Severe Weather Events (January – June 2017)

1. Introduction

During 2016, four cyclonic storms formed over the Bay of Bengal (one each in the month of May, October, November and December). In addition, four depressions formed during the monsoon season (two over the Bay of Bengal, one over the Arabian sea and one over land over central parts of the country) and two during the northeast monsoon season (one each over the Bay of Bengal and the Arabian sea). The country also experienced other high impact weather events like, extreme heavy rainfall, heat and cold waves, snow cover, thunderstorm, dust storm, lightening, floods etc. The causalities mentioned below are based on the media and government reports.

During 2016, Phalodi in Rajasthan recorded highest-ever temperature of 51°C on 19th May. The previous highest ever temperature (50.6°C) was recorded by Alwar also in Rajasthan in 1956.

The severe heat waves over central and peninsular parts of the country during April & May caused deaths of about 700 people mostly from Telangana and Andhra Pradesh.

Lightning in various parts of northern, north eastern, central and peninsular regions of the country during the pre-monsoon and monsoon seasons causing deaths of about 415 people with worst affected being parts of Bihar, Uttar Pradesh, Madhya Pradesh and Odisha.

Heavy rain & flood related incidents from different parts of the country during the monsoon season claiming deaths of about 475 people with worst affected state being Bihar where 146 people died during the period 25th July to 3rd September. The year 2016 was the warmest year ever recorded since 1901 with country averaged annual mean land surface air temperature of 0.91°C above the 1961-1990 average. The country also experienced significantly above normal mean temperature during the 2016 hot weather season (March-May) with anomaly of +1.36°C, second warmest ever since 1901.Prevalence of significantly above normal mean temperatures continued in January, 2017 (0.67°C).

The country experiences hot weather during March to July period. March to May season is known as the pre-monsoon season with many parts of the country experience heat wave conditions (days with abnormally warmer temperatures) resulting adverse impacts on the human health, water resources and power generation and outage. Severe weather events characteristic of the Pre-monsoon season are the Heat waves, thunderstorms, hailstorms and cyclones and those during monsoon are the heavy rains leading to floods. In this chapter we have mainly considered some of the reported severe weather events and detailed analysis of cyclones and depressions that originated in Indian seas during the above period.

2. Winter Season (Cold Waves and Rainfall):

Under the influence of a Western Disturbance, widespread rainfall/snowfall occurred over Western Himalayan region during 6th to 8th January 2017 and isolated to scattered rainfall occurred over adjoining plains during the same period. As the Western Disturbance moved away east north eastwards from the Western Himalayan region, incursion of cold and dry air from the northwest resulted in significant fall of temperature over northwest and central parts of the country from 9th onwards. Cold wave at a few places with severe cold wave at isolated places occurred over plains of northwest and adjoining central India during 10th to 13th January 2017.

Minimum temperatures ≤1.0°C were recorded at Narnaul (Haryana): -0.5°C; Churu (West Rajasthan): -0.3°C; Alwar (East Rajasthan):0.5°C; Amritsar (Punjab): 0.9°C and Bhilwara (East Rajasthan): 1.0° C in the plains of the country on 11th January.

Another active western disturbances affected western Himalayan region including Jammu & Kashmir, Himachal Pradesh and Uttarakhand and

plains of northwest India including Punjab, Haryana, Chandigarh and Delhi, Uttar Pradesh, north Rajasthan and north Madhya Pradesh during 24-27 January 2017. The lowest minimum temperature in the plains of the country was 0.7°C recorded at Bhatinda (Punjab) on 20th January 2017.

An active western disturbance, caused widespread rainfall/snowfall activity over western Himalayan region (Jammu & Kashmir, Himachal Pradesh and Uttarakhand) with isolated heavy falls over Jammu & Kashmir on 4th February and isolated rainfall activity over adjoining plains (Punjab and Haryana) during 4 to 6 February 2017. The lowest minimum temperature in the plains of the country was 3.8°C recorded at Ganganagar (Rajasthan) on 6th.

3.Premonsoon Season (Heat Waves, Thunderstorms and Cyclones)

3.1 Heat Waves

Under the influence of prevailing Northwesterly winds & clear sky conditions over northwest& adjoining central India and approaching western disturbance over western Himalayan region, the maximum and minimum temperatures rose over some parts of plains of northwest, west & central India and adjoining north peninsular India and were above normal by 4-6° C. It led to the heat wave conditions at a few places over West Rajasthan & Gujarat and at isolated places over West Madhya Pradesh on 27th March, 2017.

The recorded maximum temperatures were anomalously high on 27 March 2017: Jaisalmer - 42.3°C, Barmer - 44.4°C, Dessa - 43.4°C, Gandhinagar – 43.2°C,Ahemdabad – 42.8°C, Baroda – 42.7°C, Surendranagar – 43.3°C, Amreli – 43.0°C, Khargone– 42.6°C, Malegaon – 42.2°C, Akola – 43.0°C and Chandrapur – 43.0°C.

3.2 Cyclonic Storm (CS) "Maarutha" over the Bay of Bengal (15-17 April, 2017)

CS "Marutha" had its genesis from an upper air cyclonic circulation developed over south Andaman Sea & neighbourhood on 11 April. It concentrated into a depression (D) over southeast Bay of Bengal (BOB) in the morning (0000 UTC) of 15th April 2017. and into a Cyclonic Storm (CS) "MAARUTHA" over East central Bay of Bengal in the midnight of 15th. Moving nearly northeastwards, it crossed Myanmar coast near Sandoway (Thandwe) in the midnight. Three people were killed in Irrawaddy division and a total of 81 houses were damaged under the influence of the storm in Myanmar. Occurrence of cyclone in the month of April is very rare. Climatologically, three cyclones have developed over north Indian Ocean (NIO) during 1-15th April; one over Arabian Sea and two over Bay of Bengal. Both the cyclones over Bay of Bengal had a recurving tracks. The climatological tracks of the TCs during 1961-2015 are presented in Fig.1. The observed track of the system is given in Fig 2

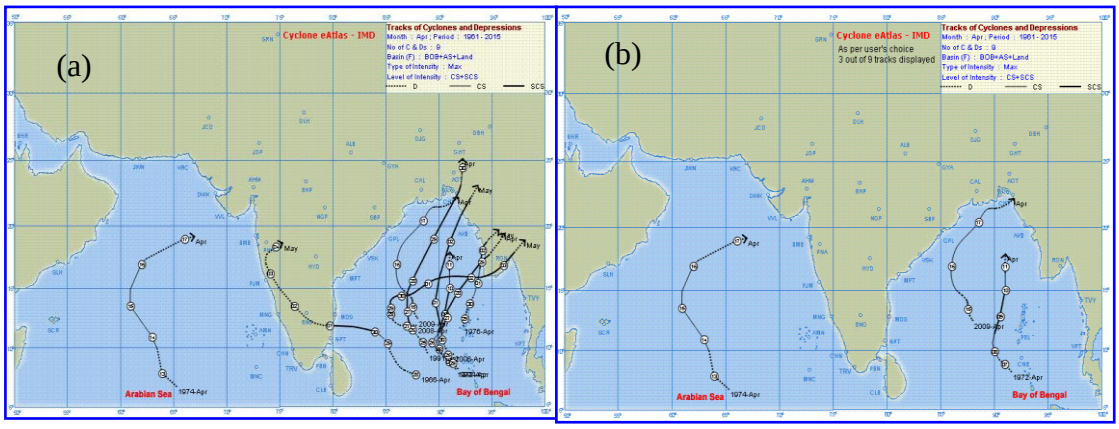

Figure. 1 Climatological tracks of TCs forming over north Indian Ocean region during 1961-2015 in the (a) month of April and (b) during 1-15 April.

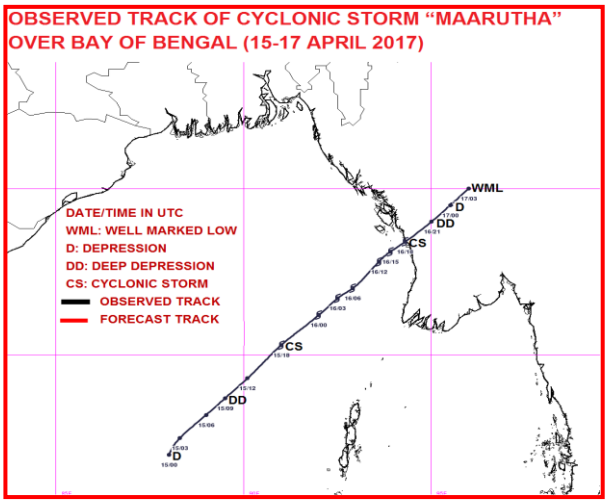

Figure. 2 Observed track of cyclonic storm Maarutha (15-17 April, 2017) over Bay of Bengal

CS Maarutha moved nearly northeastwards throughout its life period, under the influence of anticyclonic circulation located to the southeast of the system centre. There was a trough in middle and upper tropospheric levels lying to the west of system centre roughly along 85^0E which further helped in northeastwards movement of the system and higher translational speed. At the genesis stage the translational speed was maximum and was about 27 kmph. It then gradually decreased to minimum of about 16 kmph prior to landfall. After the landfall it increased sharply to about 30 kmph over Myanmar.

Rainfall associated with CS MARUTHA

The system caused heavy to very heavy rainfall in Southeast and adjoining eastcentral Bay of Bengal on 15th and heavy to very heavy rainfall over eastcentral Bay of Bengal on 16th. The rainfall was higher in eastern sector, especially in the northeast sector. The rainfall decreased significantly at the time of landfall and thereafter.

IMD-NCMRWF GPM merged gauge rainfall data associated with the system is presented in Fig 3

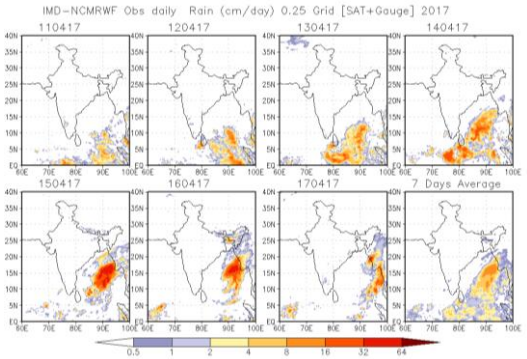

Figure.3 IMD-NCMRWF observed daily rainfall (cm/day) 0.25 grid (satellite + Raingauge) during 15-17 April, 2017

The salient features of the system can be summarized as below:

i. CS Maarutha was the first ever landfalling cyclone over Myanmar developing during the period 1-15 April in satellite era.

ii. The peak maximum sustained surface wind speed (MSW) of the cyclone was 70-80 kmph gusting to 90 kmph (40 knots) and the system crossed Myanmar coast with this peak MSW between 1800-1900 UTC of 16th April. The lowest estimated central pressure was 996 hPa (from 0000 UTC of 16th to 1800 UTC of 16th).

iii. The life period of cyclone was 51 hours (2.13 days).

iv. The track length of the cyclone was about 1170 km.

v. The system moved very fast under the influence of mid-latitude trough in westerlies lying over India in the middle and upper tropospheric levels. In addition an anticyclonic circulation lay to the southeast of system centre which further accentuated the north easterly winds over the cyclone field. Also the upper tropospheric ridge ran along 10-11^{0}N throughout the life period of the system. As a result, since the genesis stage itself, the system lay to the north of ridge. Under this scenario, Maarutha moved north eastwards very fast with a 12 hourly average speed of 22.8 kmph.

3.3 Severe Cyclonic Storm 'Mora' over the Bay of Bengal (28-31 May 2017)

A low pressure area formed over southeast Bay of Bengal & adjoining areas of central Bay of Bengal in the morning (0300 UTC) of 25th May, 2017. It moved northeastwards and intensified into a depression (D) over east central Bay of Bengal (BoB) in the early morning (0000 UTC) of 28th May and into a cyclonic storm (CS) "**MORA**" over east central BoB in the late evening (1800 UTC) of 28th. Thereafter, it moved north-northeastwards and further intensified into a severe cyclonic storm (SCS) in the evening (1200 UTC) of 29th. and crossed Bangladesh coast close to south of Chittagong in the forenoon (between 0400 and 0500 UTC) of 30th. The severe cyclonic storm, **MORA** had a north-northeastwards moving track. The observed track of severe cyclonic storm 'MORA' is given in Fig.4.

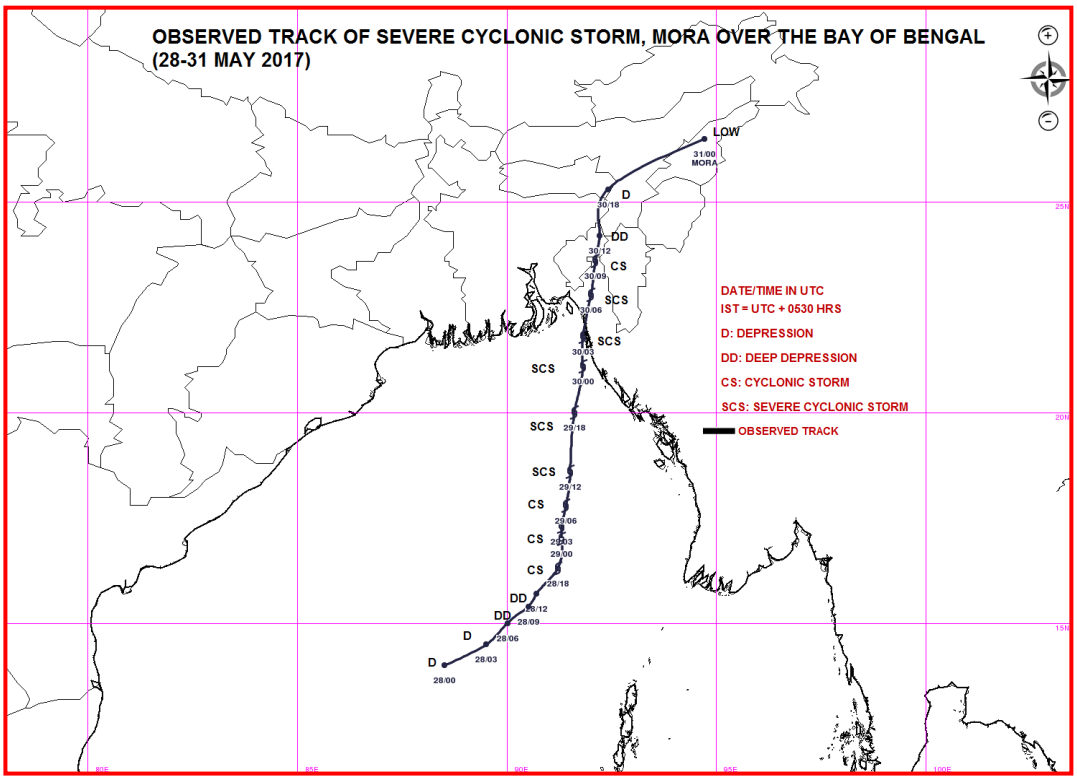

Figure.4 Observed track of SCS,'Mora' over BoB during 28-31 May 2017

Features observed through Radar

As the system was moving towards Bangladesh coast, it was tracked by DWR Khepupara, Cox's Bazar and Molvibazar. Typical Radar imageries are presented in Fig.5.

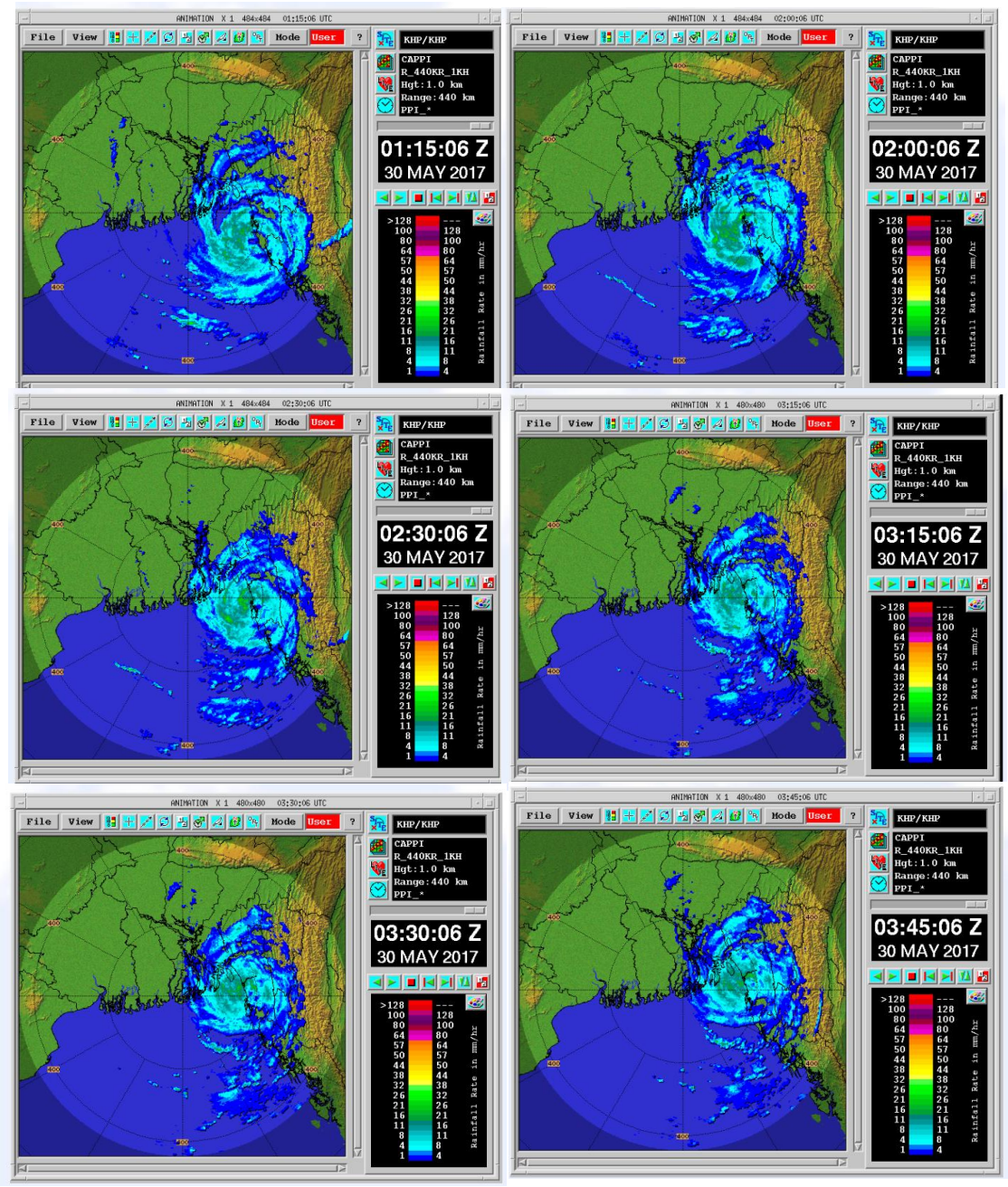

Figure.5: Imageries from Doppler Weather Radar Khepupara, Bangladesh during 0100 UTC to 0345 UTC of 30th May.

Realized Weather:

Rainfall associated with SCS Mora based on IMD-NCMRWF GPM merged gauge rainfall data is depicted in Fig 6.

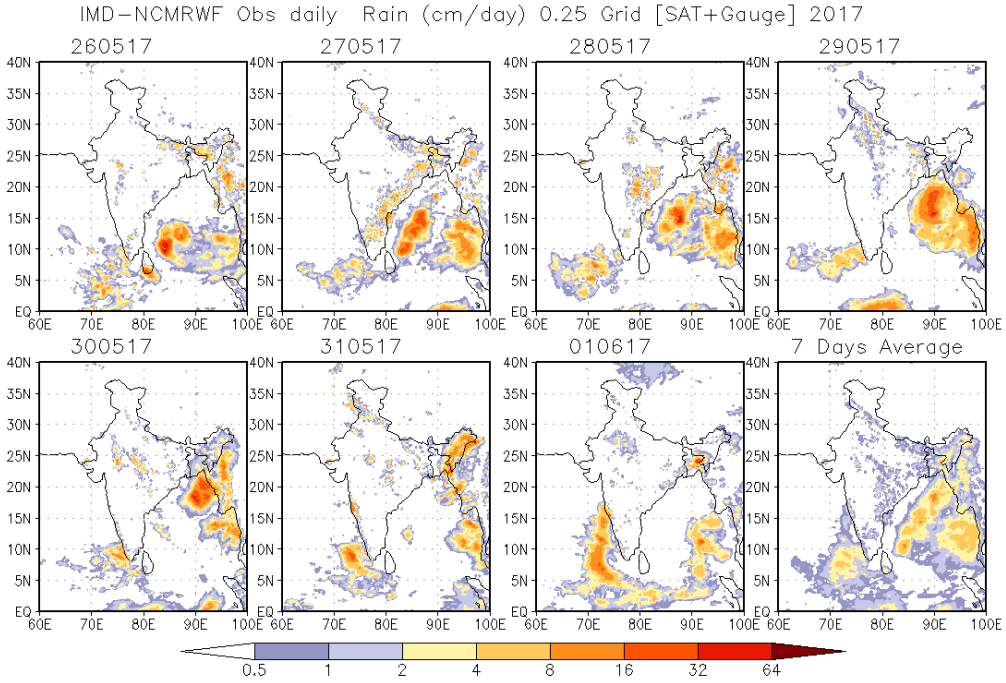

Figure.6 IMD-NCMRWF GPM merged gauge rainfall during 26th May– 1st June and 7 days average rainfall for CS Mora(cm/day)

The salient features of the system can be summarized as follows:

i. It was the first severe cyclonic storm of the year 2017.

ii. The severe cyclonic storm, **MORA** developed in the onset phase of southwest monsoon. Its intensification and movement towards north-northeastwards helped in advance of monsoon over the BOB and some parts of northeastern states.

iii. Like previous cyclone **MAARUTHA** in the pre-monsoon season, it also maintained its peak intensity till landfall.

iv. The severe cyclonic storm, **MORA** had a north-northeastwards moving track. Considering the area of genesis (± 2^0 around the genesis point), it is seen that about 63% of the cyclones moved north-north eastwards and crossed Bangladesh coast, whereas another 25% moved northeastwards and crossed Myanmar coast and 12% moved westwards towards Andhra Pradesh coast. Hence, the direction of the movement of the cyclone was climatological in nature.

v. The peak maximum sustained surface wind speed (MSW) of the cyclone was 110-120 kmph gusting to 130 kmph (60 knots) and the system crossed Bangladesh coast with this peak MSW between 0400-0500 UTC (0930-1030 hrs IST) of 30th May. The lowest estimated central pressure was 978 hPa (from 2100 UTC of 29th to till landfall around 0430 UTC of 30th).

vi. The cyclone life period was about 72 hours (3 days).
vii. The track length of the cyclone was 1086 km.
viii. The 12 hour average translational speed of the cyclone was about 20.4 kmph 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 & 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 & upper tropospheric levels, which was further accentuated by the north-northeasterly winds from anticyclonic circulation.
ix. The Velocity Flux was $3.45X10^2$ knots.
x. Lowest estimated central pressure (ECP) was 978.0 hPa with a pressure drop of 18 hPa.
xi. The Accumulated Cyclone Energy (ACE) which is a measure of damage potential was about 1.74×10^4 $knot^2$.

3.4 Deep Depression over Bay of Bengal (11-13 June 2017)

A low pressure area formed over Westcentral & adjoining north Bay of Bengal off north Andhra Pradesh - south Odisha coast in the morning of 10th June. It lay as a well marked low pressure area over northern parts of central Bay of Bengal and adjoining north Bay of Bengal on 11th morning .It concentrated into a depression over north Bay of Bengal in the evening of 11th June 2017 in association with advance of southwest monsoon over the region. It moved north-northeastwards, intensified into a Deep Depression and crossed Bangladesh coast near Khepupara between 0430 & 0530 hrs IST of 12th June 2017. It lay as a Deep Depression over coastal Bangladesh, close to northeast of Khepupara at 0530 hrs IST of 12th June 2017. It then moved northeastwards across Bangladesh and weakened gradually. It weakened into a Depression around mid night of 12th June 2017 and further into a well marked low pressure area over east Bangladesh and neighbourhood in the early morning of 13th June 2017. It caused heavy rainfall activity over northeastern states as well as over Bangladesh.
The track of the system is given in Fig 7.

Features observed through satellite

Typical INSAT-3D IR imageries are presented in Fig.8. According to satellite imageries at 1200 UTC of 11th, intensity was C.I. 1.5. The convection showed shear pattern. Maximum convection lay over southwest sector of the depression. Associated broken low and medium clouds with embedded intense to very intense convection lay over north and adjoining westcentral BoB, coastal Odisha and coastal areas of West Bengal and Bangladesh.At 0000 UTC of 12th, intensity was C.I. 2.0. The convection further got organised. Associated broken low and medium clouds with embedded intense to very intense convection lay over Northwest and adjoining Northeast Bay of Bengal. At 1800 UTC of 12th, broken low and medium clouds with embedded intense to very intense convection lay over south Bangladesh, northeast & adjoining northwest BoB and south gangetic West Bengal. At 0000 UTC of 13th, broken low and medium clouds with embedded intense to very intense convection lay over south Bangladesh, northeast & adjoining northwest BoB and south Gangetic West Bengal.

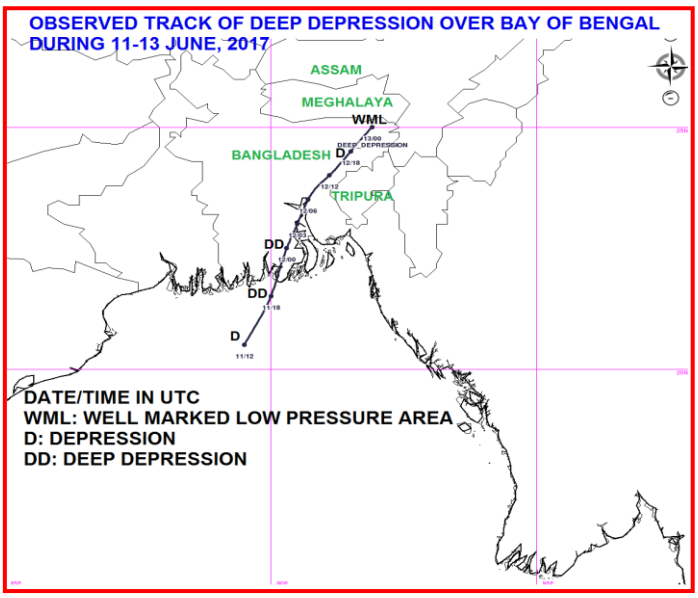

Figure.7 track of deep depression (11-13 June, 2017)

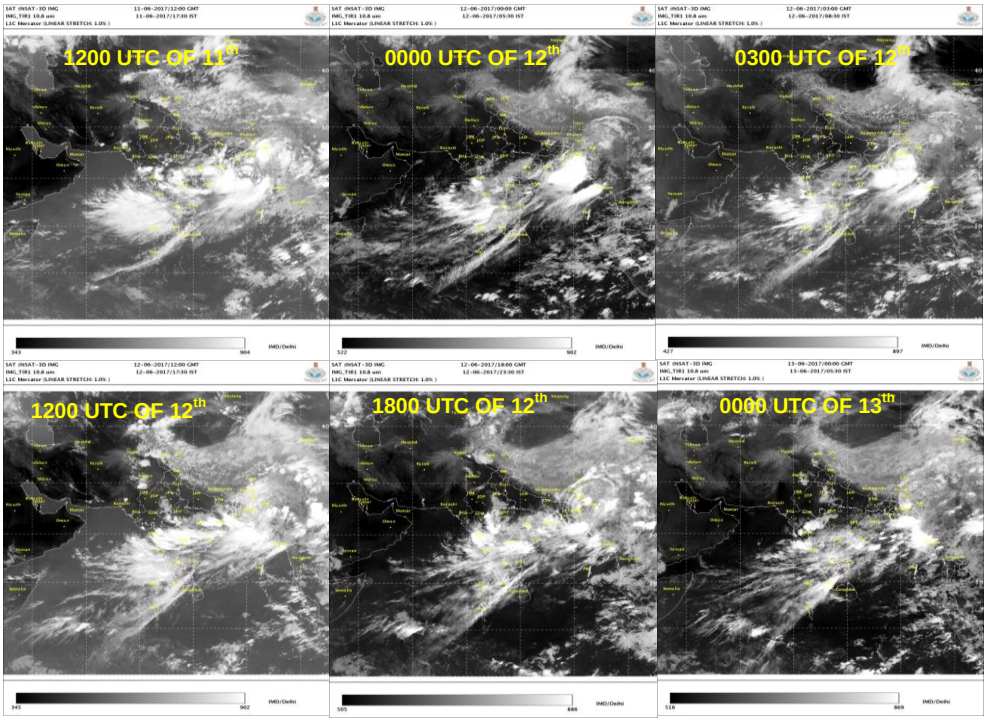

Figure.8 INSAT 3D based IR imagery of deep depression during 11-13 June, 2017

Radar features

Typical Radar imageries are presented in Fig.9. DWR Cox's Bazar could capture the location and associated rainfall correctly. It could also show curved bands entering towards the centre from the southeast.

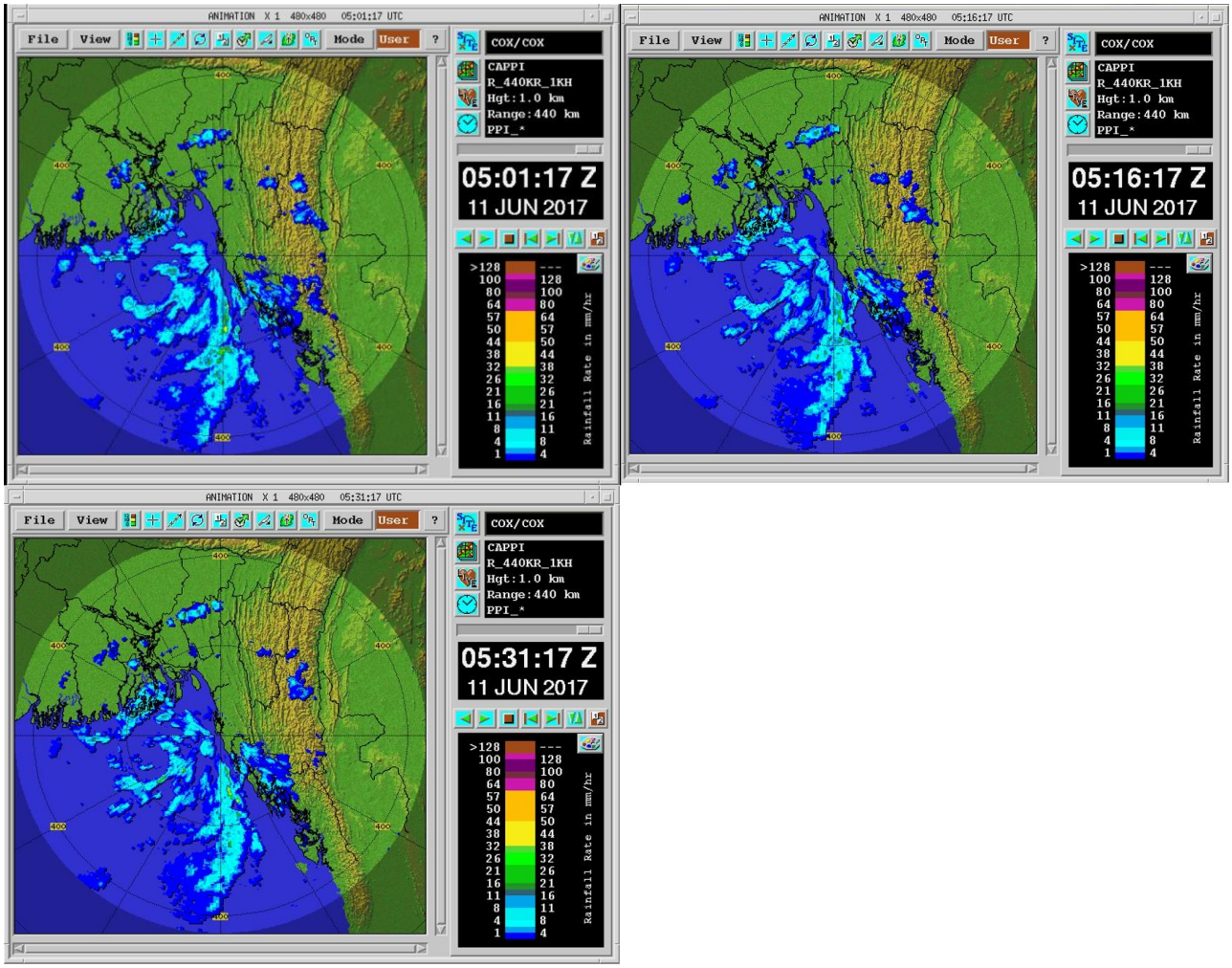

Figure.9 Typical Radar imageries of deep depression on 11th June, 2017

Realised weather:

The deep depression caused heavy rainfall over northeastern states and Bangladesh. The chief amounts of 24 hr cumulative rainfall ending at 0830 hrs IST of data are given below/

12 June 2016:

Assam & Meghalaya:

N.Lakhimpur/Lilabari and Kampur : 7cm each ,

Nagaland, Manipur, Mizoram & Tripura:

Bishalgarh: 9cm, Arundhutinagar: 7cm.

13 June 2017:

Assam & Meghalaya:

Cherrapunji: 32cm, Mawsynram: 19cm, Shillong: 11cm, Williamnagar: 10cm, Karimganj and Panbari: 10cm each, Goalpara and Barpeta: 8cm each, Beky Railway.Bridge:7cm

Nagaland, Manipur, Mizoram &Amp; Tripura:

Serchip: 24cm, Aizwal: 18cm, Bishalgarh:10cm,Agartala :9cm,Khowai:8cm, Arundhutinagar and Kailashahar : 7cm each.

14 June 2017:

Arunachal Pradesh: Itanagar and Naharlagun : 7cm each

Assam & Meghalaya: Jia Bharali N T Xing, Puthimari, Guwahati Airport: 11cm each; Tezpur, Majbat, Karimganj : 9cm each; Goibargaon, Dhekiajuli, Badatighat: 8cm each, Nalbari/Pagladia: 7cm .

Under the influence of the above system, south west monsoon advanced into the north-eastern parts of the country.

Acknowledgements: This article is compiled with reference to the reports of RSMC, IMD, New Delhi and NWFC reports of India Meteorological Department.

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