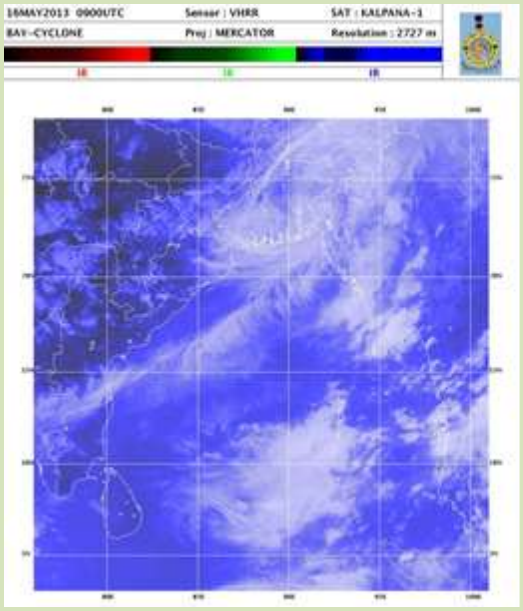
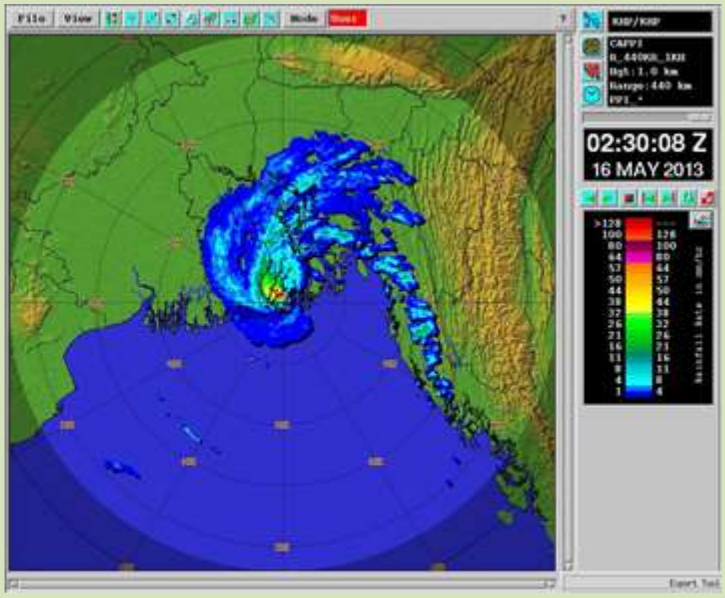
GOVERNMENT OF INDIA

MINISTRY OF EARTH SCIENCES

INDIA METEOROLOGICAL DEPARTMENT

A Preliminary Report on Cyclonic storm, Viyaru over Bay of Bengal (10-16 May, 2013)





Kalpna imagery & DWR Khepupara at the time of landfall

CYCLONE WARNING DIVISION, NEW DELHI

MAY, 2013

Cyclonic Storm, Viyaru over Bay of Bengal
(10 - 16 May, 2013)

1. Introduction

A cyclonic storm, Viyaru crossed Bangladesh coast near lat.22.8^{0}N and long. 91.4^{0}E, about 30 km south of Feni around 1330 hrs IST of 16th May 2013 with a sustained maximum wind speed of about 85-95 kmph. The salient features of this storm are as follows.

(i) The genesis of the disturbance took place in a lower latitude, near 5 degree North.
(ii) It was one of the longest track over north Indian Ocean in recent period after the very severe cyclonic storm, Phet over the Arabian Sea (31 May-07 June, 2010)
(iii) The cyclonic storm moved very fast (about 40-50 km per hour on the day of landfall, i.e. on 16th May 2013. Such type of fast movement of the cyclonic storm is very rare.
(iv) Due to the faster movement, the adverse weather due to the cyclonic storm was relatively less.

2. Brief life history

A depression formed over southeast Bay of Bengal at 1430 hrs IST of 10th May 2013 near latitude 5.0^{0}N and longitude 92.0^{0}E. It moved northwestwards and intensified into a deep depression in the evening of the same day. Continuing its northwestward movement, It further intensified into a cyclonic storm, Viyaru in the morning of 11th May 2013. Under the influence of the anticyclonic circulation lying to the east, the cyclonic storm changed its direction of movement initially from northwesterly to northerly and then to north-northeasterly on 13th and 14th May respectively. On 15th May, it further came under the influence of the mid-latitude westerly trough running roughly along 77^{0}E, which further helped in enhancing the north-northeastward movement of the cyclonic storm. As this trough came closer on 16th the north-northeastward speed of the cyclonic storm significantly increased, becoming about 40-50 kmph. The cyclonic storm crossed Bangladesh coast near lat. 22.8^{0}N and long. 91.4^{0}E, about 30 km south of Feni around 1330 hrs IST of 16th May 2013 with a sustained maximum surface wind speed of about 85-95 kmph. After the landfall, it continued to move north-northeastwards and weakened gradually due to interaction with land surface. It weakened into a deep depression over Mizoram in the evening and into a depression over Manipur around mid-night of 16th. It further weakened into a well marked low pressure area over Nagaland in the early morning and moved away towards Myanmar as a low pressure area in the morning of 17th.

The track of the system is shown in Fig. 1. It was a recurving track with north-northeastward recurvature. Climatologically, most of the cyclones generating over the

southeast Bay of Bengal recurve towards Bangladesh-Myanmar coast in the month of May. The best track parameters of cyclonic storm, Viyaru are shown in Table 1. The typical satellite and radar imageries are shown in Fig.2 & 3 respectively.

Table 1: Best track positions and other parameters of the Cyclone 'Viyaru' over the Bay of Bengal during 10-16 May, 2013

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
10-05-2013	0900	5.0/92.0	1.5	1004	25	3	D
	1200	5.5/92.0	2.0	1002	30	5	DD
	1800	6.0/91.5	2.0	1000	30	5	DD
11-05-2013	0000	6.5/91.0	2.0	998	30	6	DD
	0300	7.0/90.5	2.5	996	35	8	CS
	0600	7.0/90.5	2.5	996	35	8	CS
	0900	7.5/90.0	2.5	996	35	8	CS
	1200	8.0/89.5	2.5	994	40	8	CS
	1500	8.5/89.0	2.5	994	40	8	CS
	1800	9.0/89.0	2.5	994	40	8	CS
	2100	9.5/88.5	2.5	994	40	8	CS
12-05-2013	0000	10.0/88.0	2.5	994	40	8	CS
	0300	10.0/87.5	2.5	994	40	8	CS
	0600	10.0/87.5	2.5	994	40	8	CS
	0900	10.5/87.0	2.5	994	40	8	CS
	1200	10.5/87.0	2.5	994	40	8	CS
	1500	10.5/86.5	2.5	994	40	8	CS
	1800	11.0/86.5	2.5	994	40	8	CS
	2100	11.0/86.5	2.5	994	40	8	CS
13-05-2013	0000	11.5/86.5	2.5	994	40	8	CS
	0300	12.0/86.5	2.5	994	40	8	CS
	0600	12.0/86.5	2.5	994	40	8	CS
	0900	12.0/86.0	2.5	994	40	8	CS
	1200	12.0/86.0	2.5	994	40	8	CS
	1500	12.5/86.0	2.5	994	40	8	CS
	1800	12.5/85.5	2.5	994	40	8	CS
	2100	13.0/85.5	2.5	994	40	8	CS
14-05-2013	0000	13.5/85.5	2.5	994	40	8	CS
	0300	13.5/85.5	2.5	994	40	8	CS
	0600	14.0/85.5	2.5	994	40	8	CS
	0900	14.0/85.5	2.5	994	40	8	CS
	1200	14.5/86.0	2.5	994	40	8	CS
	1500	14.5/86.0	2.5	994	40	8	CS

	1800	15.0/86.5	2.5	994	40	8	CS
	2100	15.5/86.5	2.5	994	40	8	CS
15-05-2013	0000	16.0/87.0	2.5	994	40	8	CS
	0300	16.5/87.0	2.5	992	40	8	CS
	0600	17.0/87.5	3.0	990	45	10	CS
	0900	17.5/87.5	3.0	990	45	10	CS
	1200	18.0/88.0	3.0	990	45	10	CS
	1500	18.5/88.5	3.0	990	45	10	CS
	1800	19.0/88.5	3.0	990	45	10	CS
	2100	19.5/89.0	3.0	990	45	10	CS
16-05-2013	0000	20.0/89.5	3.0	990	45	10	CS
	0300	21.0/90.0	3.0	990	45	10	CS
	0600	22.5/91.0	3.0	990	45	10	CS
	Crossed Bangladesh coast between Chittagong and Feni, near latitude 22.8ºN and longitude 91.4ºE (about 30 km south of Feni), around 0800 UTC.						
	0900	23.5/92.0	-	994	40	8	CS
	1200	24.0/92.5	-	996	30	6	DD
	1800	25.0/93.5	-	998	25	4	D
17-05-2013	0000	Weakened into a well marked low pressure area over Nagaland					

D: Depression, DD: Deep Depression, CS: Cyclonic storm

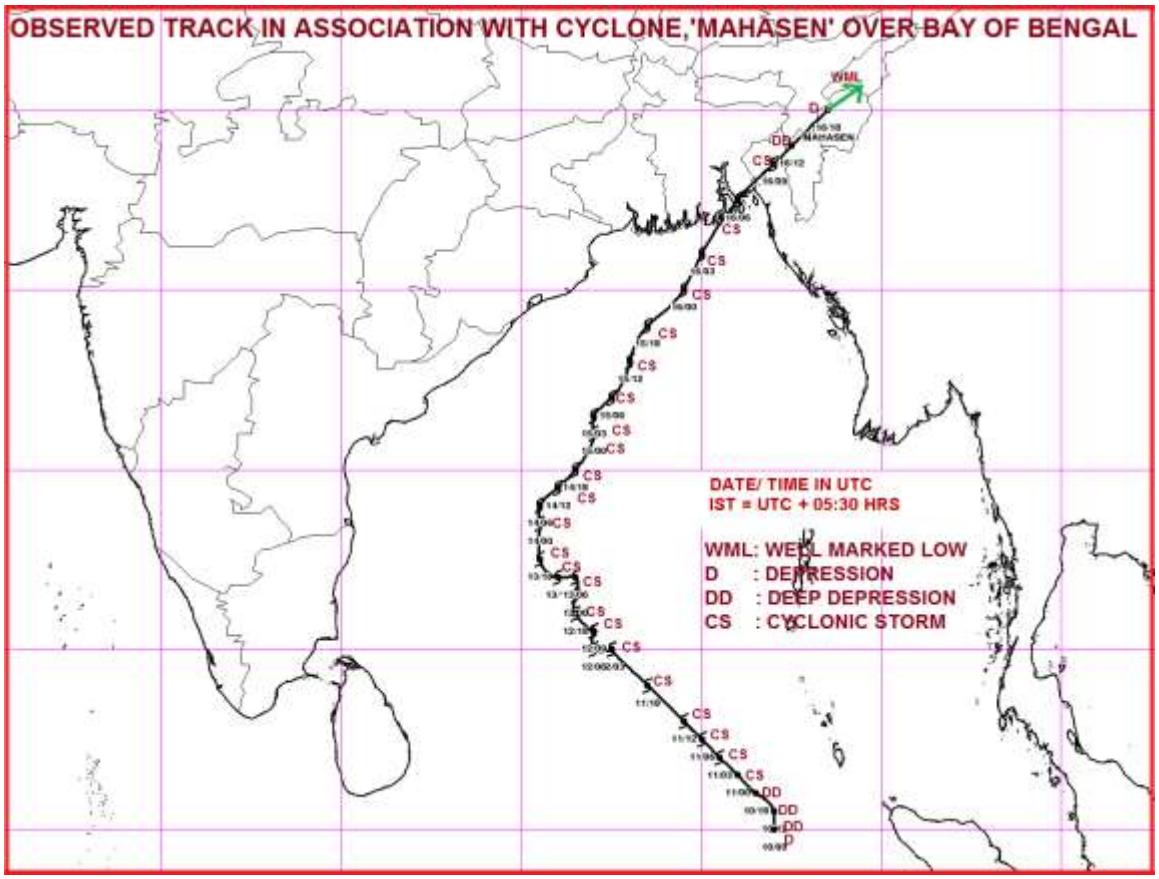


Fig.1 Track of Cyclonic Storm 'Viyaru' over the Bay of Bengal (10-16 May, 2013)

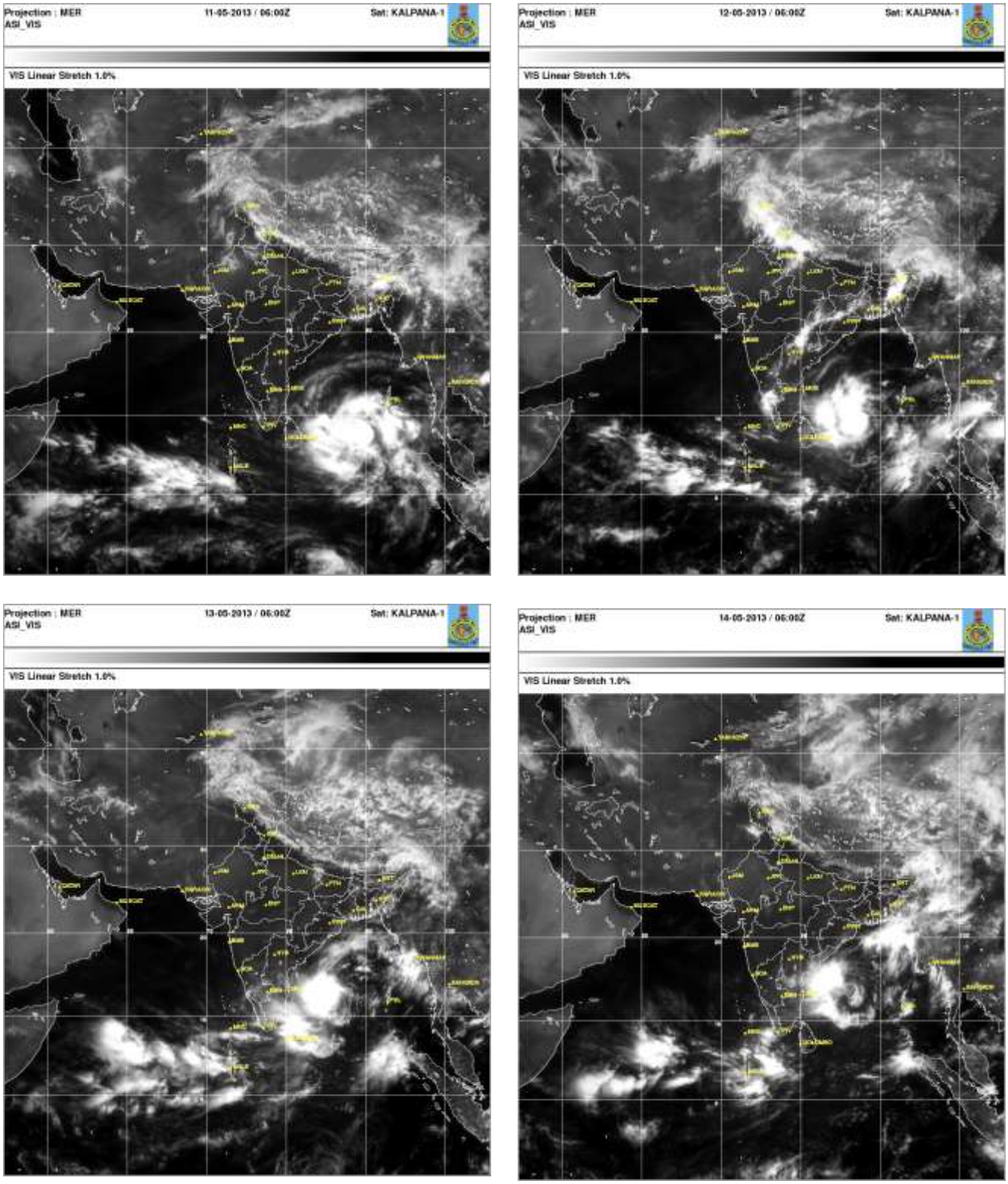


Fig.2. Typical Kalpana-1 Satellite imageries of cyclonic storm VIYARU at 0600 UTC of 11-14 May, 2013.

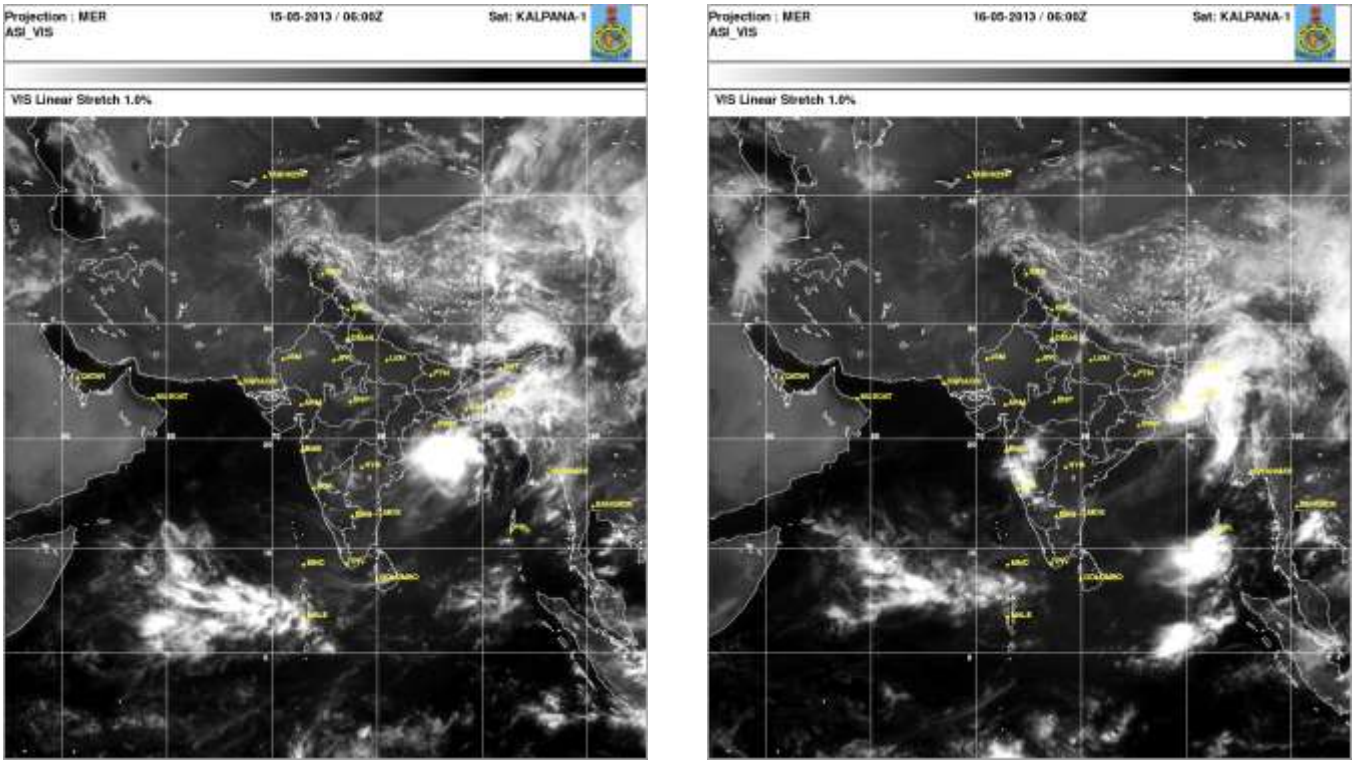


Fig.2.(contd.) Typical Kalpana-1 Satellite imageries of cyclonic storm VIYARU at 0600 UTC of 15-16 May,. 2013.

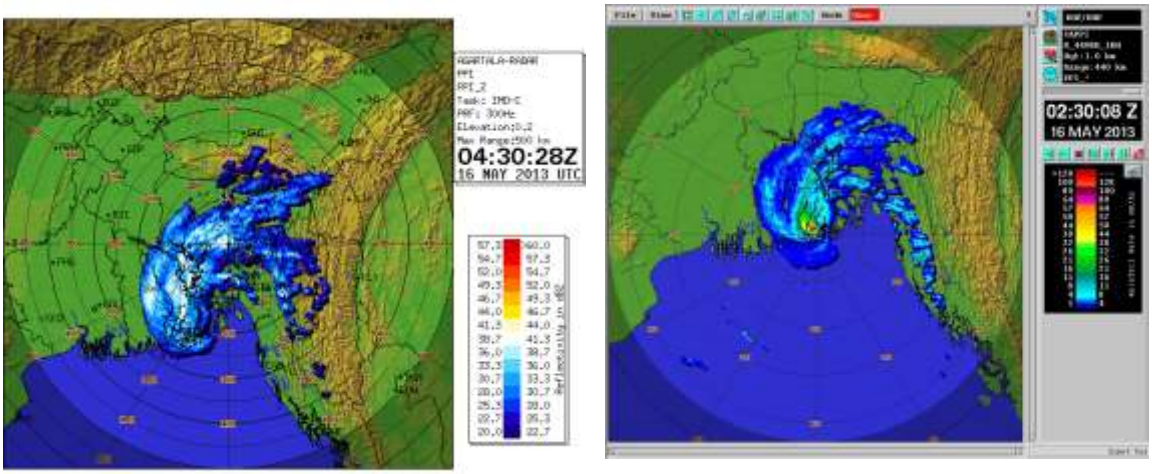


Fig.3 Typical DWR imageries of Agartala & Khepupara (Bangladesh) in forenoon of 16 May, 2013

3. Realized Weather at the time of landfall

Surface Wind: Maximum surface wind of 92 kmph has been reported over Patuakhali, Bangladesh during the time of landfall of Cyclonic Storm, VIYARU against the forecast wind speed of 75-85 kmph gusting to 95 kmph. Surface wind of 35-45

kmph prevailed over Mizoram, Manipur and Tripura against forecast of 55-65 kmph.

Rainfall: Widespread rainfall with isolated heavy to very heavy falls occurred over Bangladesh. Fairly widespread rainfall with isolated heavy rainfall also occurred over Mizoram, Manipur and Tripura.

Storm surge: A storm surge of height of about 1 metre has been reported in section of media.

4. Monitoring and Prediction

The cyclonic storm, Viyaru was monitored mainly with satellite supported by meteorological buoys, coastal and island observations. It was monitored by Doppler Weather Radar (DWR), Kolkata, Agartala and Cox's Bazar (Bangladesh) on 16th May. The half hourly INSAT/ Kalpana imageries and every 10 minutes DWR imageries and products were used for monitoring of cyclonic storm.

Various numerical weather prediction (NWP) models and dynamical-statistical models including IMD's global and meso-scale models were utilized to predict the track and intensity of the storm. The Tropical Cyclone Module in the digitized forecasting system of IMD was utilized for analysis and comparison of various NWP models and decision making process. However, there was large divergence in NWP model guidance with respect to genesis and intensification of the system. There was more unanimity in the NWP models with respect to track prediction, though most of the models could not predict the very fast movement of the cyclone on the day of landfall, i.e. on 16th May 2013.

5. Forecast Performance

5.1 Warning services

The Cyclone Warning Division/ Regional Specialised Meteorological Centre (RSMC)-Tropical Cyclone, IMD, New Delhi mobilised all its resources for monitoring and prediction of cyclonic storm, Viyaru. It issued 3/6 hourly warning/advisory bulletins to national disaster management agencies. It issued forecast and warning bulletins to various national and international disaster management agencies including National Disaster Management (NDM), Ministry of Home Affairs (MHA), concerned state Govts. and other users in regular intervals. It also issued advisories to World Meteorological Organisation (WMO)/Economic and Social Cooperation for Asia and the Pacific (ESCAP) Panel member countries including Bangladesh, Myanmar, Thailand, Pakistan, Oman, Sri Lanka and Maldives during cyclone period. As tropical cyclone advisory centre (TCAC), it also

issued tropical cyclone advisories with effect from the stage of cyclone for international civil aviation purpose as per the requirement of international civil aviation organization (ICAO).

IMD continuously monitored, predicted and issued bulletins containing track & intensity forecast at +06, +12, +18, +24, +36, +48, +60, +72, +84, +96, +108 and +120 hrs. till the system weakened into a low pressure area. The above structured track and intensity forecasts were issued from the stage of deep depression onwards. The cone of uncertainty in the track forecast was also given. The radius of maximum wind and radius of ≥34 knots, ≥50 knots and ≥64 knots wind in four quadrants of cyclone was also issued every six hours. The graphical display of the observed and forecast track with cone of uncertainty and the wind forecast for different quadrants were uploaded in the IMD's website regularly. The storm surge guidance was provided as and when required to Bangladesh and Myanmar based on IIT, Delhi and INCOIS models. The prognostics and diagnostics of the systems were described in the special tropical weather outlook and tropical cyclone advisory bulletins. The TCAC bulletin was also sent to Aviation Disaster Risk reduction (ADRR) centre of WMO at Honkong like previous year. Tropical cyclone vitals were prepared every six hourly from deep depression stage onwards and provided to various NWP modeling groups in India for synthetic vortex generation in NWP models.

The numbered warning bulletins were issued by Cyclone Warning division, IMD, New Delhi since 10th May 2013 afternoon. The bulletins were issued every three hourly since the cyclonic storm stage, i.e. from 11th May 2013 morning to WMO/ESCAP Panel countries, including Bangladesh and Myanmar. The number of bulletins issued by the Regional Specialised Meteorological Centre-Tropical Cyclone, New Delhi, to Bangladesh and Myanmar, by Tropical Cyclone Advisory Centre (TCAC), New Delhi to international civil aviation and by Cyclone Warning Division, IMD, New Delhi for India are given below.

Bulletins for India	: 36
Special Tropical Weather Outlook and Tropical Cyclone Advisory Bulletin for WMO/ESCAP Panel countries including Bangladesh and Myanmar	: 47
Tropical Cyclone Advisory Bulletin for international Civil Aviation	: 23

In addition, special e-mails about the cyclone were also sent to Bangladesh and Myanmar on 8th and 9th before the issue of structured bulletins on 10th May. The warning bulletins were issued to various disaster management agencies in the national level and to Govt. of Andaman & Nicobar Islands, Assam, Nagaland, Manipur, Mizoram and Tripura.

5.2. Forecast verification

5.2.1. Track forecast error

In the first bulletin issued in the afternoon of 10th May (six days in advance of landfall), when the system was a depression over southeast Bay of Bengal, located at 1900 km south of Chittagong, it was predicted that the system would intensify into a cyclonic storm and move towards Bangladesh-Myanmar. The average track forecast error is shown in Table 1. It was 152 km, 205 and 268 km respectively for 24, 48 and 72 hrs. forecast period against the long period average of 146, 254 and 376 km based on the *peri*od of 2003-2012. Further, for the first time the track forecast was issued for 120 hrs lead period. The 96 and 120 hr average track forecast errors were about 308 and 222 km respectively.

Table 2 Average Track Forecast Error and skill of Cyclonic Storm, Viyaru

Lead Period (hr)	Track forecast Error (km)	Track forecast skill (%)	Number of six hourly forecasts verified
12	90	28.6	24
24	152	31.8	22
36	189	46.5	20
48	205	60.0	18
60	208	68.0	16
72	268	69.5	14
84	251	75.2	10
96	308	76.9	8
108	291	80.8	6
120	222	86.3	4

Usually the track forecast errors are higher world-wide for the recurving cyclones like Viyaru. Hence, the track forecast errors of Viyaru has been compared with the average errors of recurving cyclones during 2003-12. It is found that the errors in case of Viyaru are significantly less than the average errors in case of recurving cyclones, as the average errors of recurving cyclones are about 91, 167, 249, 325, 398 and 474 km for 12, 24, 36, 48, 60 and 72 hrs lead period respectively.

The performance of the operational forecast has been compared with forecast by climatology and persistence (CLIPER) model as per international practice. CLIPER model is taken as a reference model to find out the relative performance of NWP models and operational forecasts of cyclones in different Ocean basins.

The gain in skill on operational forecast in relation to CLIPER, is quantified in percentage terms by;

$$\text{Gain in skill} = \frac{(\text{CLIPER DPE} - \text{DPE})}{\text{CLIPER DPE}} \times 100\%$$

The DPE is the direct position error or simply track forecast error. The results are shown in Table 2. It is found that the operational forecasts were highly skillful compared to CLIPER model forecast.

5.2.2. Landfall forecast error

Considering the landfall forecast error, the landfall on Bangladesh coast, near Chittagang was predicted in the first bulletin itself. The landfall point forecast errors 5 days before the landfall was about 100 km. It was 72, 125, and 165 km 24, 48 and 72 hrs respectively before landfall. However, the landfall time error was relatively higher in different forecast times (Table 3). It was mainly due to the fact that the cyclonic storm, Viyaru moved very fast on the day of landfall which could not be predicted by most of the numerical weather prediction models.

Table 3 Landfall point & landfall time forecast error (forecast-actual) of Cyclonic Storm, Viyaru

Lead Period (hrs) of forecast from the time of landfall	Landfall Point Forecast Error (km)	Landfall Time Forecast Error (hrs.)
12	**57**	**+7**
24	**72**	**+8**
36	**94**	**+13**
48	**125**	**+10**
60	**89**	**+10**
72	**165**	**+5**
96	**184**	**+10**
120	**100**	**-8**

5.2.3 Intensity forecast error

The intensity forecast error (average absolute error (AAE) and root mean square error(RMSE)) of IMD for cyclonic storm, Viyaru are shown in Table 4. The AAE was about 7, 10 15 knots against the long period average of 12, 13 and 19 knots based on the period of 2003-2012. The RMSE was about 09, 13 and 18 knots against the long period average of 15, 18 and 24 knots. Hence, both the AAE and RMSE are below the long period average.

Table 4 Average Intensity Forecast Error of Cyclonic Storm, Viyaru

Lead Period (hr)	Intensity forecast error (kt)		Number of six hourly forecasts verified
	Absolute Average Error (AAE)	Root Mean Square Error (RMSE)	
12	3.6	4.6	24
24	6.8	8.9	22
36	8.7	10.8	20
48	10	12.5	18
60	13	16.1	16
72	15	17.8	14
84	14	16.1	10
96	13	15.7	8
108	17	17.5	6
120	14	16.4	4

5.2.4. Gale and squally wind forecast over Bangladesh and northeastern states of India.

Considering the gale and squally wind speed forecast error over the land surface at the time of landfall and thereafter, the realized wind speed at the time of landfall was about 85-95 kmph as recorded by meteorological observatories in Bangladesh against the forecast of 75-85 kmph gusting to 95 kmph along and off Bangladesh coast (Table 5). The surface wind speed of 35-45 kmph has been reported over Mizoram, Manipur and Tripura against the forecast wind of 55-65 kmph gusting to 75 kmph. Due to the faster movement and increase in wind shear in association with trough in westerlies, the cyclonic storm Viyaru rapidly weakened over land leading to lower wind speed over Mizoram, Manipur and Tripura.

Table 5. Gale and squally wind forecast issued by IMD, New Delhi

Lead Period from landfall	Forecast wind	Actual wind
12	Bangladesh: 75-85 kmph gusting to 95 kmph Mizoram, Manipur and Tripura : 55-65 kmph gusting to 75 kmph	Bangladesh: Patuakhali : 92 kmph Mizoram, Manipur and Tripura : 35-45 kmph Agartala (Tripura) : 35 kmph Lengpui (Mizoram : 33 kmph
24	Bangladesh: 80-90 kmph gusting to 100 kmph Mizoram, Manipur and Tripura : 55-65 kmph gusting to 75 kmph	
36	Bangladesh: 65-75 kmph gusting to 85 kmph Mizoram and Tripura : 45-55 kmph gusting to 65 kmph	
48	Bangladesh: 65-75 kmph gusting to 85 kmph	

	Mizoram and Tripura : 45-55 kmph gusting to 65 kmph	
60	Bangladesh: 65-75 kmph gusting to 85 kmph	
72	Bangladesh: 65-75 kmph gusting to 85 kmph	

5.2.5. Rainfall forecast verification:

Widespread rainfall with isolated heavy to very heavy rainfall occurred over Bangladesh. Fairly widespread rainfall with isolated heavy rainfall also occurred over Mizoram, Manipur and Tripura. Detailed forecast and actual heavy rainfall are shown in Table 6.

Table 6. Heavy rainfall forecast issued by IMD, New Delhi

Lead Period from landfall	Forecast for heavy rainfall	Actual heavy rainfall
12	Mizoram, Manipur and Tripura, south Assam, Nagaland : Rainfall at most places with isolated heavy fall on 16th and 17th	Rainfall at most places occurred over Mizoram, Tripura, south Assam with isolated heavy fall over Tripura 24 hrs cumulative rainfall (5 cm or more) recorded at 0830 hrs IST: **16.05.2013** : Tripura : Agartala, Bishalgarh 8 cm each and Sonamura 7 cm **17.05.2013** Tripura : Gokulpur : 6 cm, Agartala : 5 cm
24	Mizoram, Manipur and Tripura : Rainfall at most places with isolated heavy fall on 16th and 17th	
36	Mizoram, Manipur and Tripura : Rainfall at many places with isolated heavy fall on 16th and 17th	
48	Mizoram and Tripura : Rainfall at many places with isolated heavy fall on 16th and 17th	

5.2.6. Storm surge:

The maximum storm surge height of 1-1.5 m above the astronomical tide (Table 7) was predicted by RSMC, New Delhi based on IIT, Delhi and INCOIS model over Bangladesh coast at the time of landfall. A storm surge of height of about 1 metre has been reported in section of media.

Table 7. Storm surge forecast issued by RSMC, New Delhi

Lead Period	Forecast storm surge above astronomical tide for Bangladesh	Actual storm surge
12	1.0-1.5 metre	1 metre storm surge has been reported in media.
24	1.0-1.5 metre	