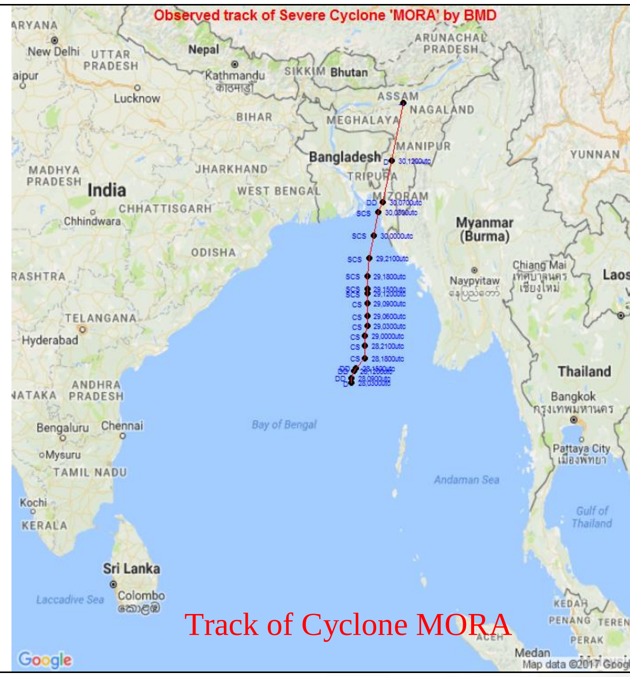
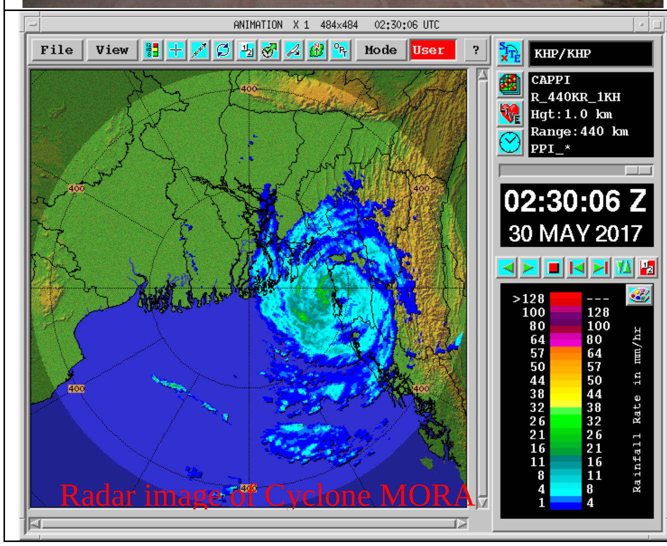
Scientific Report on Cyclone 'MORA'

BMD Headquarters



Track of Cyclone MORA



Radar image of Cyclone MORA

Damage for Cyclone MORA

Prepared by

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Preface

Cyclones are among the most devastating weather systems on the Earth. Cyclones are usually associated with strong winds and rain, high ocean waves and storm surge. Pre-monsoon (March-May) and post-monsoon (October-November) are the two primary seasons for formation of Cyclone in the Bay of Bengal. Coastal regions of Bangladesh are very much vulnerable to damage from a Cyclone.

Cyclone 'MORA' was the first tropical storm of the season of 2017 in the Bay of Bengal. It developed as a low pressure area over Southeast Bay and adjoining Central at 0900 UTC of 26 May 2017. It concentrated in to a Depression, Deep Depression and then Cyclonic Storm (CS) 'MORA' on 28 May 2017. It intensified into a Severe Cyclonic Storm (SCS) 'MORA' over North Bay and adjoining East Central at 1200 UTC of 29 May 2017. It moved north-northeastwards first and then northeastwards over North Bay and finally crossed Cox's Bazar-Chittagong Coast during 06 AM to 12 Noon of 30 May 2017.

The position and intensification of Cyclone 'MORA' was monitored by Bangladesh Meteorological Department (BMD) from its formation to landfall and issued through 17 Special Weather Bulletins containing advisories for the stakeholders and end users including fishermen and others. Port Authorities and the Coastal District Administrations of Bangladesh were also advised in time to take proper preparation through hoisting signals following the Standing Orders on Disaster (SOD). Accordingly, causalities and the loss of lives and properties were in minimum level.

I like to give my sincere thanks to the Ministry of Disaster Management and Relief (MoDMR) and Department of Disaster Management (DDM) for taking timely initiative as per the guidance of BMD for reducing the causalities and loss of lives of the vulnerable areas.

My heartfelt thanks are due to the Meteorologists and Meteorological Technicians of Storm Warning Centre (SWC), BMD for their constant effort to release the Special Weather Bulletins for Cyclone 'MORA' in time and preparation of this report.

Shamsuddin Ahmed
Director

Contents

1. Introduction

Tropical Cyclones (TCs) are one of the most devastating weather systems. They cause a lot of damage and destruction to lives and property associated with its strong gale winds, torrential rain and storm surge. It is therefore desirable to provide timely and accurate forecast of the track and intensity of cyclones for effective implementation of the disaster management. To improve the prediction, there is need of basic understanding of physics and dynamics involved in the genesis, intensity change, structure and track of tropical cyclone. Gray (1968) indicated that developing and non -developing cyclones are associated with different upper tropospheric circulation patterns e.g. non-developing TCs have uni-directional upper tropospheric flow which causes vertical shear above the cloud clusters relatively strong and the developing TCs normally have multidirectional out flow that results in weak vertical shear above the cyclones. Holland and Merrill (1984) concluded that not only upper tropospheric interactions but also the inner core convective heating may directly affect intensity change while lower tropospheric interactions will produce a size change which may indirectly affect the intensity or strength of Tropical cyclone. Craig and Gray (1996) showed that the intensification of numerically simulated tropical cyclones is due to Wind Induced Surface Heat Exchange (WISHE). Holland (1983) demonstrated that nonlinear combination of two processes: (i) an interaction between the cyclone and its basic current (steering current) and (ii) an interaction with the Earth's vorticity field, is responsible for movement of TCs.

The Cyclone MORA was mainly detected and tracked by synoptic observation in addition to numerical model products and satellite imageries. Radar imageries of BMD are also taken into consideration. Higher sea surface temperatures (SSTs) (more than 26.5°C), a deep lower level moist layer, absence of strong vertical wind shear, increase in vorticity over the area, are favourable criteria for intensification of a tropical low to a cyclonic storm and further intensification (Gray, 1992 and Frank, 1977). The satellite based monitoring and prediction of intensification were reviewed by Kelkar (1997) and further updated by Kalsi (2006) and Bhatia et al., (2006). The detailed review of the synoptic and thermodynamic characteristics associated with the intensification/ decay of the cyclonic storm over the north Indian Ocean are presented by Krishna Rao (1997). The review of the dynamical characteristics of intensification is given by Mohanty and Gupta (1997). A review of the prediction of tropical cyclone characteristics by NWP models is presented by Prasad (1997) and has been updated by Rama Rao *et. al* (2007). However, the intensity change at present is not properly captured in the NWP models (Rama Rao, *et al*., 2007). The genesis and movement of the cyclone 'MORA' though could be predicted by various NWP models, with reasonable accuracy, the intensity of the system remained unpredicted by most of the models. It posed a challenge to the NWP modelling as well as other conventional, synoptic and statistical methods to predict the intensity accordingly.

Considering all the above, an in-depth study has been undertaken to analyze various features of the cyclonic storm 'MORA' like genesis, intensification, movement, landfall and associated disastrous weather. The monitoring and prediction aspects of this cyclone by the synoptic observations, satellite observations, dynamical parameters and numerical weather prediction models and their limitations have been critically examined and discussed. A brief life history of cyclone MORA is presented in section 2. Monitoring and prediction of cyclone MORA, features observed through Satellite and Radar and numerical models and damages due to the SCS 'MORA' are presented in the following sections. Summary and conclusion is given at last.

2. Brief history of Cyclone MORA

A low pressure area developed over Southeast Bay and adjoining Central Bay in the afternoon of 26 May 2017. It intensified in to a Well Marked Low (WML) over the same area at 0900 UTC of 27 May 2017. The system concentrated in to a Depression (Lat 15.2°N, Lon 90.6°E) over the same area at 0300 UTC of 28 May 2017. It then moved northward and intensified into Deep Depression (DD) over Southeast Bay and adjoining Central Bay (Lat 15.4°N, lon 90.6°E) at 0900UTC of 28 May 2017. It then moved further north-northeastward and intensified into a Cyclonic Storm (CS) 'MORA' over East-Central Bay and adjoining area (Lat 16.2°N, lon 91.2°E). In continuation to this, cyclone 'MORA' moved north-northeastwards and intensified into Severe Cyclonic Storm (SCS) 'MORA' over North Bay and adjoining East-Central Bay (Lat 18.8°N, lon 91.3°E). Then it moved north-northeastward and crossed Cox's Bazar-Chittagong Coast during 06 AM to 12 Noon of 30.05.2017. After making landfall, SCS 'MORA' moved north-northeastward weakened into a Land DD over Rangamati Region at 0600 UTC of 30.05.2017. It then weakened further and became unimportant. The observed track of the SCS 'MORA' is shown in Fig.1.

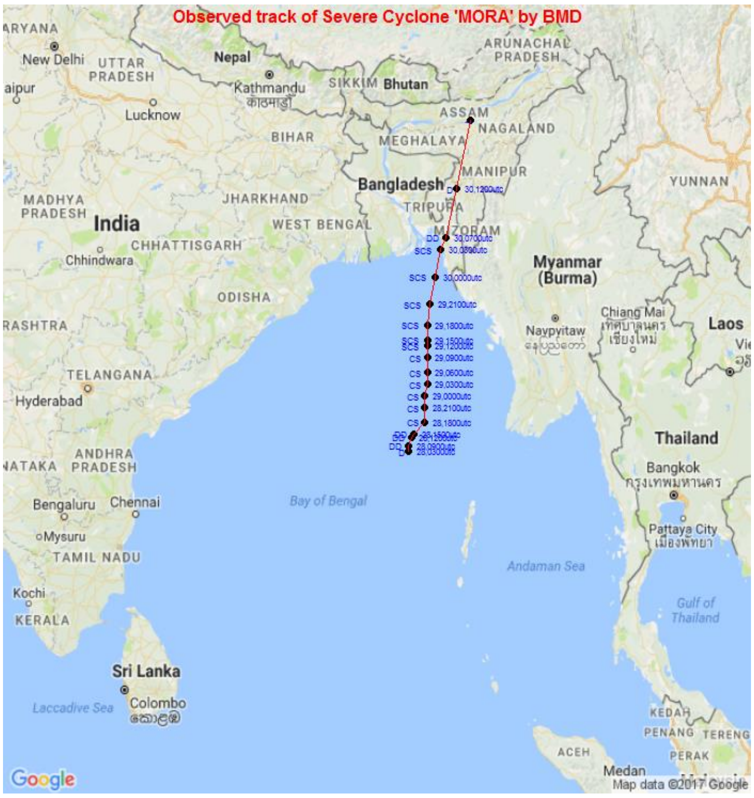

Fig. 1: Observed track of the Cyclone 'MORA'

3. Monitoring and prediction of Severe Cyclonic Storm 'MORA'

3.1 Monitoring Severe Cyclonic Storm 'MORA'

Severe Cyclonic Storm 'MORA' was monitored and predicted by BMD continuously since its formation. The observed track of the cyclone over the Bay of Bengal (BoB) during 28-31 May 2017 is illustrated in Fig.1. The details of the 'MORA' are given in Table 1**.**

Table 1: Position and Status of Cyclone 'MORA' as per BMD Record

Sl	Date	Time	Status	Area of the system	Latitude/ Longitude	Bulletin	Distance (km)	Signal
01.	26.05.2017	Afternoon	Low	SE Bay and adjoining Central Bay	-	-	-	-
02.	27.05.2017	Afternoon	WML	SE Bay and adjoining Central Bay	-	-	-	-
03.	28.05.2017	09 AM (03 UTC)	Depression	SE Bay and adjoining Central Bay	15.2° N /90.6°E	SWB: 01	Ctg:790; Cxb:710; Mgl:815; Payra:755	DC-I for all maritime ports
04.	28.05.2017	12 Noon (06 UTC)	Depression	SE Bay and adj Ctl Bay	15.2° N /90.6°E	SWB: 02	Ctg:790; Cxb:710; Mgl:815; Payra:755	DC-I for all maritime ports
05.	28.05.2017	03 PM (09 UTC	Deep Depression	SE Bay and adj Central Bay	15.4° N /90.6°E	SWB: 03	Ctg:770; Cxb:690; Mgl:790; Payra:735	DC-I for all maritime ports
06.	28.05.2017	06 PM (12UTC)	Deep Depression	SE Bay and adj Central Bay	15.7^0 N /90.7°E	SWB: 04	Ctg:735; Cxb:655; Mgl:760; Payra:700	DC-I for all maritime ports
07.	28.05.2017	09 PM (15UTC)	Deep Depression	SE Bay and adj Central Bay	15.8^0 N /90.8^{0}E	SWB: 05	Ctg:720 Cxb:640; Mgl:750; Payra:690	DC-I for all maritime ports
08.	29.05.2017 (28.05.2017)	Midnight (18UTC)	Cyclone 'Mora'	EC Bay and Adj area	16.2° N /91.2°E	SWB: 06	Ctg:670; Cxb:590; Mgl:715; Payra:650	DW-II for all maritime ports
09.	29.05.2017 (28.05.2017)	03 AM (21UTC)	Cyclone 'Mora'	EC Bay and Adj area	16.7° N /91.2°E	SWB: 07	Ctg:615; Cxb:535; Mgl:665; Payra:595	DW-II for all maritime ports
10.	29.05.2017 (28.05.2017)	06 AM (21UTC)	Cyclone 'Mora'	EC Bay and Adj area	17.1° N /91.2°E	SWB: 08	Ctg:570; Cxb:490; Mgl:620; Payra:555	LW-IV for all maritime ports
11.	29.05.2017 (29.05.2017)	09 AM (03UTC)	Cyclone 'Mora'	EC Bay and Adj area	17.5° N /91.3°E	SWB: 09	Ctg: 525; Cxb: 445; Mgl: 580; Payra:510	Ctg, Cxb- **DS-VII** Mgl, Pyra- **DS-V**
12.	29.05.2017 (29.05.2017)	12 Noon (06 UTC)	Cyclone 'Mora'	EC Bay and Adj North Bay	17.9° N /91.3°E	SWB: 10	Ctg: 480; Cxb: 400; Mgl: 540; Payra:470	Ctg, Cxb- **DS-VII** Mgl, Pyra- **DS-V**
13.	29.05.2017	03 PM	Cyclone	EC Bay and	18.4° N	SWB:	Ctg: 425;	Ctg, Cxb- **DS-**

Sl	Date	Time	Status	Area of the system	Latitude/ Longitude	Bulletin	Distance (km)	Signal
	(29.05.2017)	(09 UTC)	'Mora'	Adj North Bay	/91.3°E	11	Cxb: 345; Mgl: 490; Payra:415	**VII** Mgl, Pyra- **DS-V**
14.	29.05.2017 (29.05.2017)	06 PM (12 UTC)	SCS 'Mora'	North Bay and adj EC Bay	18.8° N /91.3°E	SWB: 12	Ctg: 385; Cxb: 305; Mgl: 450; Payra:370	Ctg, Cxb- **GDS-X** Mgl, Pyra- **GDS-VII**
15.	29.05.2017	09 PM (15 UTC)	SCS 'Mora'	North Bay and adj EC Bay	19.0° N /91.3°E	SWB: 13	Ctg: 360; Cxb: 280; Mgl: 430; Payra:350	Ctg, Cxb- **GDS-X** Mgl, Pyra- **GDS-VII**
16.	30.05.2017 (29.05.2017)	Midnight (18 UTC)	SCS 'Mora'	North Bay and adj EC Bay	19.5° N /91.3°E	SWB: 14	Ctg: 305; Cxb: 230; Mgl: 380; Payra:300	Ctg, Cxb- **GDS-X** Mgl, Pyra- **GDS-VII**
17.	30.05.2017 (29.05.2017)	03 AM (21 UTC)	SCS 'Mora'	North Bay and adj EC Bay	20.2° N /91.4°E	SWB: 15	Ctg: 230; Cxb: 150; Mgl: 320; Payra:235	Ctg, Cxb- **GDS-X** Mgl, Pyra- **GDS**-VII
18.	30.05.2017 (30.05.2017)	06 AM (00 UTC)	SCS 'Mora'	North Bay	Started Crossing Cox's Bazar-Chittagong Coast near Kutubdia	SWB: 16	-	Ctg, Cxb- **GDS-X** Mgl, Pyra- **GDS-VII**
19.	30.05.2017 (30.05.2017)	12 Noon (06 UTC)	Land Deep Depression	Rangamati and adjoining area	Crossed Cox's Bazar-Chittagong Coast during 06 AM to 12 Noon	SWB: 17	-	Ctg, Cxb- **GDS-X** Mgl, Pyra- **GDS-VII**

Note:'SWB' indicates 'Special Weather Bulletin', 'GD' Stands for 'Great Danger Signal', 'GDS' stands for 'Great Danger Signal', 'EC' Stands for 'East Central' 'L' indicates Low; 'WML' indicates Well Marked Low; 'D' indicates Depression; 'DD' indicates Deep Depression; 'CS' indicates Cyclonic Storm

3.2 Feature of SCS ‘MORA’ observed through BMD Radar

As the system was moving along the east coast, it was tracked by DWR Khepupara, Cox’s Bazar and Moulvibazar of BMD. Typical Radar imageries collected through these Radars are Fig. 10.

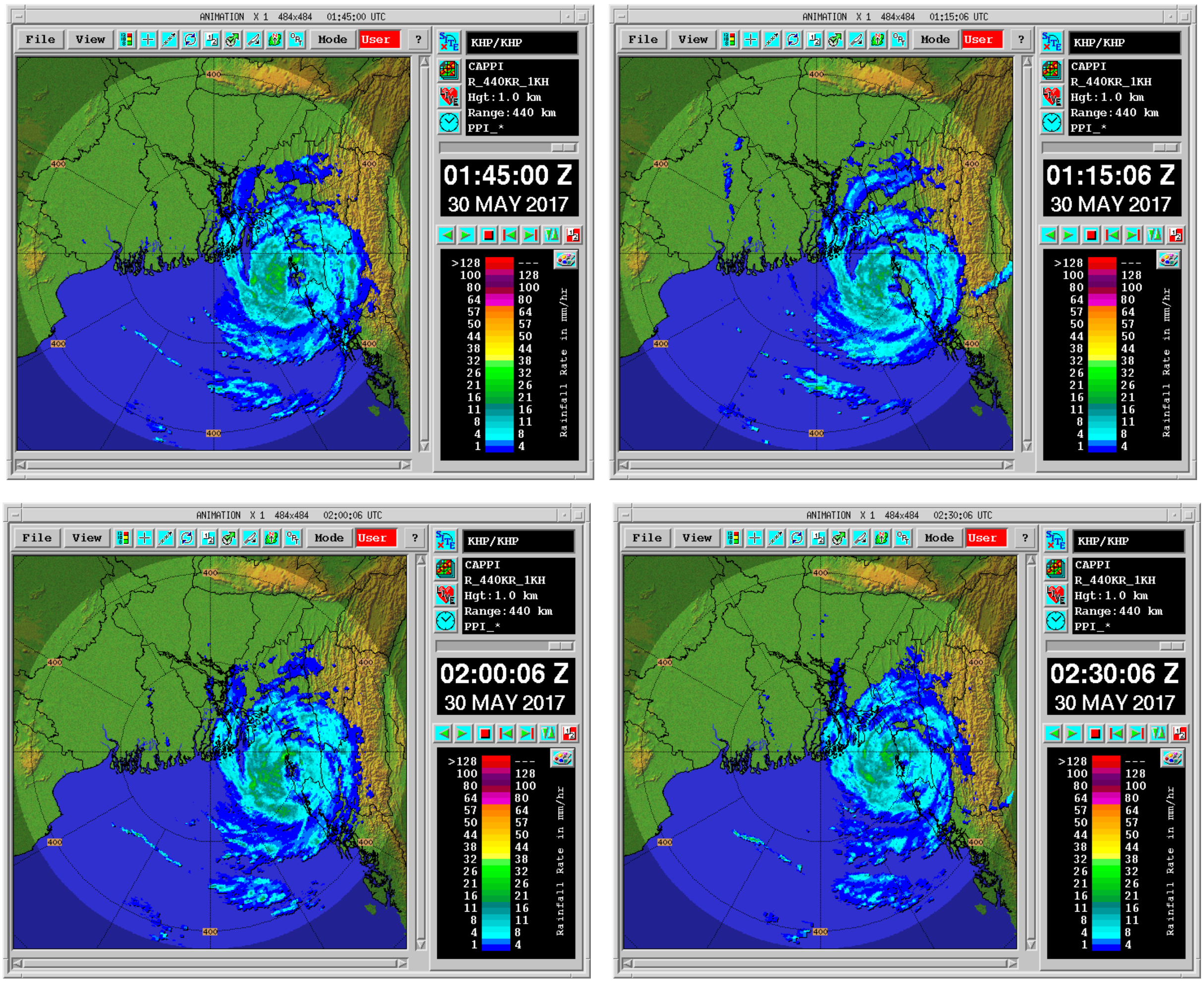

Fig. 2: Khepupara Radar imageries for Cyclone ‘MORA’ during 30 May 2017

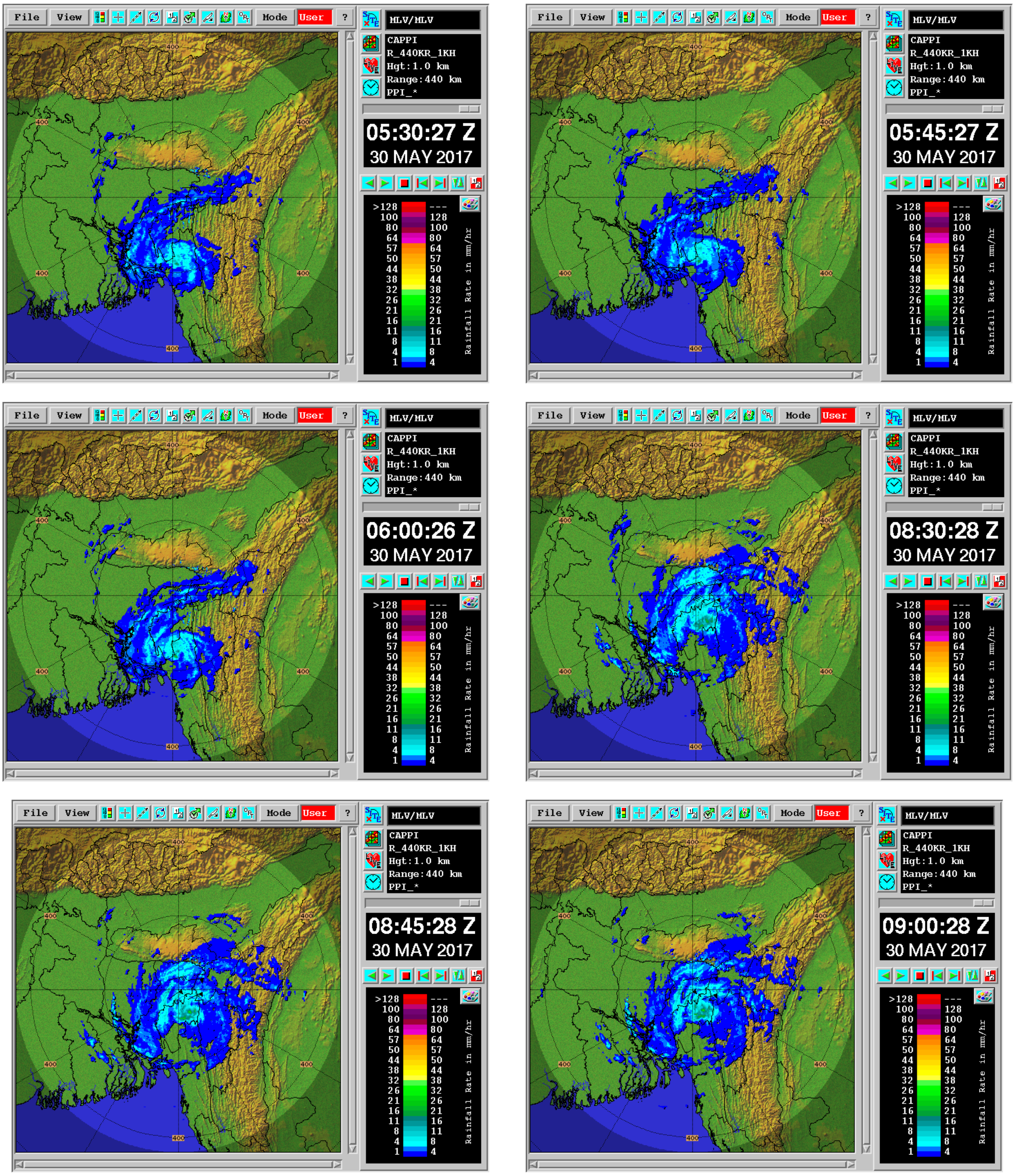

Fig. 3: Moulvibazar Radar imageries for Cyclone 'MORA' during 30 May 2017

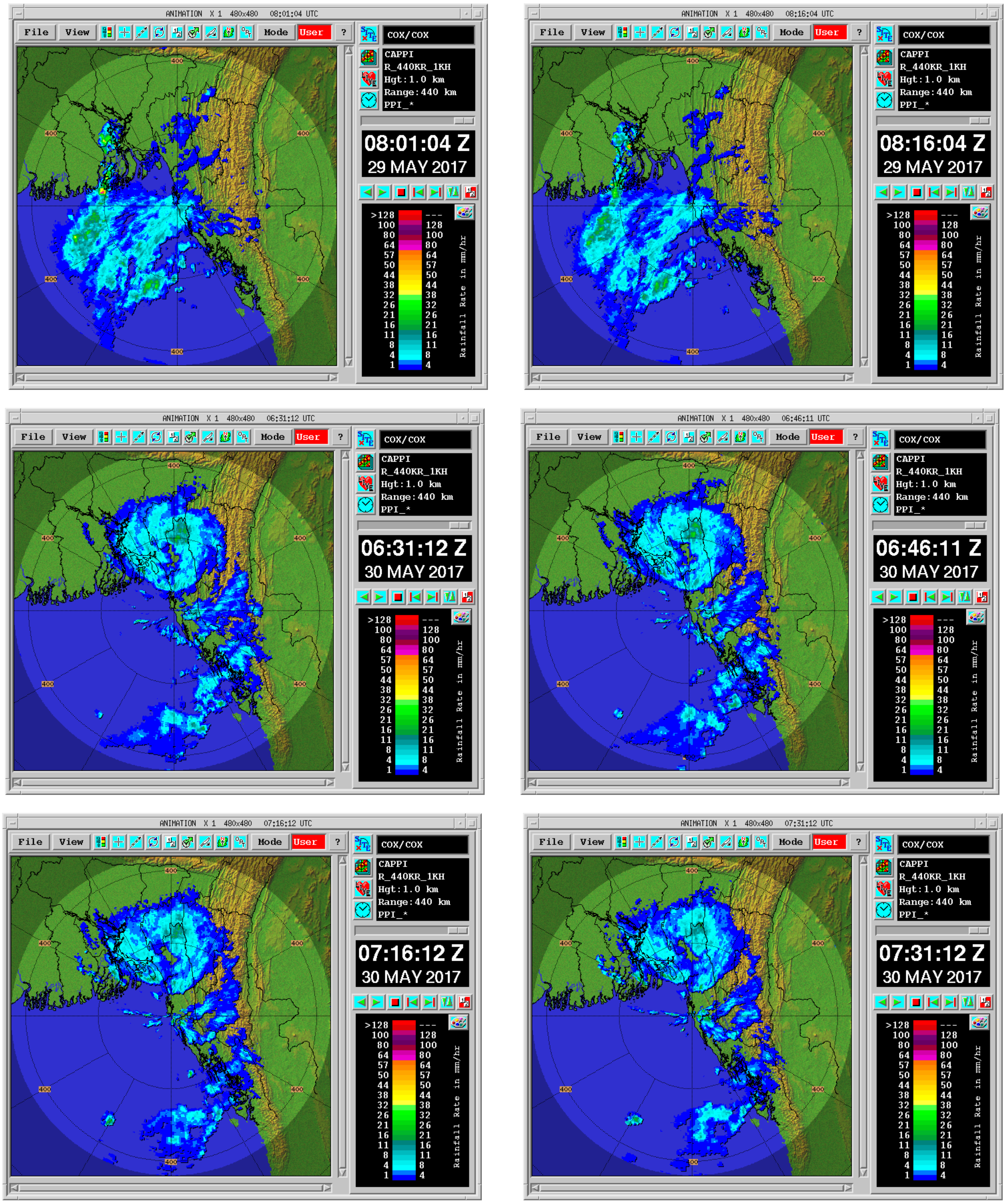

Fig. 4: Cox's Bazar Radar imageries for Cyclone 'MORA' during 30 May 2017

3.3 Recorded meteorological information related to SCS ‘MORA’

3.3.1 Recorded Pressure

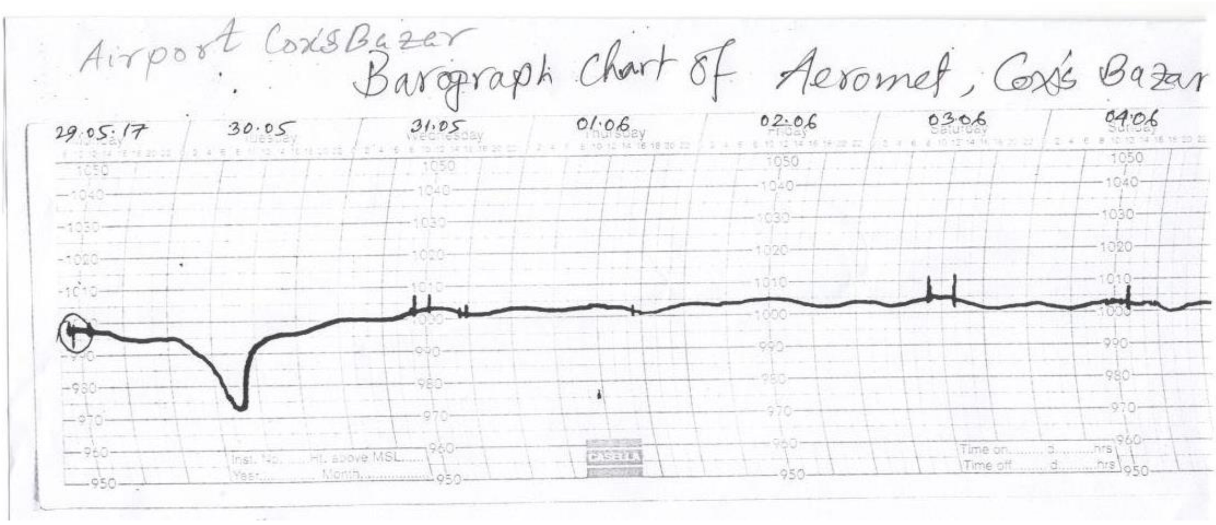

Fig. 5a: Change of Observed atmospheric pressure (Barograph chart) at Cox’s Bazar Airport office of BMD during the landfall of Cyclone ‘MORA’

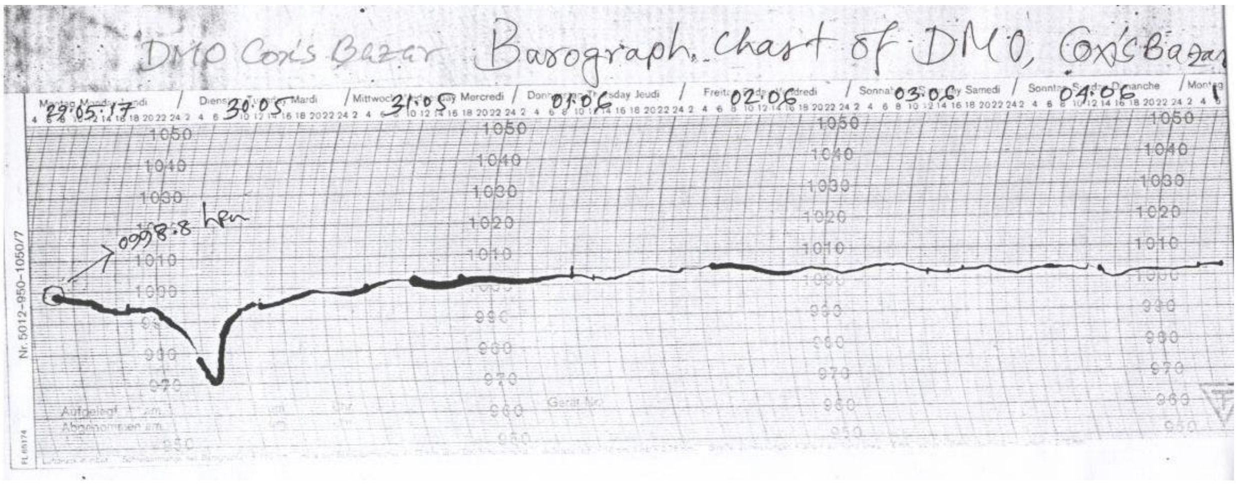

Fig. 5b: Change of Observed atmospheric pressure (Barograph chart) at Dependent Meteorological Office (DMO), Cox’s Bazar of BMD during the landfall of Cyclone ‘MORA’

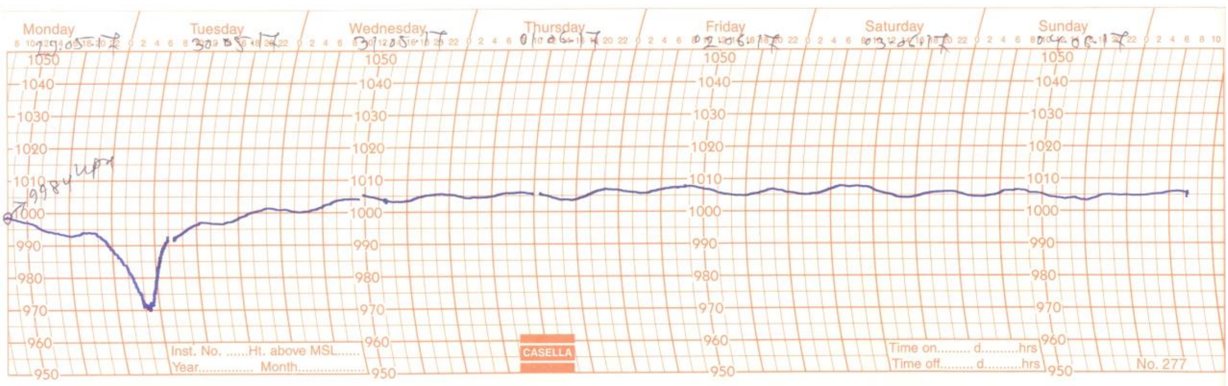

Fig. 5c: Change of Observed atmospheric pressure (Barograph chart) at Meteorological Office, Teknaf of BMD during the landfall of Cyclone ‘MORA’

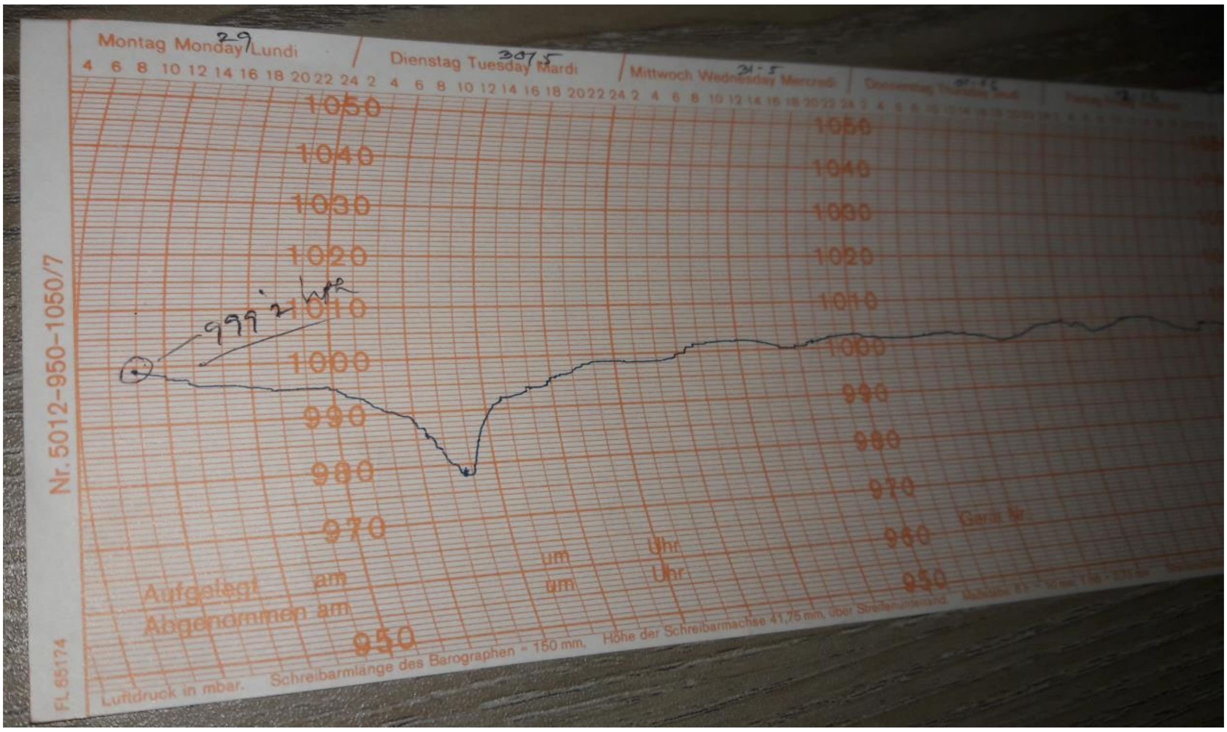

Fig. 5d: Change of Observed atmospheric pressure (Barograph chart) at Main Meteorological Office (MMO), Chittagong Airport of BMD during the landfall of Cyclone 'MORA'

3.3.2 Recorded wind

Table 2: Recorded wind speed and Direction at Cox's Bazar during the landfall of Cyclone 'MORA'

Aeromet, Cox's Bazar Airport				DMO, Cox's Bazar.		
Time (UTC)	Wind Speed (Kts.)	Direction		Time(UTC)	Wind Speed (Kts.)	Direction
29May 2340	40	NNE		29May 2000	25	N
29May 2345	50	NNE		29May 2210	22	NNE
29May 2355	45	NNE		29May 2300	22	WNW
30May 0000	40	NNE		29May 2301	28	NNE
30May 0005	60	NNE		29May 2306	35	NNE
30May 0010	55	NNE		29May 2320	42	NNE
30May 0015	55	NNE		29May 2342	35	NNE
30May 0020	45	NNE		29May 2347	40	NNE
30May 0025	50	NNE		30May 0010	50	NNE
30May 0030	50	NNE		30May 0038	43	NNE
30May 0035	40	ENE		30May 0040	51	NNE
30May 0040	45	ENE		30May 0255	62	NNE
30May 0045	45	ENE		30May 0300	45	NNE
30May 0050	50	ENE				
30May 0100	45	ENE				
30May 0105	40	ENE				
30May 0110	35	ENE				
30May 0115	45	ENE				
30May 0120	40	ENE				
30May 0125	25	ENE				

Note: NNE indicates North-Northeast, ENE indicates East-Northeast, NNE indicates North-Northeast, WNW indicates West-Northwest and N indicates North direction.

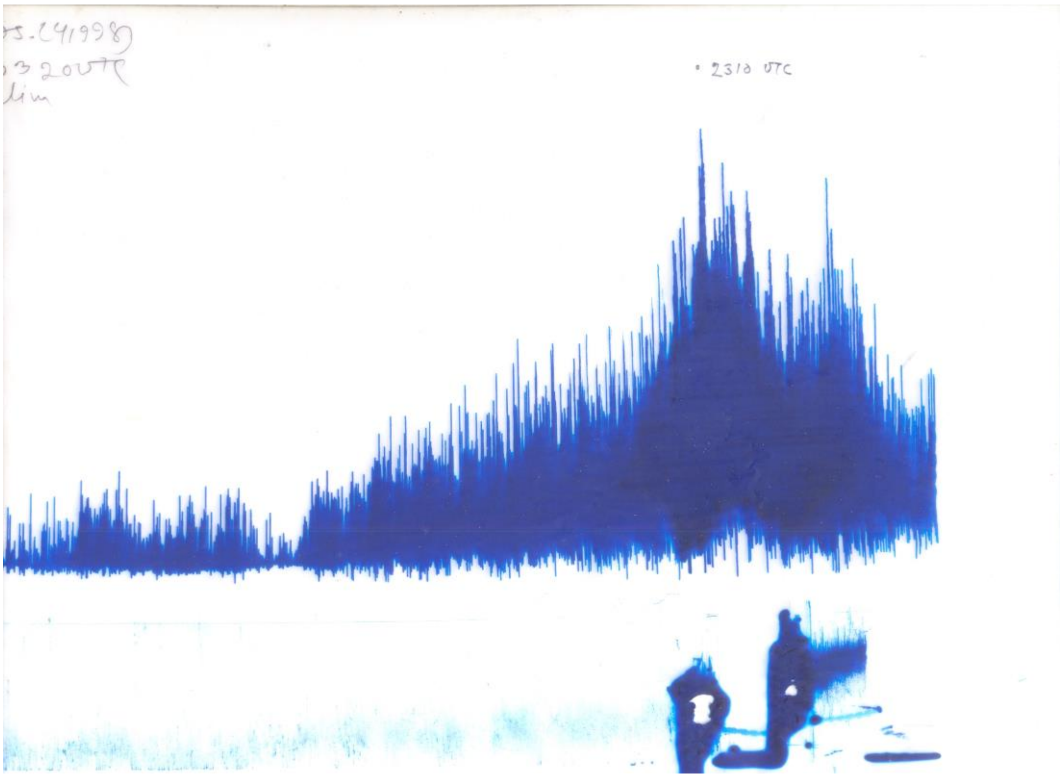

Fig. 6a: Recorded wind speed and Direction at Teknaf during the landfall of Cyclone 'MORA'

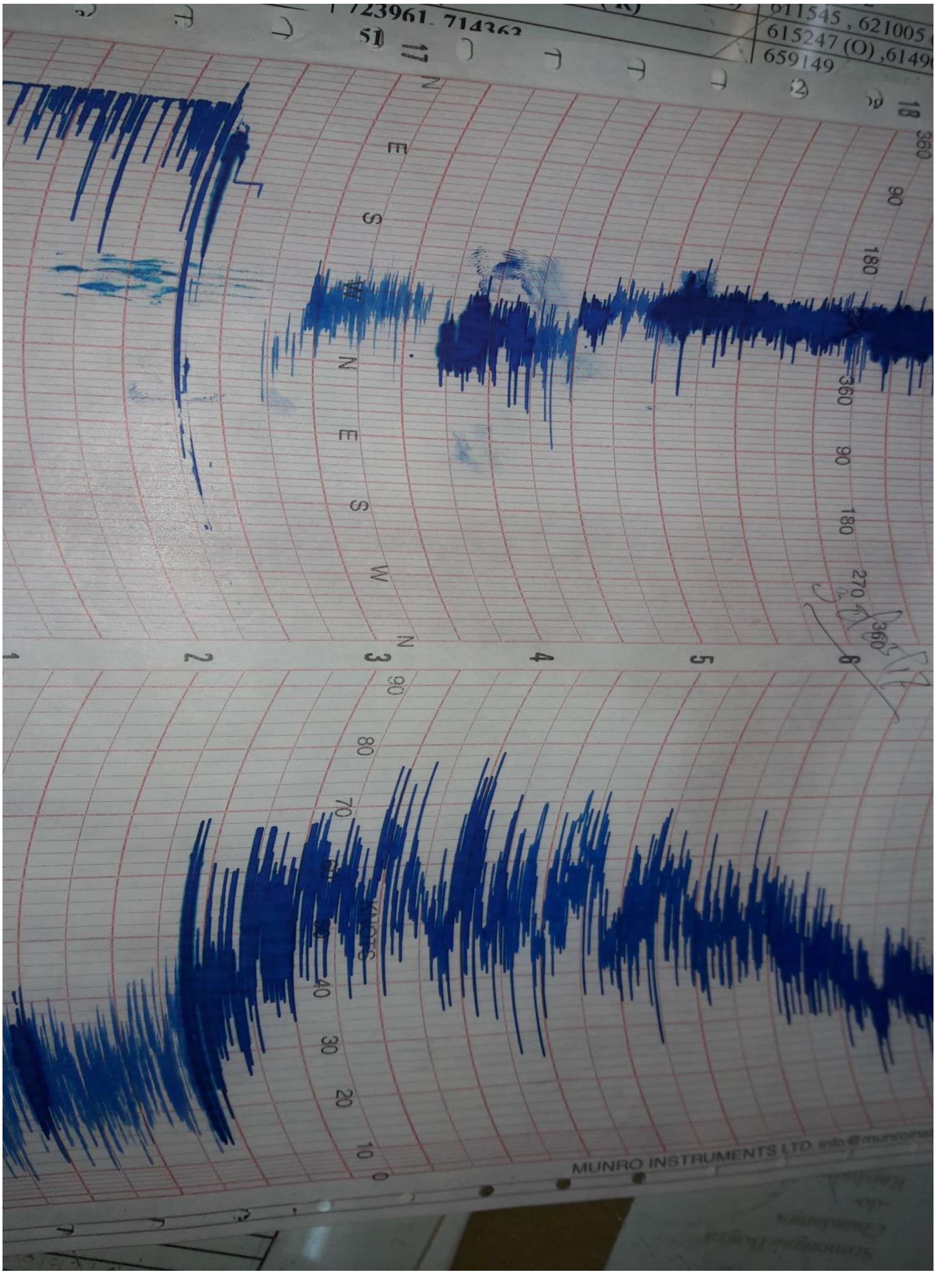

Fig. 6b: Recorded wind speed and Direction at Main Meteorological Office (MMO), Chittagong Airport of BMD during the landfall of SCS 'MORA'

Table 3: Recorded maximum wind (km/hr) during the landfall of SCS 'MORA'

Sl	Station	Maximum wind Speed		Wind Direction	Date/Time (in UTC)
		Knots	Km/hr		
1.	Chandpur	15	28	North	30/0300
2.	Comilla	10	19	North	30/0500-0600
3.	M.Court	12	22	Northwest	30/0600
4.	Srimongal	25	46	Northwest	30/0800-0820
5.	Bhola	05	09	-	30/0300-0400
6.	Sandwip	30	56	Southwest	30/0550-0600
7.	Rangamati	20	37	South	30/0600
8.	Patuakhali	05	9	North	-
9.	Kutubdia	45	83	North	30/0110
10.		75	119	Northwest	30/0345
11.	Hatiya	28	52	Northwest	30/0500-0510
12.	Mongla	06	11	Northwest	30/0500
13.	Teknaf	59	109	South-southeast	29/2230
14.		73	135	South-southeast	29/2315
15.	Saint Martin	62	114	Southeast	29/2200
16.	Cox's Bazar	25	46	South-southwest	29/2300
		51	94	South-southwest	30/0000
		62	114	Northeast	30/0255
17.	Chittagong (Patenga Air Port)	40	74	-	30/0220
		46	85	-	30/0225
		68	125	-	30/0300
		69	128	-	30/0326
		79	146	-	30/0526

Table 4: Recorded rainfall (mm) during the landfall of cyclone ‘Mora’

SL	Stations	Latitude	Longitude	Recorded Rainfall (mm)			
				28 May	29 May	30 May	31 May
1.	Dhaka	23.77	90.38	4	3	3	17
2.	Tangail	24.25	89.93	0	14	T	23
3.	Faridpur	23.60	89.85	T	9	27	16
4.	Madaripur	23.17	90.18	0	43	48	27
5.	Goplaganj	23.01	89.82	0	8	2	14
6.	Mymensingh	24.73	90.42	0	2	T	35
7.	Netrokona	24.89	90.73	0	3	2	96
8.	Chittagong (AP)	22.22	91.80	0	7	177	68
9.	Sandwip	22.48	91.43	0	11	173	22
10.	Sitakunda	22.63	91.70	0	6	138	23
11.	Rangamati	22.63	92.15	25	3	87	4
12.	Comilla	23.43	91.18	T	7	41	41
13.	Chandpur	23.23	90.70	0	12	29	18
14.	Maijdee Court	22.87	91.10	51	5	68	4
15.	Feni	23.03	91.42	9	4	68	2
16.	Hatiya	22.45	91.10	0	8	83	139
17.	Cox’s Bazar	21.45	91.97	37	15	43	8
18.	Kutubdia	21.82	91.85	T	12	115	T
19.	Teknaf	20.87	92.30	40	64	49	3
20.	Sylhet	24.90	91.88	T	1	43	34
21.	Srimangal	24.30	91.73	0	1	32	39
22.	Rajshahi	24.37	88.70	1	1	T	0
23.	Ishwardi	24.15	89.03	0	2	0	0
24.	Bogra	24.85	89.37	0	T	T	4
25.	Badalghachi	24.58	88.54	1	1	0	0
26.	Tarash	24.26	89.23	0	1	T	0
27.	Rangpur	25.73	89.27	0	1	1	T
28.	Dinajpur	25.65	88.68	8	3	T	0
29.	Syedpur	25.75	88.92	1	T	0	0
30.	Tetulia	26.49	88.47	1	1	7	0
31.	Dimla	26.09	88.56	0	1	1	0
32.	Rajarhat	25.80	89.55	0	0	1	6
33.	Khulna	22.78	89.57	32	5	14	2
34.	Mongla	22.47	89.60	0	20	6	0
35.	Satkhira	22.72	89.08	35	5	0	2
36.	Jessore	23.20	89.33	0	5	0	18
37.	Chuadanga	23.65	88.82	0	5	0	6
38.	Kumarkhali	23.52	89.15	2	2	0	2
39.	Barisal	22.72	90.37	0	27	17	0
40.	Patuakhali	22.33	90.33	2	6	9	0
41.	Khepupara	21.98	90.23	2	37	0	1
42.	Bhola	22.68	90.65	2	4	18	0

4. Salient Features associated with SCS MORA

The salient features of the system were as follows:

i. The severe cyclonic storm 'MORA' developed in the onset phase of southwest monsoon. Its intensification and movement towards north-northeast helped in the advancement of monsoon over the Bay of Bengal and some parts of Bangladesh (Chittagong, Dhaka, Barisal, Sylhet and Mymensingh divisions) including northeastern states of India.

ii. The severe cyclonic storm, MORA had a northeastwards moving track. Considering the area of genesis (+/- 2° around the genesis point), it is seen that about 63% of the cyclones moved north-northeatwards and crossed Bangladesh coast whereas another 25% moved northeastwards and crossed Myanmar coast and 12% moved westwards towards Andhra Pradesh coast (Fig.3). Hence, the direction of the movement of the cyclone was climatological in nature.

iii. The peak maximum sustained surface wind speed (MSW) of the cyclone was 110-120 km/hr gusting to 130 km/hr and the system crossed Cox's Bazar- Chittagong Coast (near Kutubdia) of Bangladesh coast with this peak MSW between 0400-0500 UTC (100-1100 hrs BST) of 30 May 2017. The lowest estimated central pressure was 978 hPa (from 2100 UTC of 29 May to till landfall around 0430 UTC of 30 May 2017).

iv. The cyclone was short lived with the life period of about 72 hours (3 days).

v. The track length of the cyclone was 1086 km.

vi. The 12 hour average translational speed of the cyclone was about 20.4 km/hr and hence was fast moving in nature. The system moved fast under the influence of mid-latitude trough in westerlies lying over India in the middle and upper tropospheric levels and the anti-cyclonic cyclonic circulation lying to the northeast of the system. This trough created strong north-northeasterly steering winds over the cyclone field in middle and upper tropospheric levels, which was further accentuated by the north-northeasterly winds from anticyclonic circulation.

vii. The Velocity Flux, Accumulated Cyclone Energy (ACE) and Power Dissipation Index (PDI) were 3.45×10^2 knots, 1.74×10^4 knots^2 and 0.899x106 knots^3 respectively.

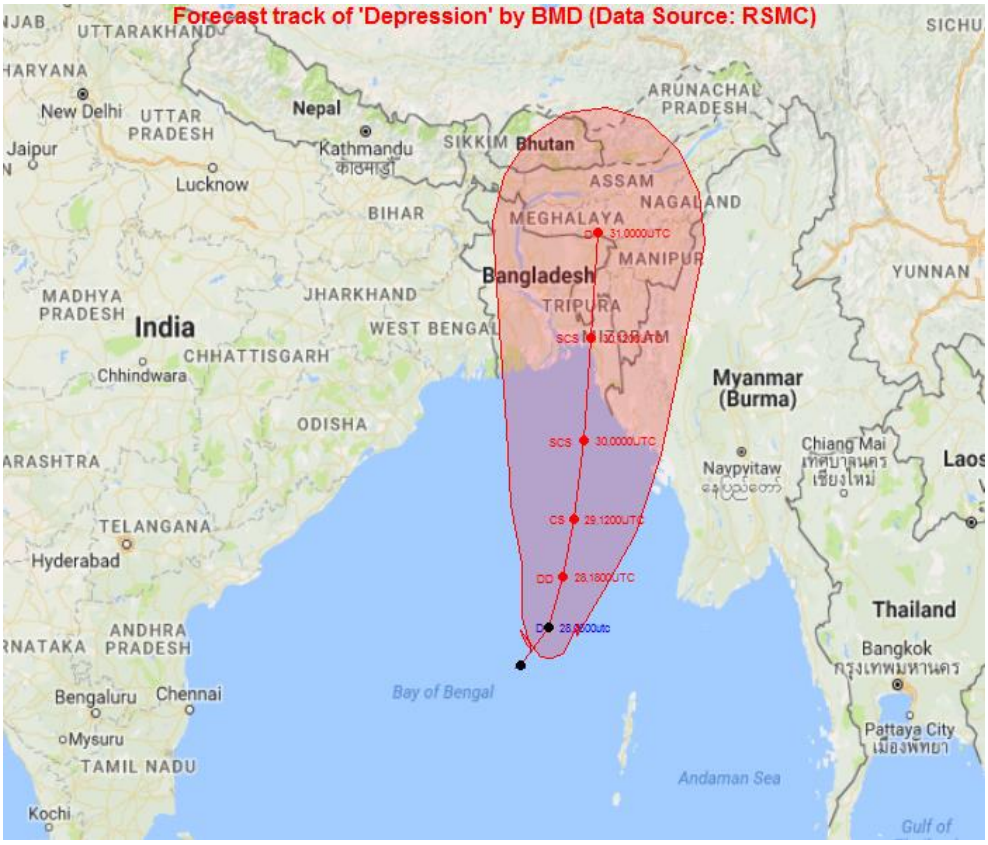

Fig. 7: Typical graphical products displaying observed and forecast track with cone of uncertainty

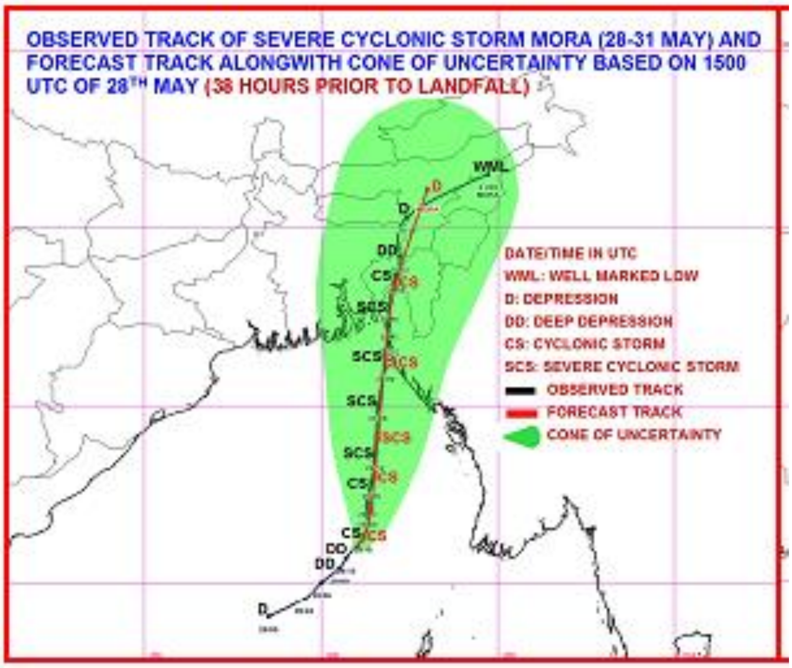

Fig. 8: Typical graphical products displaying observed and forecast track with cone of uncertainty

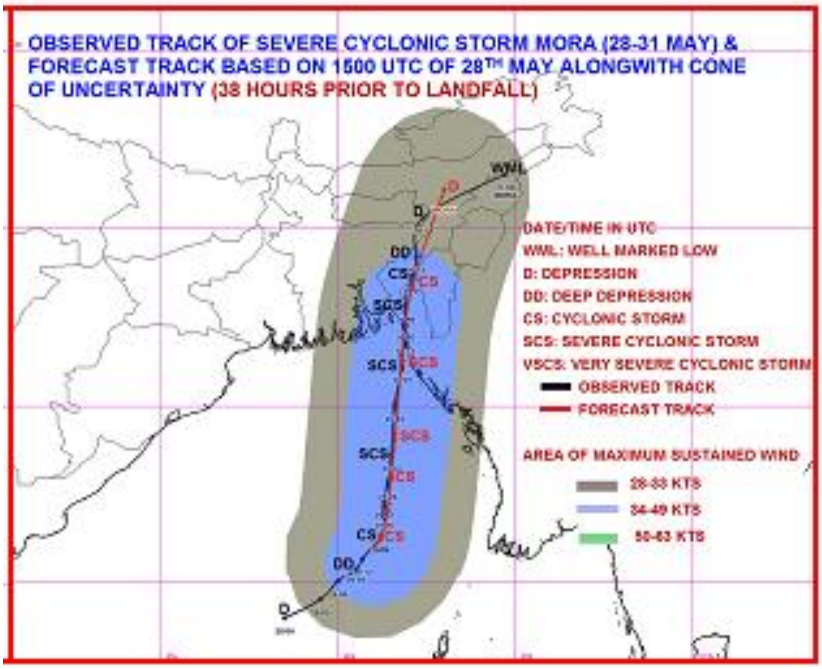

Fig. 9: Typical graphical products displaying observed and forecast track with cone of uncertainty

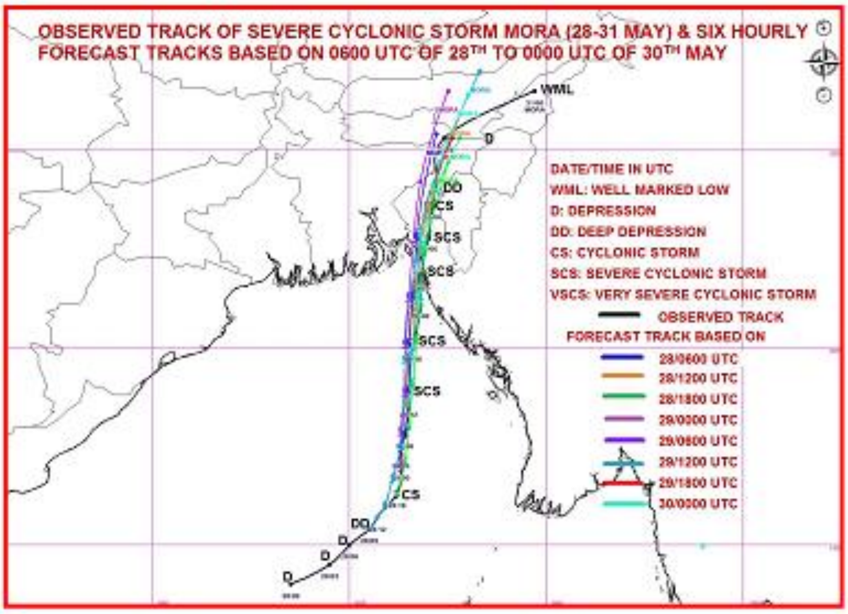

Fig. 10: Typical graphical products displaying observed and forecast track with cone of uncertainty

5. Warning Services for SCS MORA

i. **Track, intensity and landfall forecast:** Bangladesh Meteorological Department (BMD) continuously monitored, predicted and issued bulletins containing track, intensity, and landfall forecast till the system weakened into a low pressure area. The forecasts were issued from the stage of the development system onwards but the cone of uncertainty in the track forecast was provided after it intensified into a Depression.

ii. **Cyclone structure forecast for shipping and coastal hazard management:** The radius of maximum wind and radii of Maximum Wind Speed ≥ 44 km, ≥ 48 km, ≥ 54 km, and ≥ 64 km was issued every three hourly with sufficient lead time.

iii. **Diagnostic and prognostic features of cyclone:** The prognostics and diagnostics of the cyclone 'MORA' including the distance from the each of the maritime ports, past movement, future movement, intensification etc. were described in every bulletins named as Special Weather Bulletin.

iv. Special Weather Bulletin: Special Weather Bulletins were prepared and distributed every six hourly from its Depression Stage containing Warning Signals for the maritime ports and the coastal areas of Bangladesh. Advisory services for fishing boats, trawlers locating over North Bay and Deep Sea are routinely provided through it.

6. Special Bulletins issued by Storm Warning Centre (SWC) of BMD, Dhaka

i. **Tropical cyclone forecasts and adverse weather warning bulletins:** The tropical cyclone forecasts along with expected adverse weather like heavy rain, gusty/squally wind and storm surge were issued with every three hourly update during cyclone period to Hon'ble Prime Minister's Office, Cabinet Secretary, Principal Secretary to the Hon'ble Prime Minister, Secretary and Joint Secretary of all concerned Ministries, Department of Disaster Management (DDM), Cyclone Preparedness Programme (CPP), Naval Headquarter, NDRCC, BIWTA, BTV, Bangladesh Betar, Flood Forecasting and Warning Centre (FFWC), BSS, Coast Guard, Armed Forces Division (AFD), Bangladesh Army, Bangladesh Air Force, BIWTC, UNHCR, UNDP and to the print and Electronic Media.

ii. **Warning graphics:** The graphical display of the observed and forecast track with cone of uncertainty were uploaded in the BMD website ((http://www.bmd.gov.bd) regularly.

iii. **Warning and advisory through social media:** All the three hourly updates were uploaded on facebook during the life period of the system.

iv. **Press release and press briefing:** Press and electronic media were given updates through e-mail, SMS, website and Press Briefing.

v. **Warning and advisory for marine community:** Special Weather Bulletins were distributed to the Port of Authorities of Mongla, Chittagong and Payra, Shipping Community.

vi. Advisory for international civil aviation: Special Weather Bulletins for Bangladesh Civil Aviation Authority were issued for issuing significant meteorological information (SIGMET).

7. **Dynamical features**

7.1 WRF Model Products based on the initial condition at 0000UTC of 28May 2017

7.1.1 Simulated Sea Level Pressure (SLP)

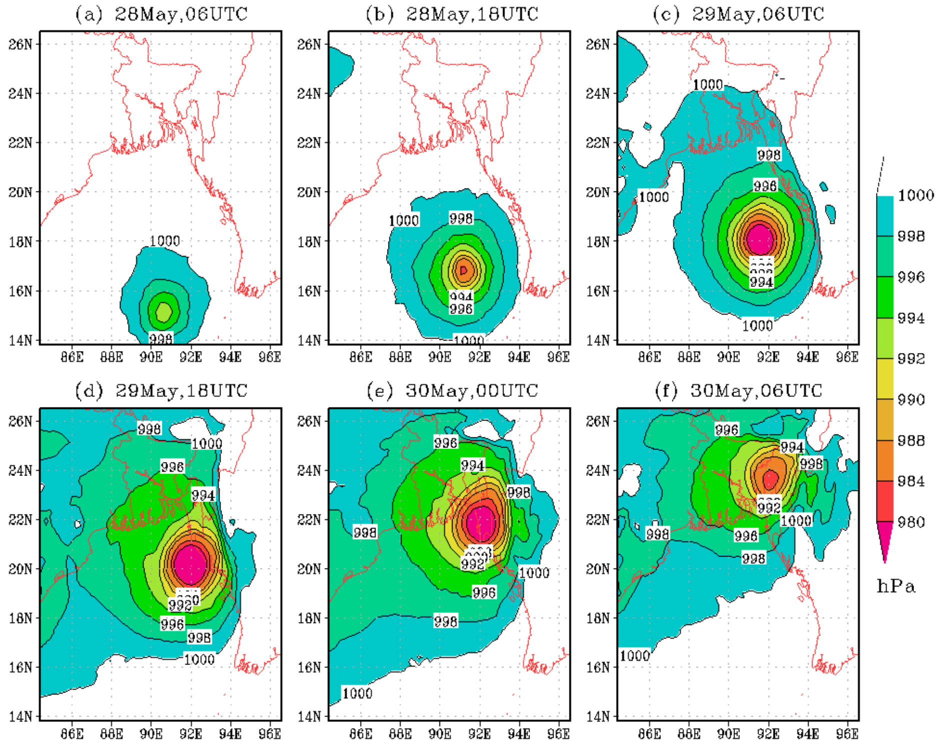

Fig. 11: Simulated Sea Level Pressure based on the initial condition at 0000 UTC of 28 May 2017

7.1.2 Simulated wind at 10 m and vorticity

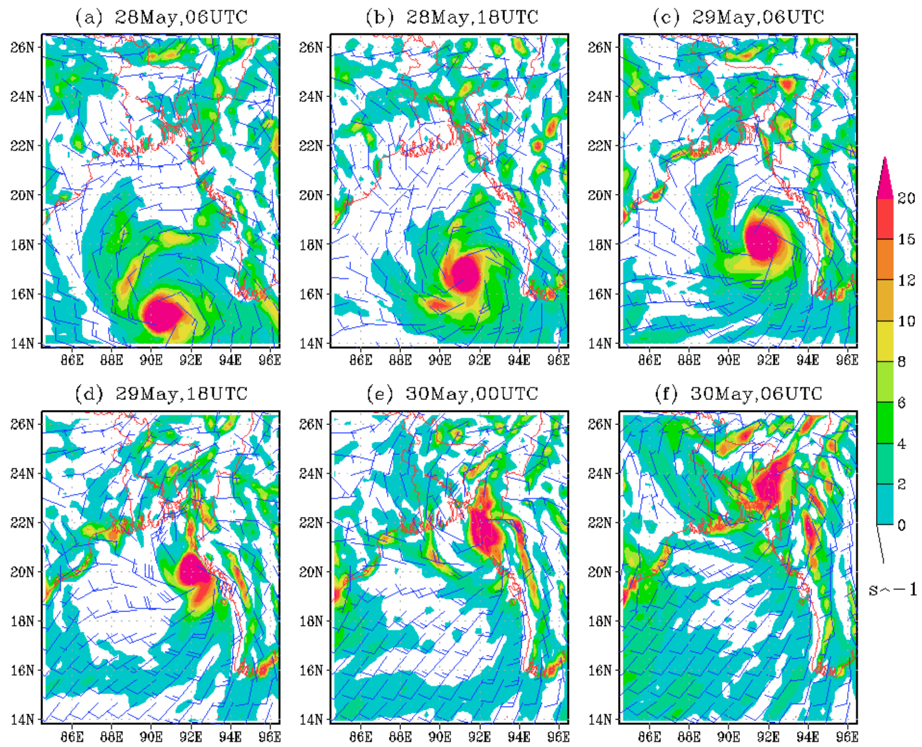

Fig. 12: Simulated surface wind and vorticity based on the initial condition at 0000 UTC of 28 May 2017

7.1.3 Simulated wind speed (km/hr) at 10 m height

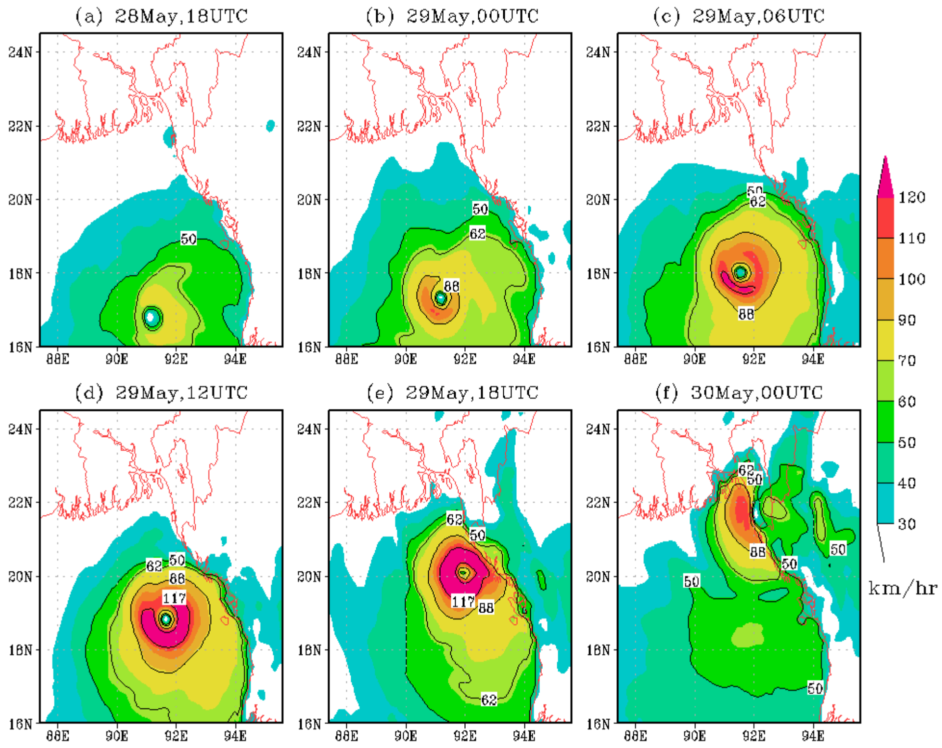

Fig. 13: Simulated wind speed at 10 m based on the initial condition at 0000 UTC of 28 May 2017

7.1.4 Simulated 06 (six) hourly rainfall in mm

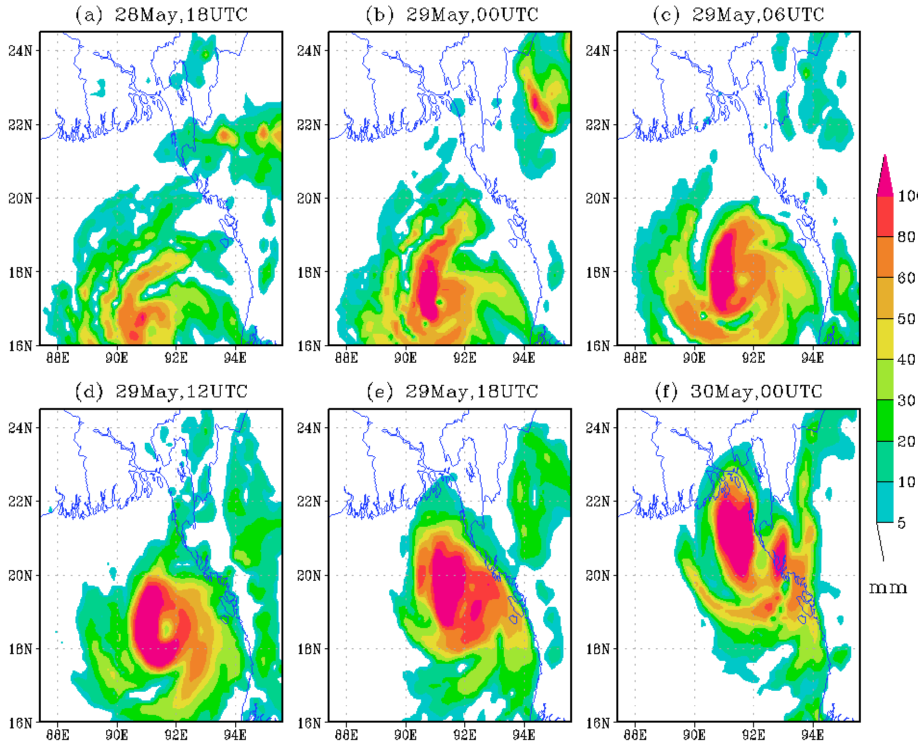

Fig. 14: Simulated rainfall (mm) based on the initial condition at 0000 UTC of 28 May 2017

7.2 WRF Model Products based on the initial condition at 0000UTC of 29May 2017

7.2.1 Simulated Sea Level Pressure (SLP)

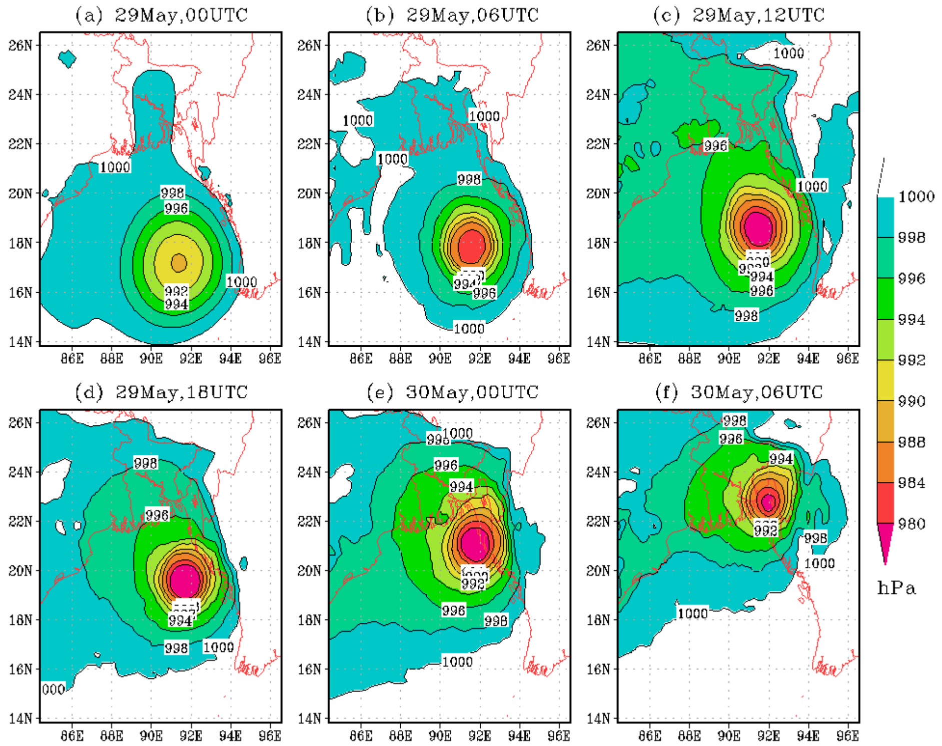

Fig. 15: Simulated Sea Level Pressure (hPa) based on the initial condition at 0000 UTC of 29 May 2017

7.2.2 Simulated wind at 10 m and vorticity

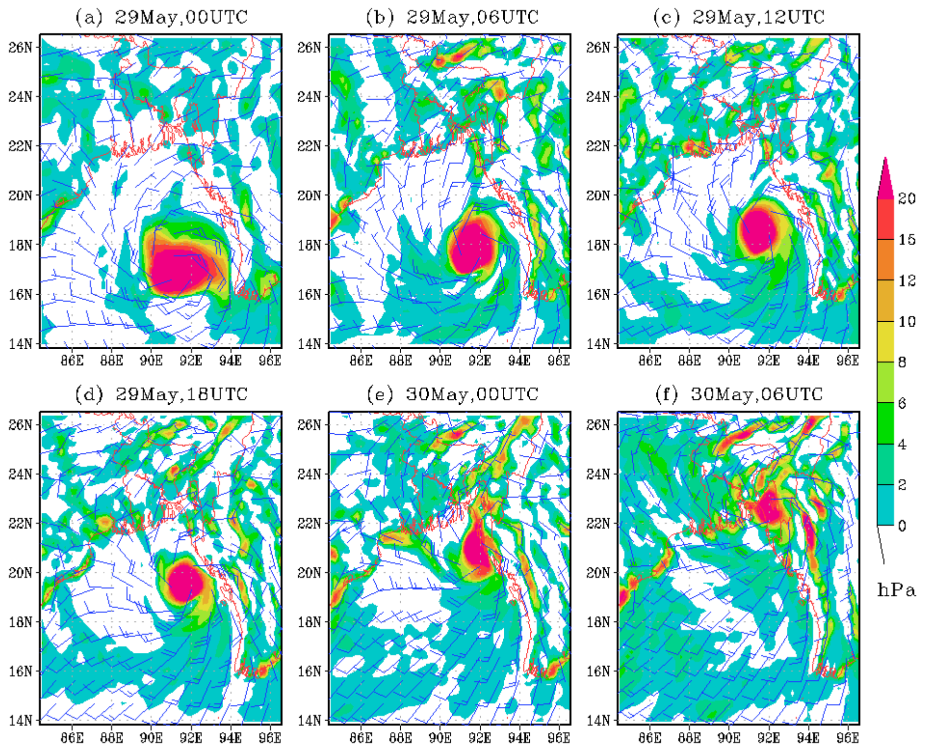

Fig. 16: Simulated surface wind and vorticity based on the initial condition at 0000 UTC of 29 May 2017

7.2.3 Simulated wind speed (km/hr) at 10m height

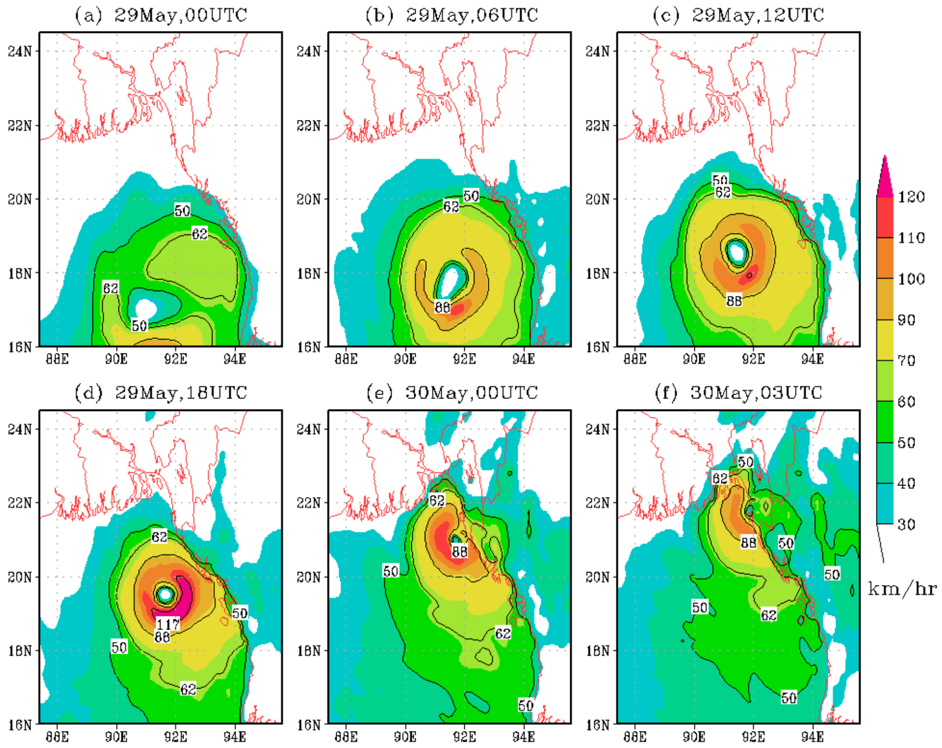

Fig. 17: Simulated wind speed at 10 m based on the initial condition at 0000 UTC of 28 May 2017

7.2.4 Simulated rainfall (six hourly) rainfall

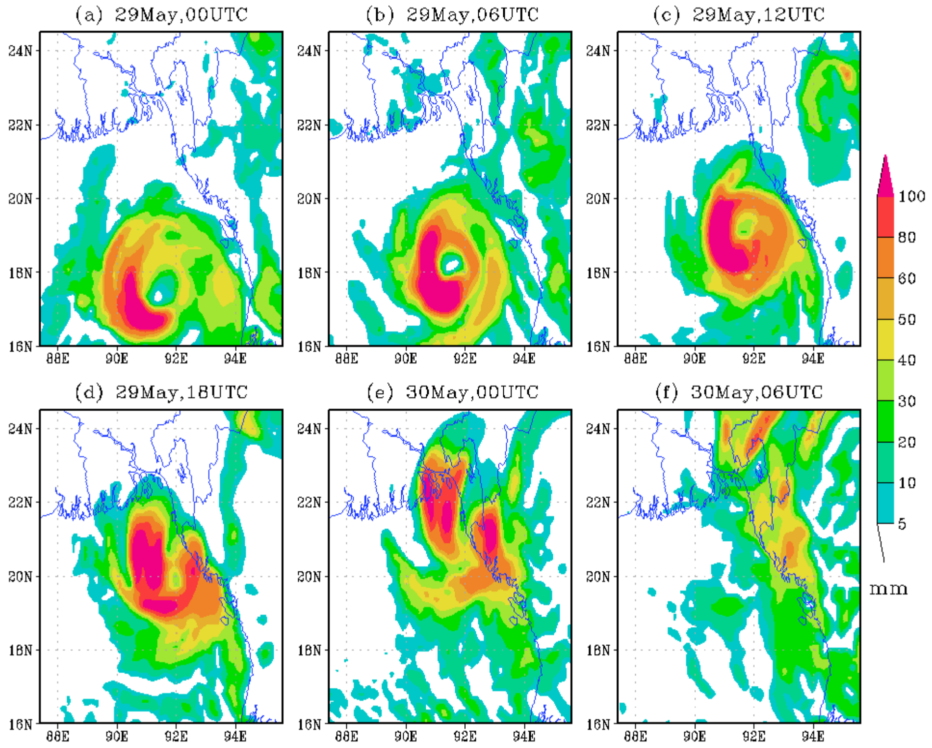

Fig. 18: Simulated rainfall (mm) based on the initial condition at 0000 UTC of 28 May 2017

7.3 ECMWF Model Products based on the initial condition at 0000UTC of 23 May 2017

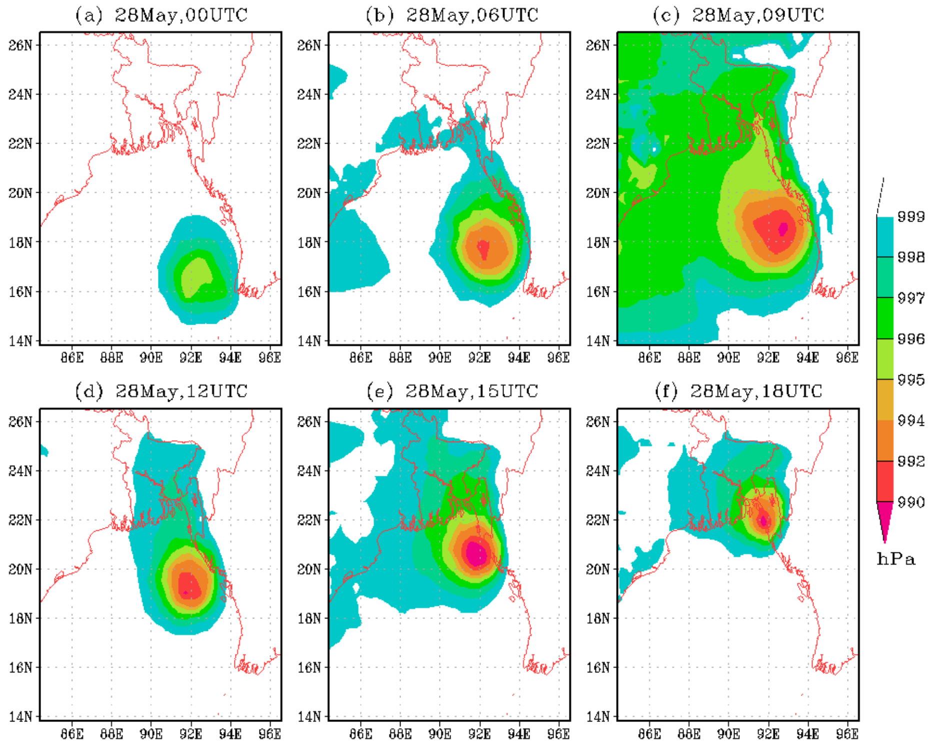

Fig. 19: Simulated Sea Level Pressure (hPa) based on the initial condition at 0000 UTC of 23 May 2017

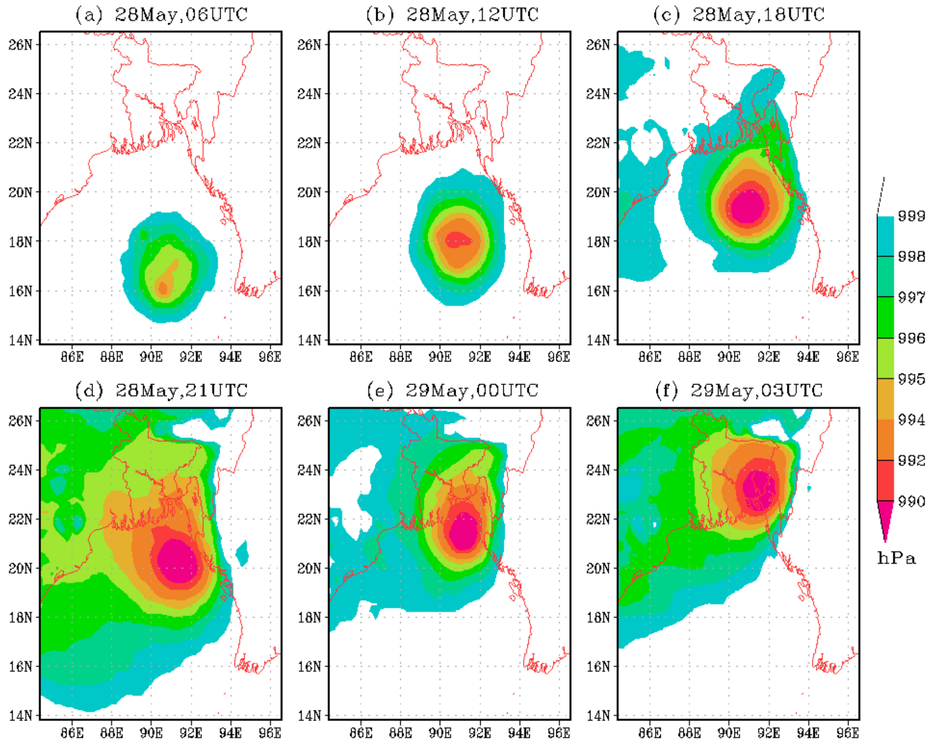

Fig. 20: Simulated Sea Level Pressure (hPa) based on the initial condition at 0000 UTC of 24 May 2017

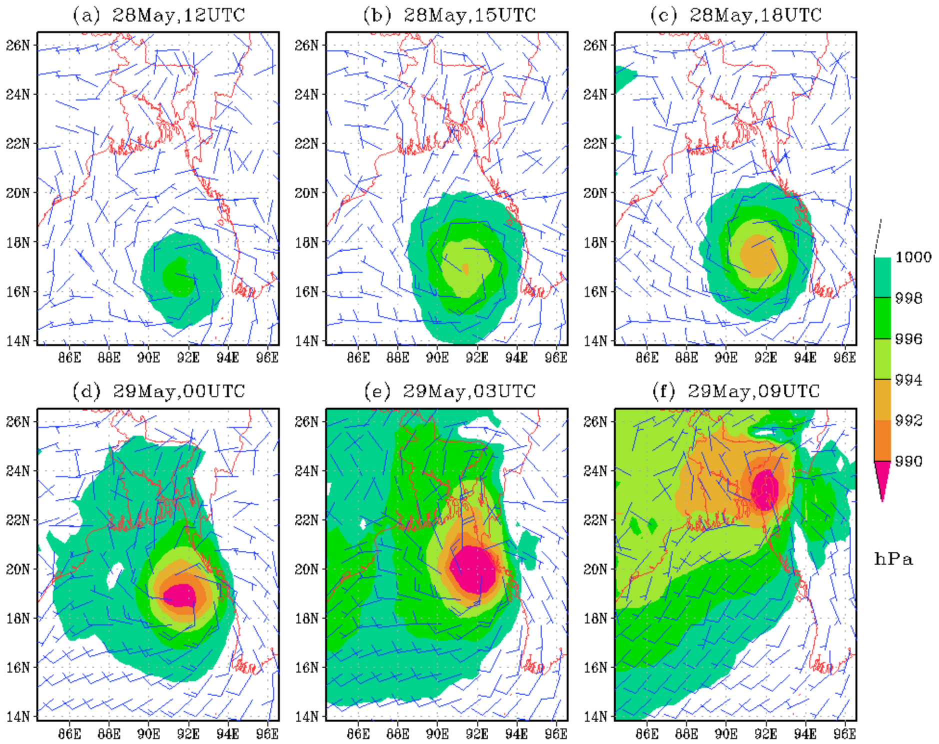

Fig. 21: Simulated Sea Level Pressure (hPa) and wind at 10 m based on the initial condition at 0000 UTC of 25 May 2017

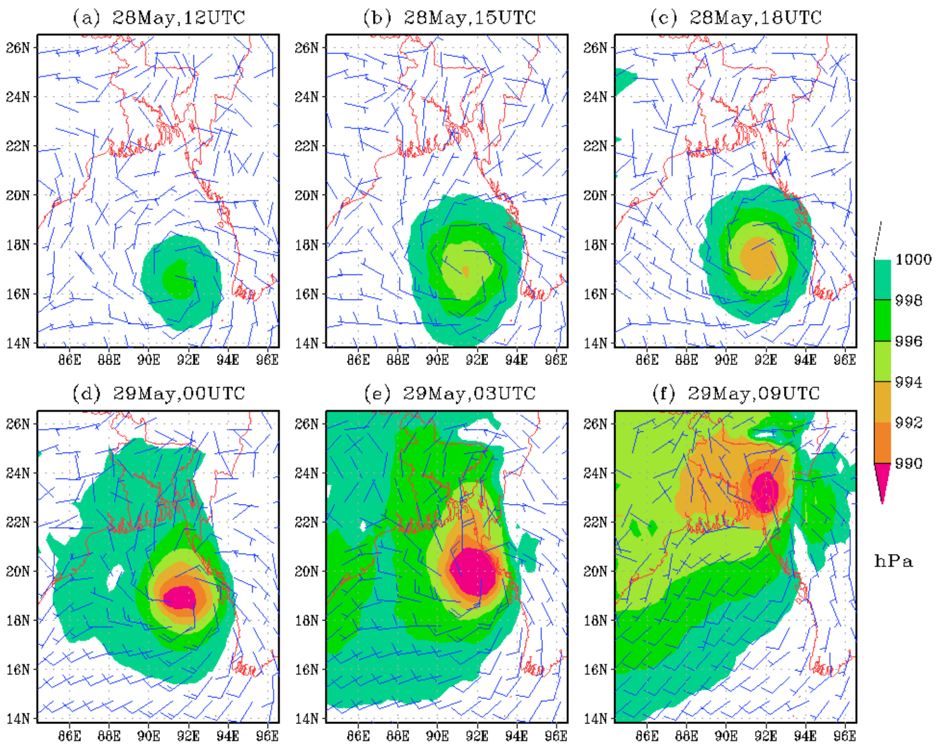

Fig. 22: Simulated Sea Level Pressure (hPa) and wind at 10 m based on the initial condition at 0000 UTC of 26 May 2017

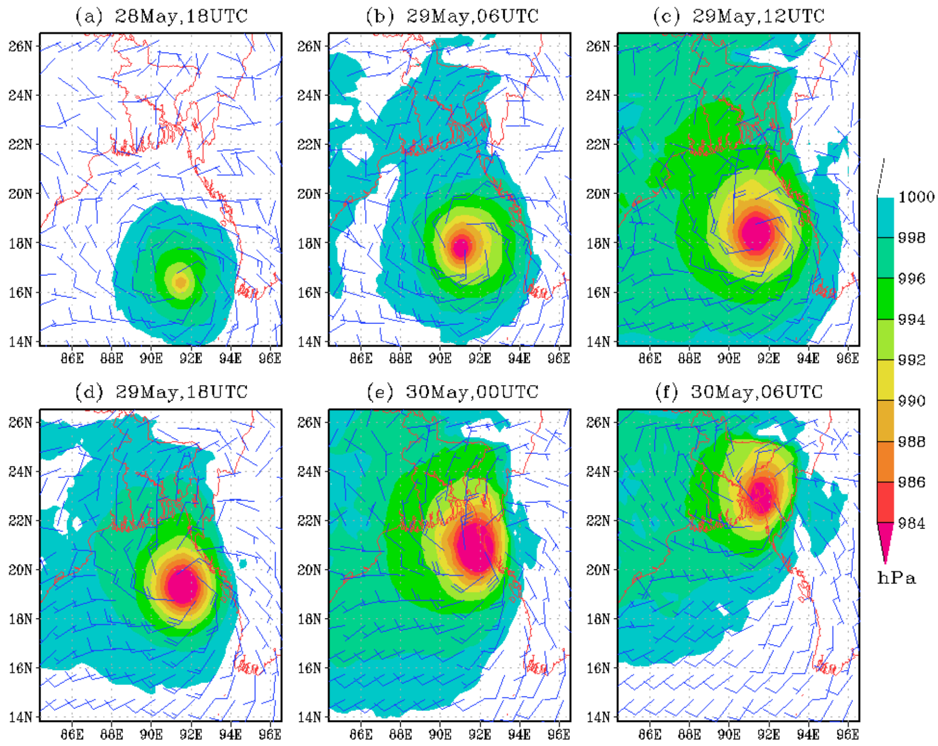

Fig. 23: Simulated Sea Level Pressure (hPa) and wind at 10 m based on the initial condition at 0000 UTC of 27 May 2017

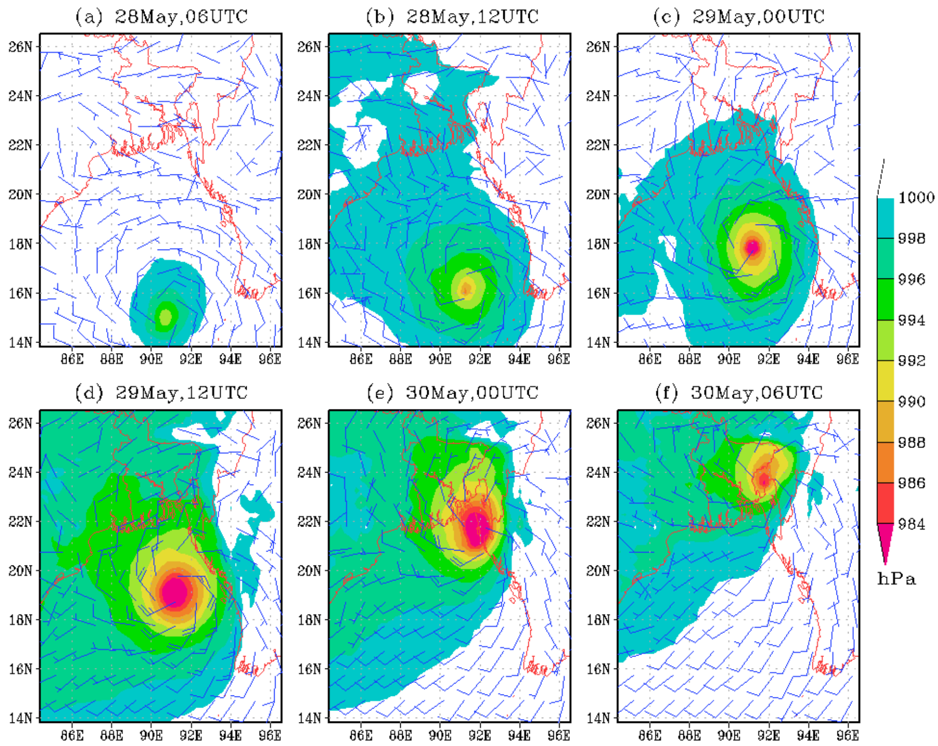

Fig. 24: Simulated Sea Level Pressure (hPa) and wind at 10 m based on the initial condition at 0000 UTC of 28 May 2017

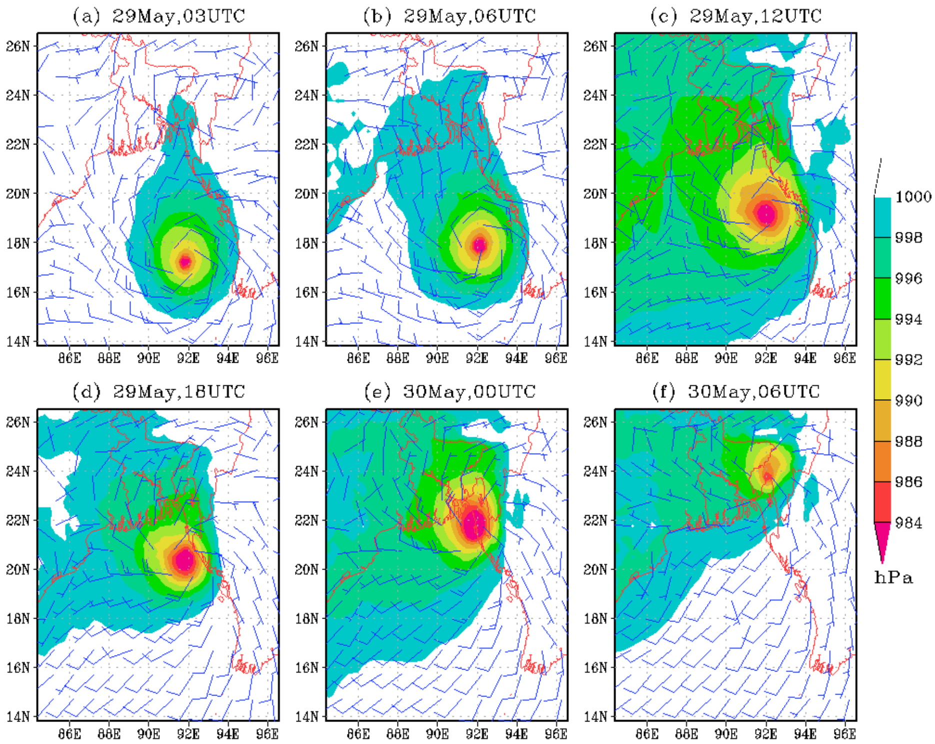

Fig. 25: Simulated Sea Level Pressure (hPa) and wind at 10 m based on the initial condition at 0000 UTC of 29 May 2017

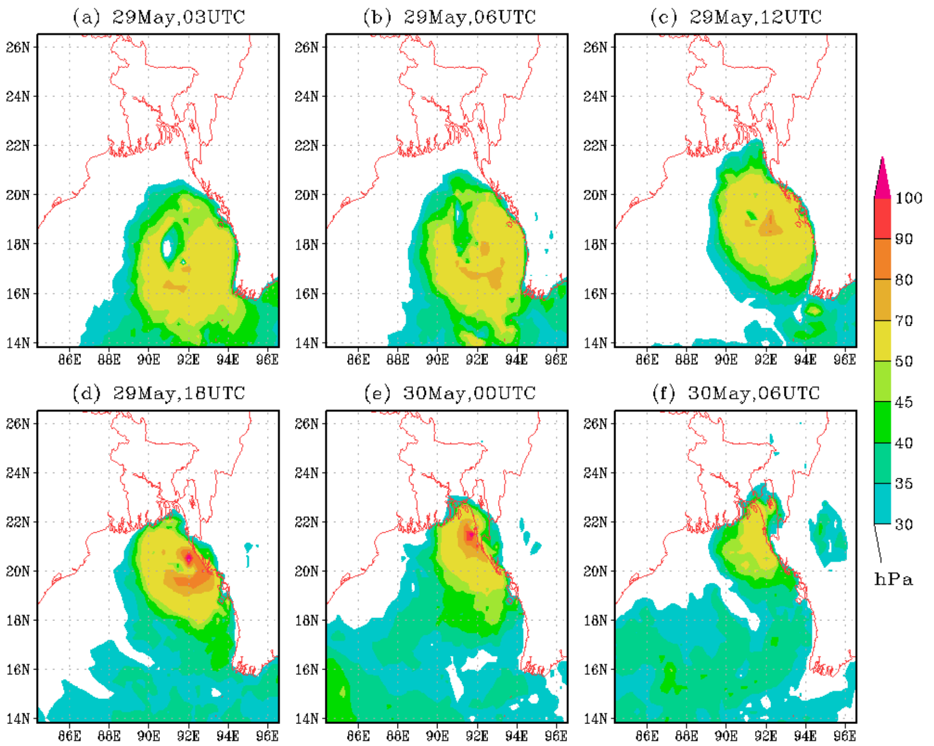

Fig. 26: Simulated wind speed Sea Level Pressure (hPa) and wind at 10 m based on the initial condition at 0000 UTC of 29 May 2017

8. Damage due to SCS 'MORA'

Rohingya refugee children are repairing roof of a hut that damaged due to Cyclone Mora

Damage of house at Bangladesh's Cox's Bazar district after Cyclone Mora made landfall in the region

Typical effect of approaching: Cyclone Mora

Cyclone Mora is making landfall

The cyclone Mora makes landfall in the coastal district of Cox's Bazar in Bangladesh on May 30, 2017. (Photo by Daily Star)

Highlights. 1. Cyclone Mora battered Rohingya refugee camps in Bangladesh.

Cyclone Mora hits Bangladesh: Heavy winds, incessant rains claim 2 lives, damage over 20,000 house

Impact of Cyclone Mora in the coastal areas of Bangladesh


Camps for Rohingya refugees have been badly damaged


The capital Dhaka saw rainy weather in the lead-up to the storm


Hundreds of thousands of Bangladeshis have been moved to cyclone shelters


Deadly Cyclone Mora hits Bangladesh with high winds and rain


Bangladeshi villagers sleep in a cyclone shelter following an evacuation by authorities in the coastal villages of the Cox's Bazar district on May 29, 2017


Damage due to Cyclone Mora at Teknaf on 30 May 2017

Damaged homes in Cox'x Bazar district following Cyclone Mora. Munir Uz Zaman/Reuters.

Damage related to cyclone in Cox’s Bazar

Cyclone Shelter

Cyclone Mora made landfall in Bangladesh (Cox’s Bazar Coast)

Cyclone Mora ravages Rohingya refugee camps in Bangladesh

Rohingya refugees fix the damaged roofs of huts in a makeshift camp near Cox's Bazar on Tuesday, after Cyclone Mora made landfall

Local area peoples are carrying household items

Local area peoples are carrying household items

Cyclone Mora hit Bangladesh Tuesday, packing winds of up to 135 kilometres (84 miles) per hour, damaging thousands of homes as more than 300000

People are in Cyclone Shelter for their safety

Bangladeshi people walk with their belongings towards a safer area near the coastal line at the Cox's Bazar district in the Chittagong, Bangladesh

Two dead, hundreds of thousands flee as cyclone batters Bangladesh Cyclone Mora battered Bangladesh on Tuesday, killing two people, ripping through camps ...

6 Eliminated As Cyclone Mora Strikes Bangladesh, Numerous Thousands Left

Cyclone 'Mora' made landfall in Bangladesh early Tuesday. (Photo: AP)

People are goning to Cyclone Shelter

CPP volunteers are abnnouncing signal

Inundation at Teknaf coast due to Cyclone

9. Summary and Conclusion

The Cyclone 'MORA' formed from a low pressure area over southeast Bay of Bengal and adjoining Central Bay on 26 May 2017 and concentrated into a well marked low (WML) in the afternoon of 27 May 2017. It intensified into a Depression at 09 AM of 28 May and further intensified into Deep Depression (DD) at 03 PM of same day and then into a cyclonic storm 'MORA' at Midnight of 28 May 2017. The system intensified further into Severe Cyclonic Storm (SCS) at North Bay and adjoining East Central Bay at 06 PM of 29 May 2017. It moved nearly northeastwards initially, then north-northeastwards and finally crossed Cox's Bazar- Chittagong coast near Kutubdia during during 06 AM to 12 Noon of 30 May 2017. BMD utilized all its resources to monitor and predict the genesis, track and intensification of SCS 'MORA'. The forecast of its genesis, track, intensity, time and location of landfall were predicted well with sufficient lead time. Its movement across the Bay is also predicted well in advance.

10. Acknowledgements of RSMC New Delhi

Regional Specialized Meteorological Centre (RSMC), New Delhi acknowledges the contribution of Bangladesh Meteorological Department for providing real time Radar Products and valuable information for tracking the system. India Meteorological Department (IMD) mentioned that DWR products from Khepupara and Cox's Bazar helped especially in monitoring the SCS 'MORA' prior to and during landfall in better estimation of location, intensity and landfall processes like heavy rainfall, gale wind etc. BMD also acknowledged the collaboration of Nowegian Meteorological Agency (met. no) for providing ECMWF Products to BMD.

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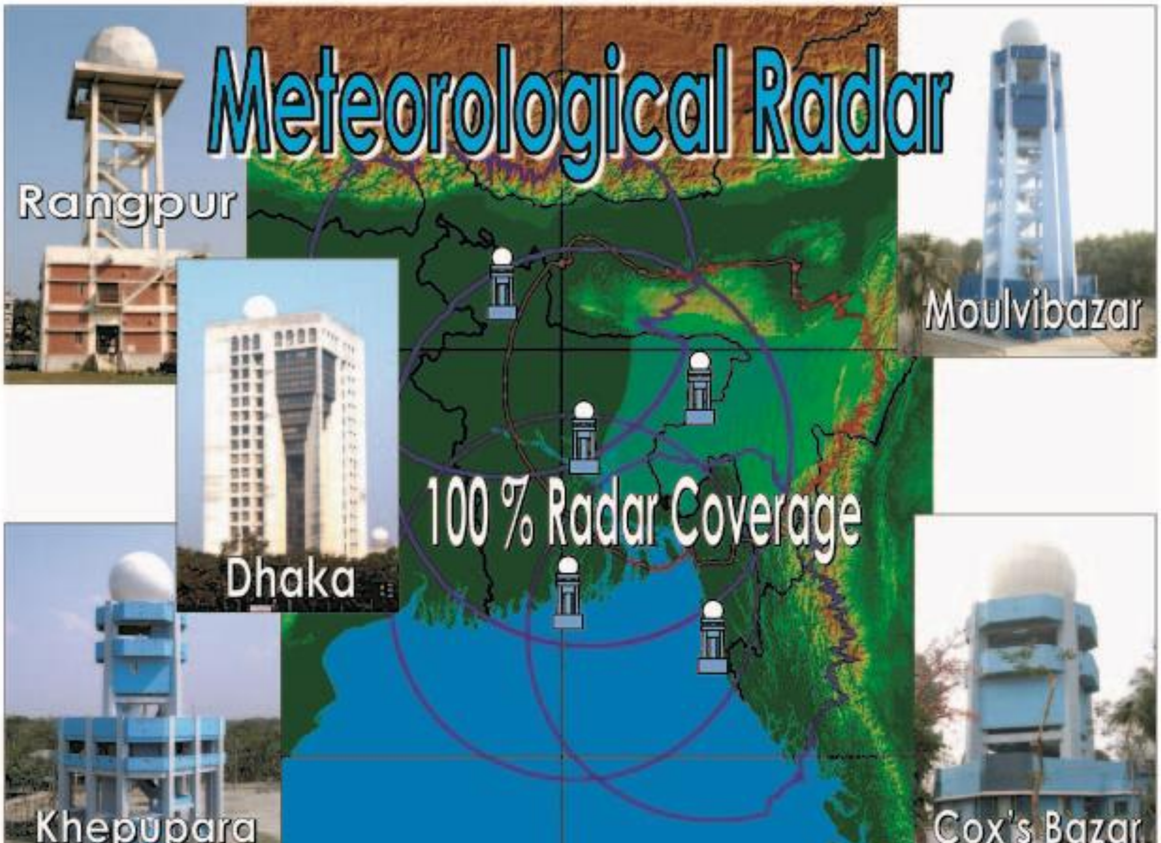
District wise death and causalities due to Cyclone 'MORA' (Source: Department of Disaster Management, date: 31.05.2017)

(N~wY©So Ó‡gvivÓ Kvi‡Y wewfbœ †Rjvq cÖv_wgK ÿqÿwZi cwigvY (2017 mvj))

of t vg)	Total no Population (‡gvU Rb msL¨v)	Affected no Upa-zila (ÿwZMÖ¯' Dc‡Rjvi/ ‡cŠt msL¨v (e:wK:)	Affected no of Family (ÿwZMÖ¯' cwievi msL¨v)		Affected no of People (ÿwZMÖ¯' †jvK msL¨v)		Affected no og Houses (ÿwZMÖ¯' Ni evox)		No of People died (g"Z e¨w³i msL¨v)	No of injured people (AvnZ e¨w³i msL¨v)	No of Missing People (wb‡LvR e¨w³i msL¨v)	No of Shelters (AvkÖq †K‡›`ªi msL¨v)	No of People taken into shleter (AvwkÖZ †jvK msL¨v)
			Partial (AvswkK)	Full (m¤ú~Y©)	Partial (AvswkK)	Full (m¤ú~Y©)	Partial (AvswkK)	Full (m¤ú~Y©)					
	2	3	4	5	6	7	8	9	10	11	12	13	14
; ' vi)	2232064	12	52539				35516	17023	4	60		296	159600
ong vg)	7516352	16			14250		25096	27045				538	7516352
ali vjx)	3108083	9										251	35000
ur)	1797761	5	0	0	0	0	0	0	0	0	0	102	1797761
Yx)	1465203	6										88	1465203
ur vi)	2297201	15										99	2297201
na)	892721	6										335	892721
ali vjx)	1596222	8										331	1596222
ı)	1776795	7										73	1776795
l j)	2323199	11										229	2323199
ır cyi)	1161653	7										115	1161653
ati V)	683187	4										45	683187
at vU)	1476090	9										234	1476090
a)	2062428	10										219	2062428
ra iv)	2063600	7										159	2063600
	32452559	132	52539		14250		60612	44068	4	60	0	3114	27307012


Meteorological Radar
Rangpur
Moulvibazar
Dhaka
100 % Radar Coverage
Khepupara
Cox's Bazar