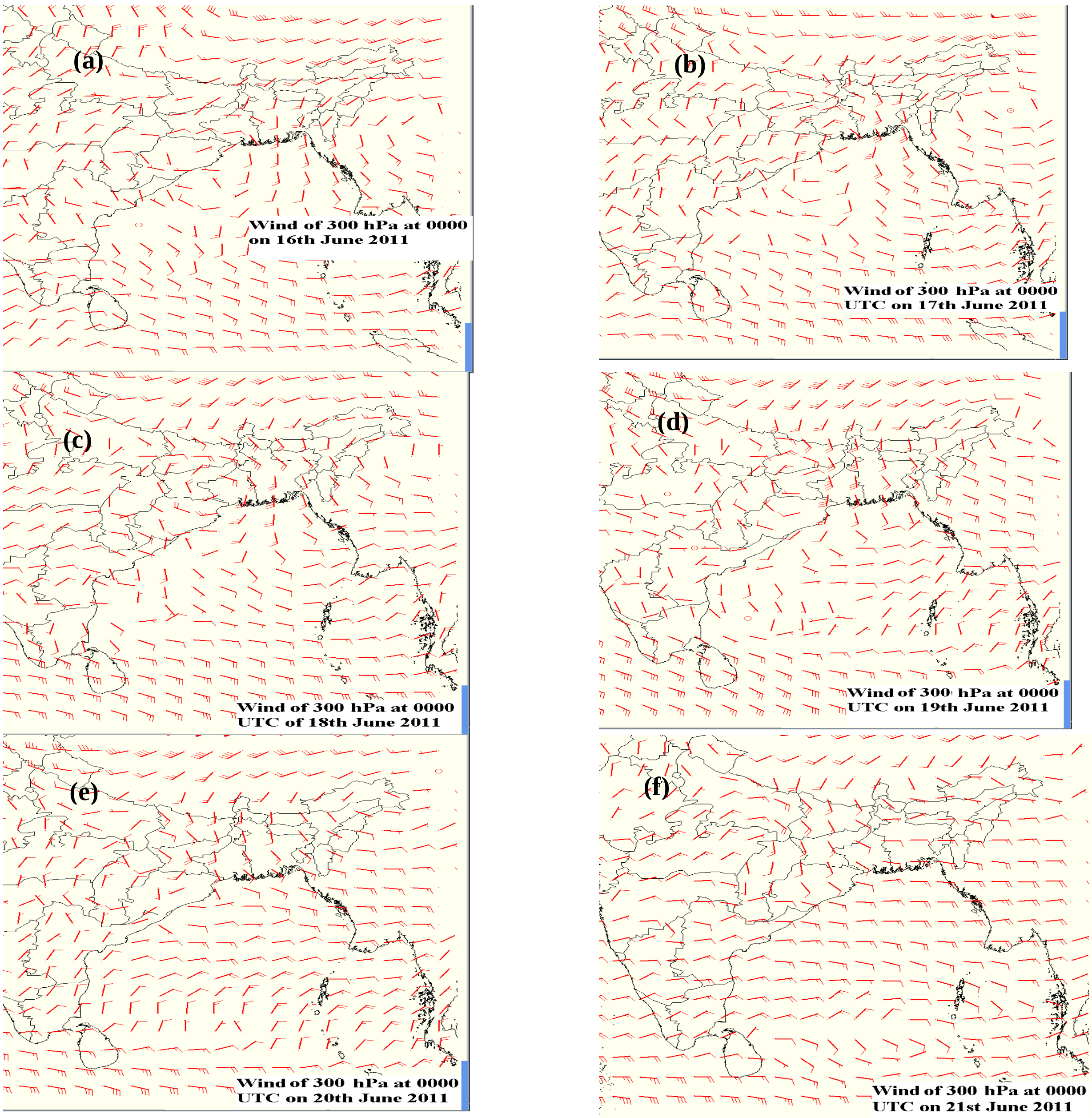

Fig.8 (a-f): Analysis of Wind at 300 hPa