MJSAT 2 (4) 156-162

MJSAT

Malaysian Journal of Science and Advanced Technology

journal homepage: https://mjsat.com.my/

Investigation of the Effects of Climate Change on Tropical Storms and their Genesis in the Bay of Bengal

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KEYWORDS

Bay of Bengal
Coast
Climate
Cyclone
Genesis

ARTICLE HISTORY

Received 11 September 2022
Accepted 25 September 2022
Available online 26 September 2022

ABSTRACT

This study investigates the impact of climate change on the genesis of storms in the Bay of Bengal. Almost all the countries of the world are facing losses due to the global warming issue and related climate disasters. Bangladesh is one of the most vulnerable countries in South Asia facing damage due to climate change. In this study, the characteristic features of genesis have been analysed using the probability formula in the small latitude area of 2 degrees. To analyse the characteristics of Genesis's behaviour, we reviewed storms that occurred in the 21st century. A reliable probability calibration is derived for every 2 degrees of latitude that explains the changes of genesis due to climate changes. For a clear view of climate change's impact on cyclone genesis, we have regenerated the study domain in a 1 by 1-degree longitude and latitude box. Which represents the clear view of genesis probability. And, it is clearly viewed that the genesis will be shifted from low latitude to high latitude.

1. INTRODUCTION

Every year Bangladesh confronts lots of different types of disasters. Among these some are created by nature and also in many cases men are responsible directly or indirectly [1]. However, within these natural calamities the most horrendous name is tropical cyclone and the resultant cataclysm due to cyclone. In Bangladesh, on an average every year 3-7 deadly cyclones strike, whose severity are seen by the coastal region mostly. But due to climate change on a large scale this number shows disparity at times [2]. In addition to that, the number of landfall is altering as a consequence of climate change [3]. Many researchers have analysed the tropical cyclone and the resulting inundation with tide which can be found by [4]. They have examined and explored the different aspects of storm surge from different cyclones. We can also see that researchers have given their attention to new kinds of numerical solutions, for instance [1], [5]–[10]. Seemingly many investigations have been done on the cyclone which was created in the Bay of Bengal but among these very few were focused on the genesis of a cyclone. Some of them were concentrated on seasonal variation of genesis [11]. Therefore, we have focused on the disparity of genesis due to climate change on a large scale. Considering climate change and annual dissipation we have investigated the activity and mobility of genesis. In this research, three annual dissipations have been considered. Moreover, for accurate and analytical results our estimated area was divided into infinitesimal latitude whose detailed description is given in the later part of this paper. In section two there is delineation about the research area and also which types of data were used, detailed description is in section three. Further details about methodology have been described in section four. Finally, the results and discussion have been discussed in section five and six respectively.

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2. MATERIAL AND METHODS

2.1. Study Area

The study area of our study is the coastal region of Bangladesh. That is, the coastal region of Bangladesh, the coastal region is a total of 19 districts and 153 police station areas. This coastal area covers 32% of the area and 28% of the population of Bangladesh [12]. Out of this, 12 districts and 51 police station areas are at risk of disaster. The lowest land area of Bangladesh is called the delta which forms the coastal region of Bangladesh, which is an extended Himalayan drainage ecosystem. The river system of Bangladesh is very complex and is dominated by three major rivers, namely Padma, Brahmaputra, and Meghna, which form the world's largest delta. The coast of Bangladesh is a region that experiences about 5% of tropical cyclones worldwide. In 1970, one of the most devastating cyclones of the century hit the Meghna estuary in Bangladesh, killing nearly 300,000 people. In April 1991 the cyclone made landfall near Chittagong killing about 1,38,000 people. In view of the determination of Bangladesh's maritime boundaries with India and Myanmar, Bangladesh gained ownership over one hundred thousand 18 thousand 813 square kilometres of sea area along the coast of Bangladesh, an exclusive economic zone of 200 nautical miles, and all kinds of animal and non-animal resources located in Mahisopan up to 354 nautical miles from Chittagong coast. Bangladesh is bounded by the border of INDIA (see, Fig. 1).

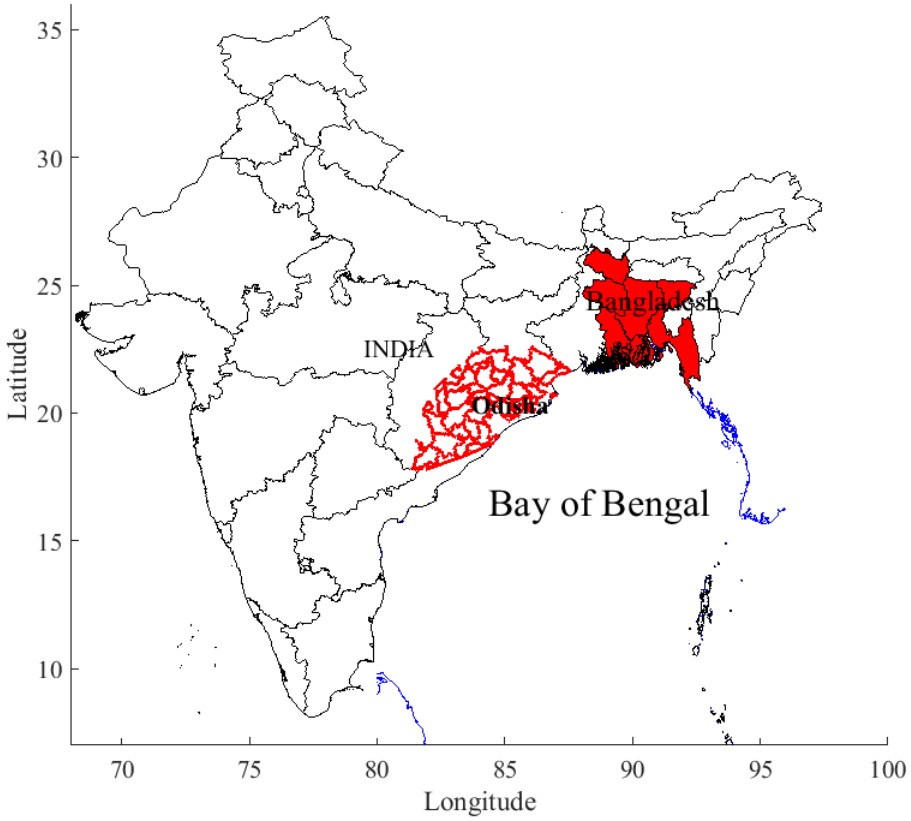

Fig. 1. Study area with some tide station location

2.2. Data and Methodology

Bangladesh Meteorological Department (BMD) was exercised in this study. The BMD data is the best track data or observed data. Some useful simulation data is available to analyse the climate behaviour. But in this study, we have used BMD data. At first, [13] developed a NCAR Community Climate Model version 1 (CCM1) which is now known as an Atmospheric Global Circulation Model (AGCM). In this model, heat momentum, and dynamic mass were used in the horizontal spectrum conversion method where 18 vertical levels were used to adjust the system. In each layer, the Delta-Eddington calculation was performed which was developed from the solar radiation scheme [14]. In the present situation, the Meteorological Research Institute (MRI) and Japan Meteorological Agency (JMA) have jointly developed a new operational numerical weather prediction model known as MRI-AGCM [15]. For further development, a Semi-Lagrangian three-dimensional advection scheme was used, which is accelerating the time integration with a 20 Km horizontal grid and 60 level altitude 0.1 hPa vertical grid spacing [16]. The higher resolution (20 Km) AGCM experiment was performed by the time-slice method, which has two layers, one is the global warming projection system that consists of an Atmospheric-Ocean General Circulation Model (AOGCM), and the higher part of the vertical level AOGCM generated by AGCM. For the further development of the climate experiment, the database for policy decision-making for future climate change (d4PDF) data was revised for global experiment data. The d4PDF data was produced from the weather prediction model of the Japan Meteorological Agency [17] with the modified model of MRI-AGCM 3.2 (Mizuta et al., 2012). The developed model used triangular truncation with a linear Gaussian grid (TL319) and the 64 vertical levels with the top at 0.01 hPa [18]. The

boundary conditions of the model were sea surface temperature (SST) and sea-ice concentration (SIC, and sea-ice thickness (SIT) for the lower boundaries. The external forcing was considered as Global-mean concentrations of greenhouse gasses, and three-dimensional distributions of ozone, and aerosols [19]. These data were used in different studies which were simulation data. Therefore, we used observational data instead of simulation data. This observation data is collected and provided only by the Bangladesh Meteorological Department. After collecting the data, we separate the genesis points of the storm from it. Then use the formula below to determine the probability of genesis.

$$P(Genesis) = \frac{Number\ of\ favourable\ outcomes\ to\ Genesis}{Total\ number\ of\ possible\ outcomes} \quad (1)$$

We have applied these rules in every box of 2-degree latitude longitude boxes. Then observe the results and mark them with different colours.

3. RESULTS

In our research, in this section we have presented our findings. The storm tracks used in our research were visualized as current climate storm data from 2000 to 2021. However, in this study we used storm data from 1975 to 2015 to review. Although we have data collected till 2021. Since 1975, every 10 years have been visualized as one location of climate change. In Fig. 2 we show the behaviour of the storm tracks on the left from 2000 to 2021 and from 2004 to 2009 for 6 years. Similarly, in Fig. 3 we show the results of analysing the storm track behaviour over 6 years.

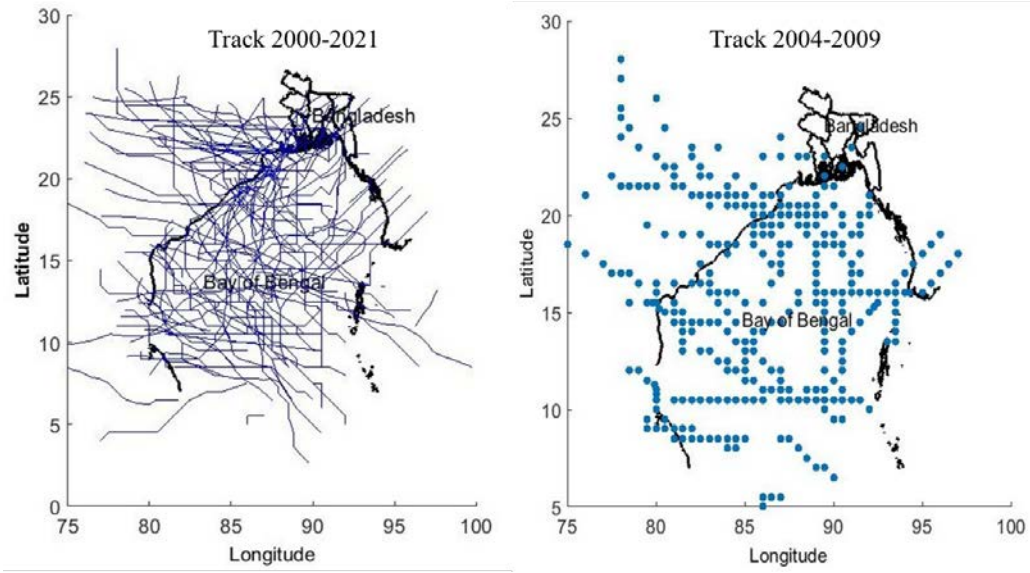

Fig. 2. Tropical cyclone track behaviour 2000-2021 and 2004-2009

From the figures it is evident that the activity of the storms is more in the south-west. We considered the initial detection point of the tropical disturbance as the genesis point. Fig. 4 represents the genesis point in each time slice. Genesis is an important factor for cyclone movement behaviour. Due to climate change, birth place may change.

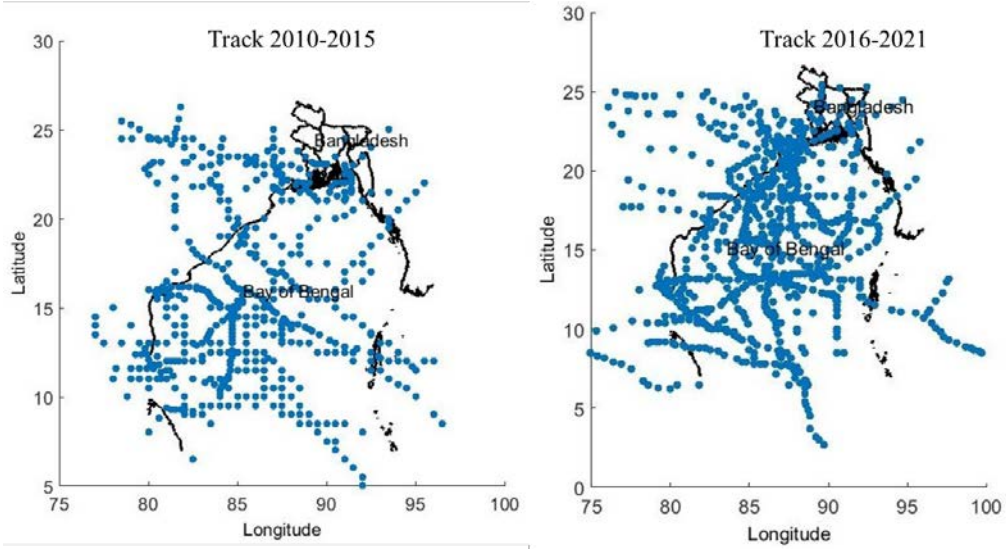

Fig. 3. Tropical cyclone track behaviour 2010-2015 and 2016-2021

There are several factors that depend on the origin of the cyclone. The responsible factors are the small magnitude of vertical wind shear in the horizontal wind, the low-level relative vorticity, and a large magnitude of thermal energy.

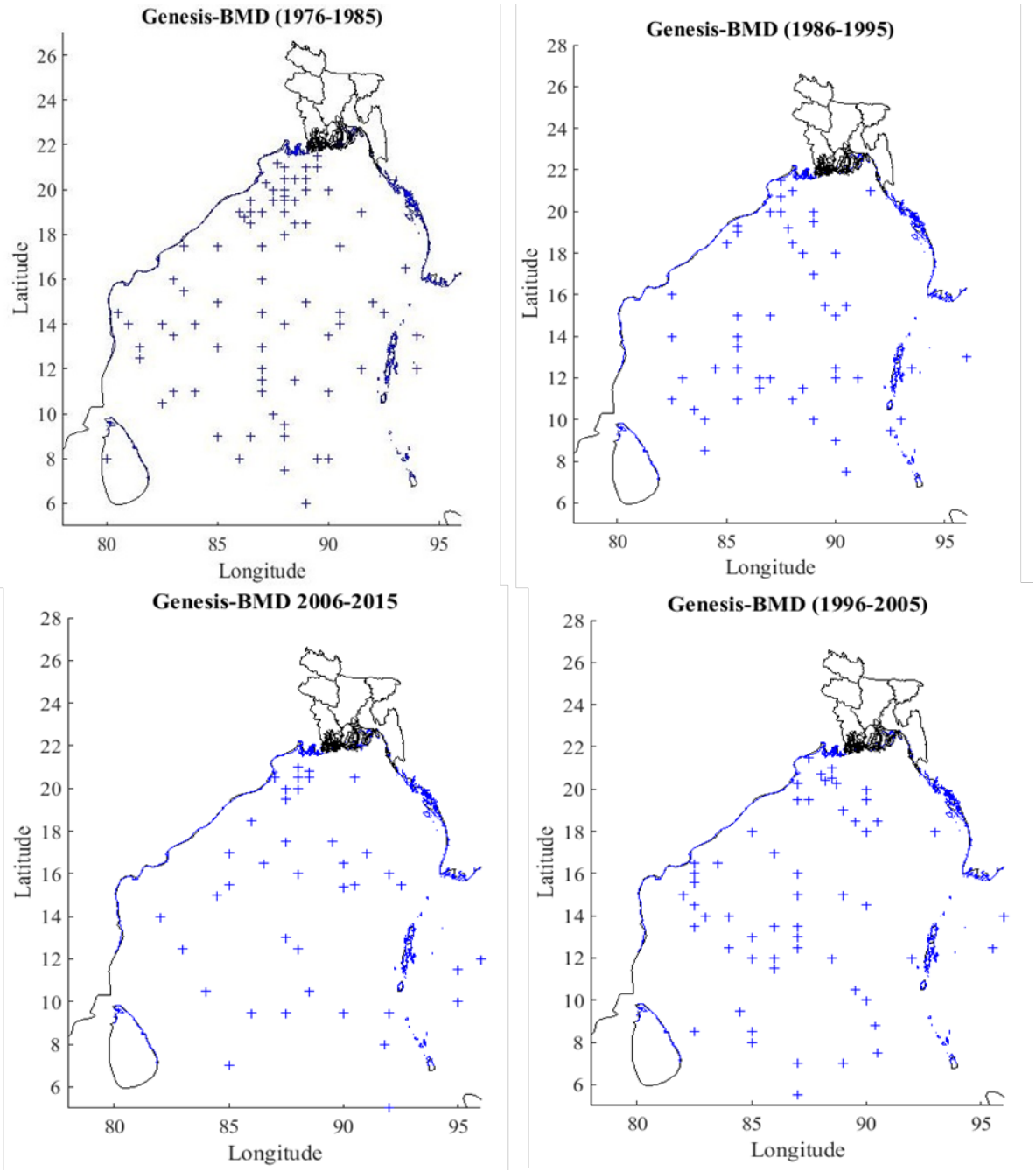

Fig. 4. Genesis behaviour in the Bay of Bengal in different time segments

By the early 19th century, it was observed that the rotation of the Earth near the equator was an important factor in the development of a formation in the upper part of the equatorial region.

Because the wind is very weak in the 40-50 latitude band. Therefore, in 50 latitudes there is no possibility of cyclonic formation near the equatorial belt. In the present study, it can be seen that the main factors of cyclone formation are the Coriolis parameter, low-level relative vorticity, sea surface factors such as SST>26 C within 60-m above sea level, vertical gradient change pressure with respect to 500 hPa, and mean Moisture in the troposphere. The role of low-level relative vorticity in cyclone formation is important. The role of low-level relative vorticity in cyclone formation is also important. Development of a tropical cyclone requires a continuous import of mass, water vapour, and momentum. Tropical cyclones form in regions of large loci with low-level vorticity at 950 hPa [20]. So, all factors depend on local climatic conditions. In this research, we have found the probability in every 2 degrees but the fact is not clear. That's why we regenerate the latitude and longitude boxes as 1 degree.

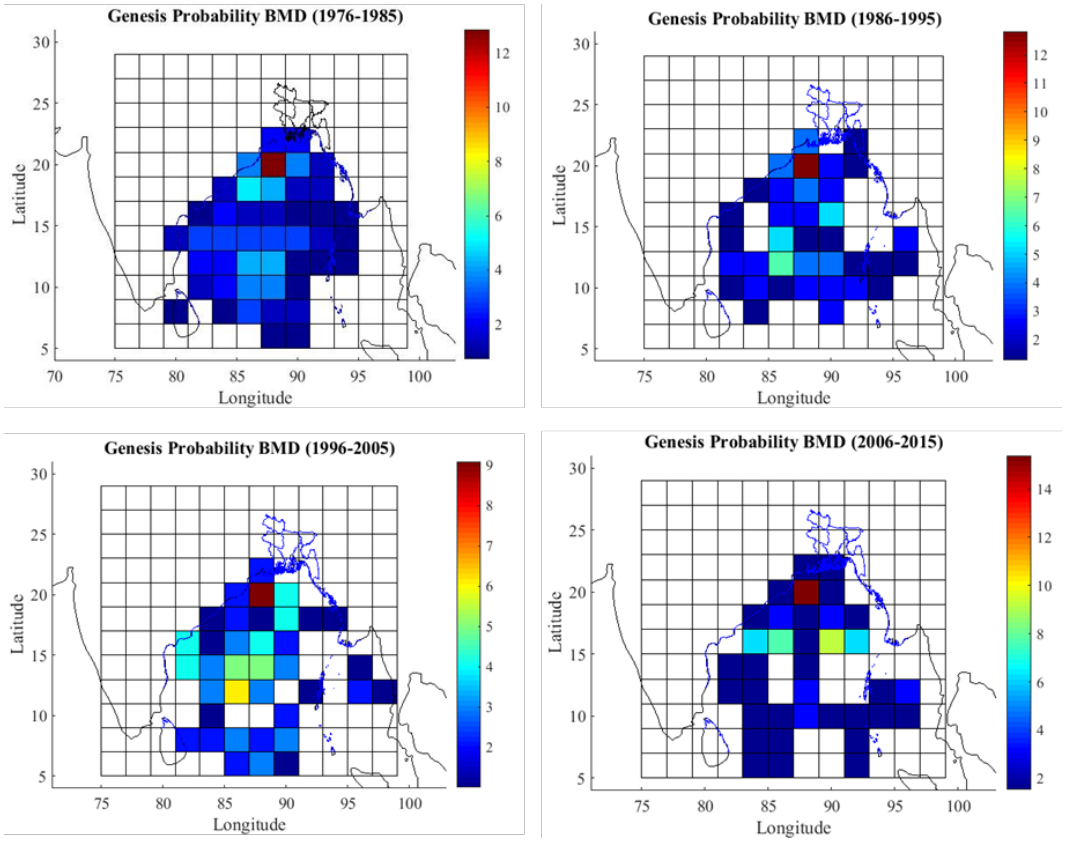

Fig. 5. Behaviour of genesis probabilities at 2 by 2 degrees' latitude and longitude

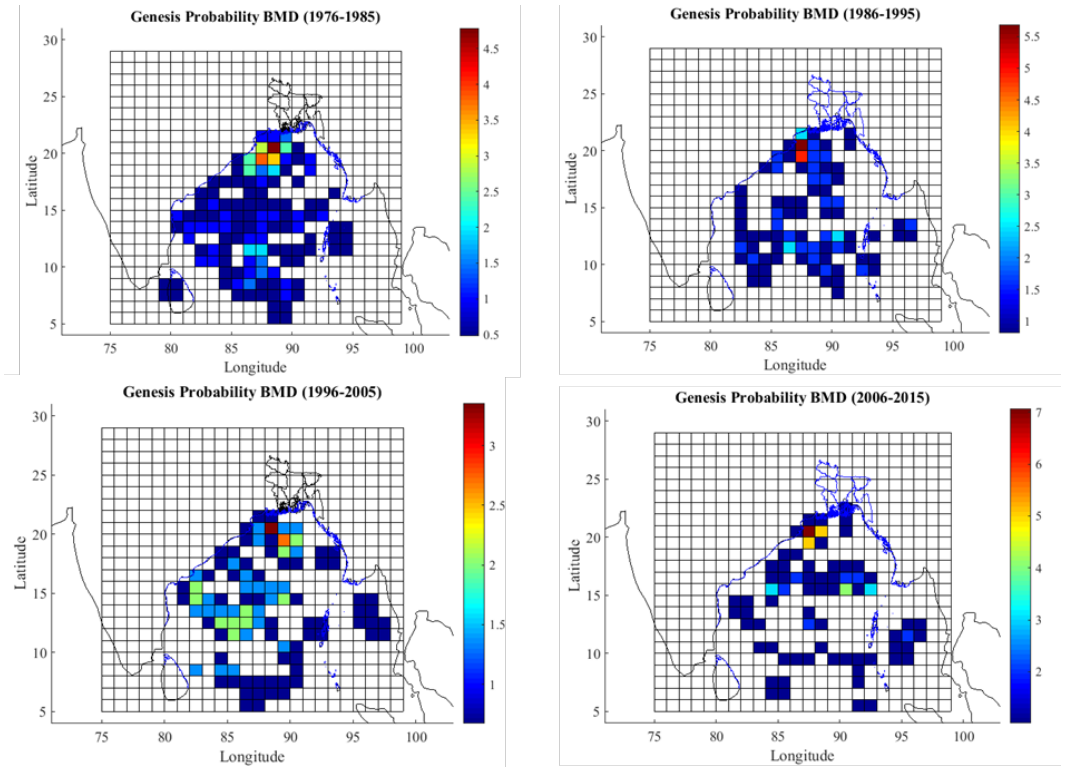

Fig. 6. Behaviour of genesis probabilities at 1 by 1 degree's latitude and longitude

By shifting the latitude and longitude boxes to 1 degree we notice a change in Genesis. As it was in the early 20th century, it changed later. We can see this in Fig. 6. Genesis is slightly modified and moves to the southwest.

4. DISCUSSION

To understand the genesis behaviour of cyclones due to climate change under different scenarios, we separated the cyclone genesis point from the original cyclone track data. The future projection of Gene Point along the Bay of Bengal is presented in Fig. 5 and Fig. 6. This figure shows the location of current climate genesis behaviour along the Bay of Bengal. The figure shows that the origin of the cyclone is found near the central and eastern coast of India for the current climate (initial time) conditions. However, under future climate conditions (last 10 years), the genesis location may change. To understand the probability of the genesis location of each (20×20) latitude longitude area, we have investigated the genesis probable area. From this analysis, it is found that the cyclone genesis potential area will shift in the near future. In the current climatic conditions, the Genesis area is found in the middle of the Bay of Bengal. But, in the near future, it will shift to higher latitudes and the most likely origin location will be found near the east coast of India. Fig. 6 shows the potential for cyclone formation under various current climate conditions. The colour bars indicate the probability of birth in each individual area. Some of the genesis areas outside the Bay of Bengal are due to our selection of the first depression point as the genesis point. Thus, it is clear that climate change affects the generation of cyclones. Future climate will change due to global warming and associated cyclone formation will also change. From the above analysis, we found that the east coast of Indian territory and its adjoining region is the most cyclone formation-prone area. Due to climate change, the genesis area will change.

5. CONCLUSION

This study investigates cyclones and their origin within the Bay of Bengal region. From this study, storms formed in the Bay of Bengal have multidimensional behaviour. The origin of cyclones will shift to higher latitudes and the number of occurrences will decrease under future climate conditions. The current climate shows that the post-monsoon season is a season prone to cyclone occurrence. But, the seasonal behaviour of cyclones will change in the future due to the effects of climate change. However, even if the number of cyclones will decrease in the future, the accumulated cyclone strength will be higher. Which indicates the possibility of dangerous cyclone formation in the region.

Acknowledgments

The first author acknowledges receipt of a project from the University Grant Commission (UGC) of Bangladesh. The first author would like to express his gratitude to the Government of Bangladesh for the project fund during the research period. We would also like to thank the staff of the Department of Mathematics (Islamic University, Bangladesh) for their endless support of laboratory facilities.

Conflict of Interest

The authors declare no competing financial or personal interests that may appear and influence the work reported in this paper.

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