Investigations on Characteristic Features of Cyclonic Storm 'MORA 2017' Through Radio Signal, Satellite and Radar Over the Bay of Bengal

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Abstract The coastal districts of West Bengal and Bangladesh observed tropical cyclones with the devastating consequences on socio-economic conditions of the affected region and the daily life of human beings. This study provides an understanding of localization, tracking, threat identification and characterization of cyclone and lightning associated with the cyclonic storm Mora 2017 over the Bay of Bengal. Three types of observations as derived from radio signal data recorded at Kolkata, satellite data of INSAT-3D enhanced imageries and the cyclone detection Doppler radar data have been considered for investigating the characteristic feature of the said cyclone. The radio receiver in the ELF and VLF bands recorded the EM wave radiated from the core of cyclone due to lightning discharges. Analyzing the observed data, we have been reported some interesting features noted during the cyclone Mora.

Keywords Radio signal · Satellite · Radar · Cyclonic storm · EM wave

1 Introduction

The cyclone Mora was the name suggested by Thailand, came from a Thai word, meaning 'star of the sea.' In this work, we have examined characteristic changes of tropical cyclone Mora experienced during the pre-monsoon month May 2017, and identified some interesting features using a combination of observations from radio signal in ELF/VLF (Extremely low frequency/Very low frequency) band, satellite imagery and data of cyclone detection Doppler Weather Radar. The investigation has been executed by dividing the life cycle of the TC (Tropical Cyclone) into various stages of intensification and weakening.

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1.1 Previous Work Related to Tropical Cyclone

In the satellite period 1981–2020, Tropical Cyclone (TC) data have shown the intensity of the strongest Tropical Cyclones had increased tremendously over the northern Indian Ocean [1–3]. In fact, TCs in the Bay of Bengal and the Arabian Sea were grouped together. A subsequent observation reported that the Bay of Bengal Cyclones, in the post monsoon season, increased the intensity over the past 40 years which creates large-scale changes in ocean-atmospheric conditions [4, 5]. But, a large number of early studies of Bay of Bengal Tropical Cyclones pointed up on the post monsoon season. Most of the climatic phenomena which impact global climate at inter annual timescales, e.g., the El Niño–Southern Oscillation (ENSO) and Indian Ocean Dipole, tend to visible more strongly during winter. A significantly large-scale ocean-atmosphere state was observed for Tropical Cyclone development in the post monsoon Bay of Bengal during La Niña and the negative phase of the Indian Ocean [6, 7]. However, the impact on the surroundings, pre-monsoon TCs at inter annual timescales is not clearly noted. But, after the study of correlation between Niño 3.4 SST anomalies and the accumulated cyclone energy for the months of March–May in the pre-monsoon Bay of Bengal, ENSO is not having a proper impact on pre-monsoon Bay of Bengal Tropical Cyclones activity [8–11]. Scientist Emanuel collected data for a long period of time to calculate the Tropical Cyclone power dissipation index (PDI) and the intensification tendencies [10]. The power dissipation index for a season and for a particular tropical cyclone strength category, i.e., tropical storm, tropical cyclone, major tropical cyclone, is estimated as the sum of the cubes of the maximum wind speed at every 6 h. Tropical Cyclone location during the months of October–November is the maximum wind speed of the storm is within the range defined for the particular category [12–14]. During 1981–1995, it was observed that total of eight storms obtained Tropical Cyclone strength which was higher than total strength of 27 storms. Alternatively, between 1996 and 2010, 10 cyclones out of 24 tropical cyclones gained total strength or higher, causing a higher conversion rate of about 42%. A thrilling characteristic features of the Bay of Bengal Tropical Cyclone formation is the zonally asymmetry in nature. All seven sub-tropical cyclones take place in the Bay of Bengal in 90°E longitude. This geographical weakness of Tropical Cyclones can be credited to the longer time spent over the warm ocean for cyclonic storms which forms in the 90° E [2]. Moreover, it was executed that the frequency of storms during the two consecutive 15-year periods, 1981–1995 and 1996–2010, was statistically same. Moreover, further investigations exposed that the total occurring storm days were nearly the same for the above two consecutive periods. Again, the mean duration, of each Mid Troposphere Cyclone in Mid Troposphere Cyclone-phase during the 15-year period 1996–2010, was statistically identical from that during the 15-year period 1981–1995. Also, it was observed that the mean maximum intensity carries due to the storms during Mid Tropospheric Cyclonic phase increased with time. On an average, the maximum wind speed of storms during the first period 1981–1995 was nearly 54 ms^{-1}, category 3 and the mean maximum wind speed for storms during the second period 1996–2010 was about 62 ms^{-1}, category 4. Just observing this authentication, it can be noted that the intensity of post monsoon Bay of Bengal cyclonic storms is increasing [15, 16].

2 Equipment Used for Measurements Related to Cyclone MORA

Three major equipment provided data for the present investigation. The first one is a Radio signal receiver; operating in our Laboratory at Techno India University, in the ELF and VLF bands which recorded EM wave radiated signal originating from the core of cyclone as radiation owing to lightning discharges. The second one is the satellite INSAT-3D enhanced imageries and the third is the real-time data as derived from the cyclone detection Doppler radar. We have used RAS-make (Radio Astronomical Supplies, USA) radio signal receiver for recording signal in the ELF/VLF frequency band. This radio signal receiver recording data round-the-clock. The RAS-make receiver is unique in type and can be used suitably for filtering, decoding, receiving and demodulating signals with the soundcard or other audio input devices [17, 23].

3 Investigations Related to MORA Storm Path

Under favorable atmospheric conditions, convective area developed over the Bay of Bengal (BoB). It causes advancement of a circulation and low-pressure area (LPA) over southeast and adjoining central BoB on May 27, 2017 [18–20]. It is then concentrated into a depression over the central Bay of Bengal at 0000 UTC on May 28, 2017 and rapidly reinforced into a deep depression on the same day. During the early hours of May 29, the storm attained the intensity of the cyclonic storm and named as MORA which followed an NNE track parallel to Burma coast, reaching its maximum strength as a severe cyclonic storm with the wind speed of 110 km/h and lowest mid pressure of 978 hpa during 0300 UTC on May 30. We have shown the Mora tracker in Fig. 1 showing the storm path when entered into Bangladesh, touching Dhaka and Chittagong. The tropical cyclone MORA made landfall in Bangladesh in the morning of May 30, 2017 accompanied by heavy rains and winds estimated at 117 km/h (73 mph).

After the land interaction, the cyclone weakened gradually to be lost into a distinct LPA over Nagaland and its surroundings at 0000 UTC on May 31, 2017 [21]. The low-lying areas of the coastal districts and their offshore islands and chars of Bangladesh and Myanmar are inundated by the storm surge of the cyclone. The well-marked LPA centered at 0000 UTC on May 28 over SE and adjoining areas of central Bay of Bengal, which then concentrated into a depression and moved along NE and lay centered at 1200 UTC on May 28, over EC BoB near (15.7° N, 90.7° E). Continuing

Fig. 1 MORA tracker showing the storm path when entered into Bangladesh. *Courtesy* IMD

its movement, the system slowly weakened into a DD and lay centered at 1200 UTC on May 30 over Tripura and surrounding areas (24.2° N, 92.2° E) and into a well-marked LPA over Nagaland and neighborhood at 0000 UTC on May 31. According to the report of India Meteorological Department, on May 30, 2017 between local time 7:30 AM and 9:30 AM the cyclone MORA made landfall along the SE coastal area of Bangladesh in the vicinity of Kutubdia Island between Cox's Bazar and Chittagong [22].

Some prominent INSAT-3D imageries in association with CS MORA have shown in Fig. 2. The convection experienced during May 28, 2017 exhibits curved band pattern with well-marked wrapping into the center from eastern sector. Broken low to medium clouds accompanied by intense to very intense convection covered over BoB between latitude 11.0–19.0° N and longitude 84.0–91.0° E.

As pointed out before, the cyclone Mora made landfall in the morning of May 30, 2017 as a Category 1 cyclone between Chittagong and Cox's Bazar. The powerful cyclone damaged largely with packing winds of up to 117 km per hour and moved toward India's Northeast. Satellite image of the cyclone Mora is shown in Fig. 3.

As a result of this severe cyclone, heavy rainfall occurred to lash the states of Mizoram, Tripura, Arunachal Pradesh, Meghalaya, Assam and Nagaland on May 30 and 31.

In Fig. 4, Typical Kalpana-1 imageries of cloud top temperature obtained by using VHR (very high resolution) sensor at 0445 UTC on May 30, 2017 in association with CS MORA. The cyclonic storm was detected by the above satellite and the related imageries are send to the observatory through radio communication.

Doppler Weather Radar (DWR) imageries of some typical selected Max (Z) as recorded by IMD, Kolkata center using cyclone detection radar during May 29 and May 31, 2017 associated with cyclone Mora are presented in Fig. 5.

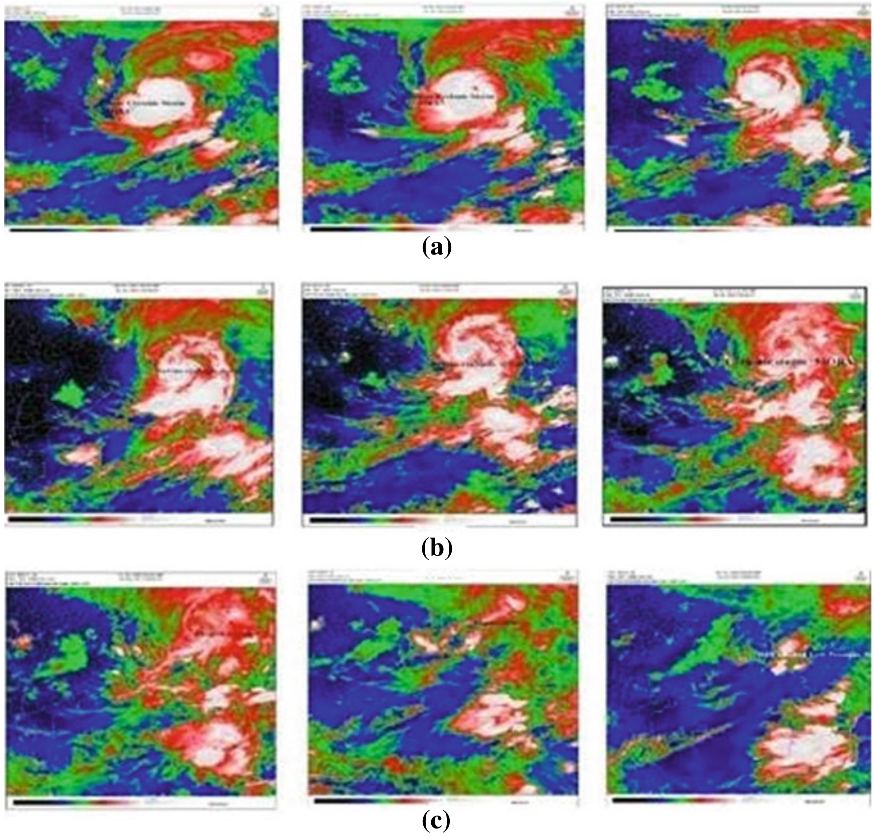


Fig. 2 INSAT-3D enhanced colored imageries associated with CS MORA during May 29 and May 31, 2017. *source* IMD

4 Analysis and Results

The ELF/VLF data recorded with an embedded instrument in our observatory [23]. The recordings of the data shown in Fig. 6. Figure 6a shows a typical sample of the data on an undisturbed day, May 23, 2017, while Fig. 6b exhibits the spectral pattern of the signal which was received and recorded on May 30, 2017 when the cyclone was severe in nature. It appears from the figure that on an undisturbed day the noise level of the spectra in the ELF/VLF range was low as compared to that on the disturbed day. The level was enhanced rapidly with the atmospheric perturbations due to cyclone MORA and maintained throughout the period of its existence. When it disappeared, the level further came down as before which is not shown in the figure. It is further clear from the record of Fig. 6b that the noise level in the ELF range is slightly higher in comparison with that in the VLF range. When compared both the

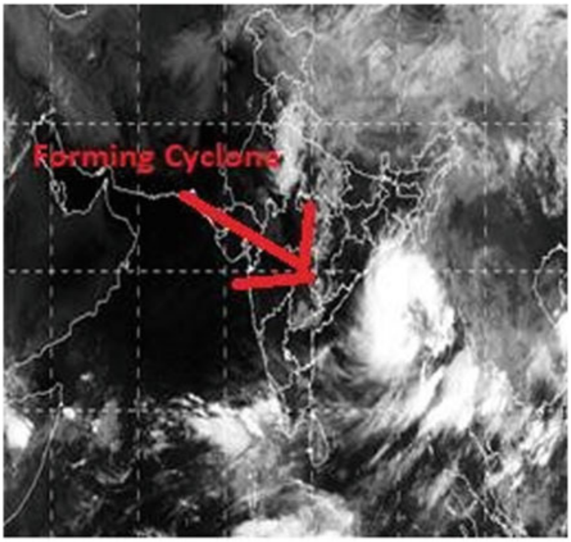


Fig. 3 Satellite image of cyclone Mora. *Credit* IMD

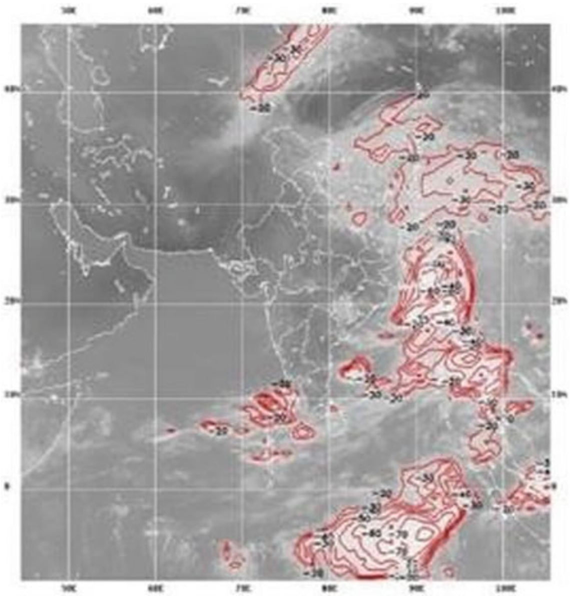
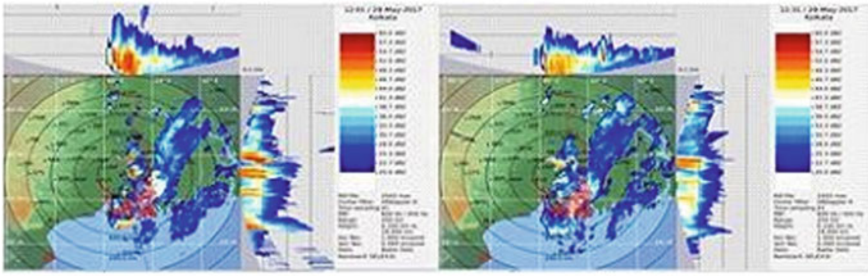


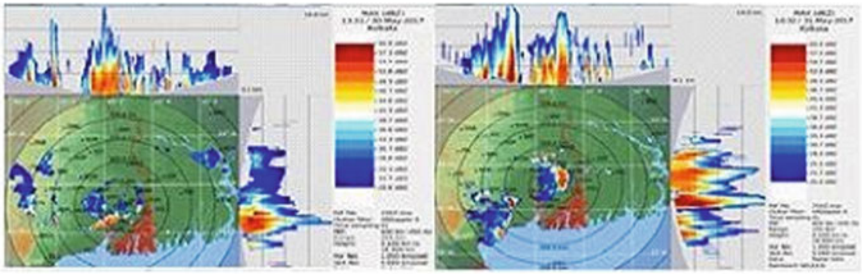
Fig. 4 Kalpana–1 satellite imageries of cloud top temperature using VHR sensor with 8000 m resolution at 0445 UTC on May 30, 2017 in association with cyclonic storm MORA. *source* IMD

records of Fig. 6a, b, we find that the peak-to-peak excursion of the noise level is smaller on a clear day as compared to that on a disturbed day.

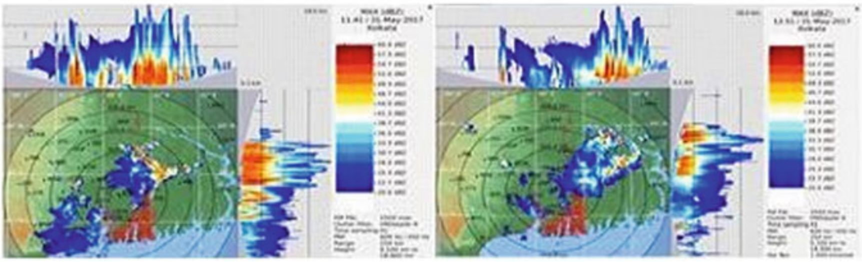
Comparison with existing methods as desired, is beyond the scope of this paper as it dealt with the observations in disturbed day as the cyclonic storm MORA was passing through the area.



(a)



(b)



(c)

Fig. 5 (**a**) (**b**) (**c**) Doppler weather radar (DWR) imageries of some typical selected max (Z) as recorded by IMD, Kolkata center using cyclone detection radar during May 29 and May 31, 2017. *source* IMD, Kolkata

5 Observations

Tropical cyclones and associated lightning are the most destructive and recurrent natural hazards in the tropical and sub-tropical areas of the globe with widespread impacts. A significant number of the deadliest cyclones, like the cyclone Mora reported here, have occurred in the Bay of Bengal affecting widely the state of West Bengal and Bangladesh. A combination of factors like a flat coastal terrain and high population density of the related areas of West Bengal to Bangladesh always has devastating consequences upon landfall for the cyclones over Bay of Bengal.

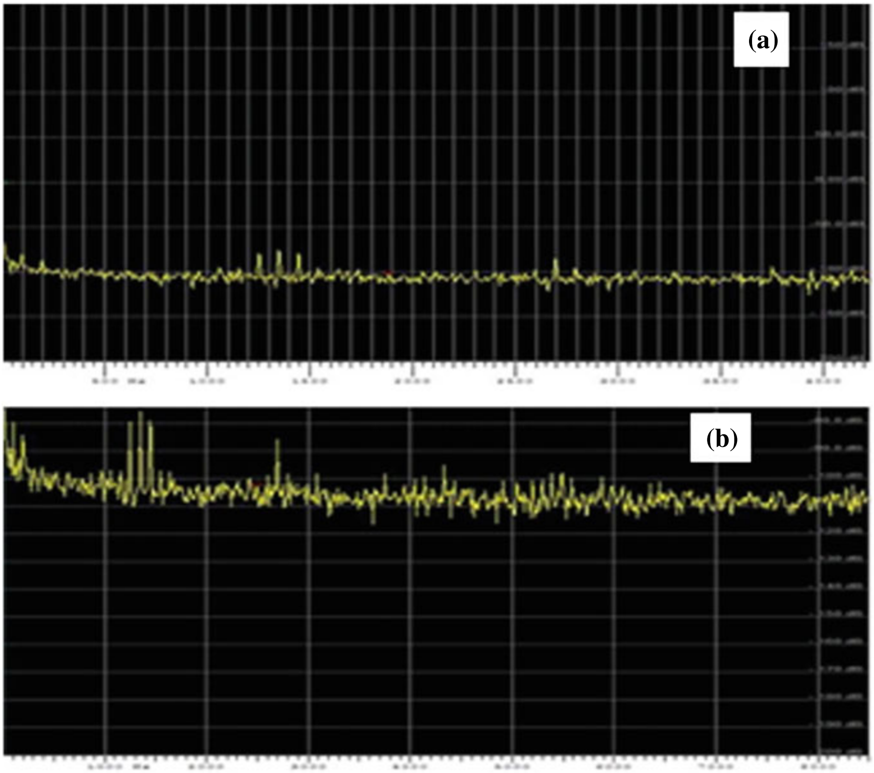


Fig. 6 **a** Typical sample of ELF/VLF data on an undisturbed day, May 23, 2017, **b** the spectral pattern of the signal on May 30, 2017 when the cyclone was severe in nature

The annual cycle of tropical cyclones (TCs) in the northern Indian Ocean exhibits a clear bimodal structure. The season starts from April when the sea surface temperatures increase and continues to intensify through May. By the second week of June, the monsoon sets in and the accompanied strong vertical wind shear and unfavorable atmospheric vortices largely limit the formation of TCs during the monsoon from June to September. In October, the TC activity increases further, getting a second peak during the month of November. While more TCs form during the post monsoon months, the most intense storms are found to form during the pre-monsoon period. Large ocean heat content and strong variability of northward propagating intra seasonal oscillations during April–May are mainly responsible for the formation of intense TCs during pre-monsoon months.

6 Conclusions

The work is associated with disaster study which is a combination of consequences of hazardous natural or social phenomenon and environmental condition at the place of occurrence. As a consequence of a devastating Tropical Cyclone, both fishing and tourism are seriously affected. The outcome of the study strongly supports the socio-economic activity of the government. This interdisciplinary program may promote an understanding of key environmental issues with localization, tracking, threat identification and characterization of cyclone and associated lightning and precipitation which can serve largely to the society and environmental management related to studies of severe cyclones in West Bengal. Similar study will impart knowledge on environmental issues at local and regional levels.

Further, percentage frequency distribution, radial profile as well as quadrant-wise mean rain rates can be determined for each Tropical Cyclone.

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