Numerical Study on Rainband of Cyclone Sidr Using a Cloud Resolving Model

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1. Introduction

Bangladesh is located at the northern most point of the Bay of Bengal of Indian Ocean. The funnel shape coast makes the region very sensitive for being affected by tropical cyclone originated in the Northern Indian Ocean. In the last 100 years, 17 percent out of 508 cyclones that formed in the Bay of Bengal landed on Bangladesh (Bhuiyan, 2008). Among them cyclone Sidr of 2007 is one of the ten strongest cyclones for the last 131 years from 1876 to 2007 (Hasegawa, 2008). Initially Sidr appeared as a depression near the Andaman Islands of Indian Ocean on 9 November 2007. Over a few days it moved slowly towards north and turned to be intensified gradually and finally hit the coast of Bangladesh on 1430 UTC of 15 November 2007. Cyclone Sidr became a Category-4 class tropical cyclone with a maximum wind speed of 69 m/s and the lowest central pressure of 944 hPa. According to the record of Bangladesh Government, 3,363 deaths, 871 missing, 8.9 million affecting people, 2,472,944 acres crops damage and 3.1 billion US dollars economical loss are the consequences of the devastation caused by Sidr.

Considering the severity of Sidr it is essential to be acquainted with its various parameters, especially its rainband structure and characteristics. For executing this purpose, the numerical model CReSS (Cloud Resolving Storm Simulator) has been used to simulate cyclone Sidr.

2. Model Configuration & Method

CReSS is a three dimensional non-hydrostatic, compressible and terrain following cloud resolving model developed by HyARC (Hydrospheric and Atmospheric Research Center), Nagoya University, Japan (Tsuboki and Sakakibara, 2007). In this study a simulation was performed for the period of 48 hours from 0000 UTC of 14 November to 0000 UTC of 16 November 2007. For domain area selection, the grid resolution is chosen as 2.5 km x 2.5 km x 0.5 km with grid number of 600 x 630 x 60 which cover the area of 1500 km x 1575 km x 30 km (Fig. 1). The initial and lateral boundary conditions are taken from 6 hourly Global Spectral Model (GSM) data with 0.5 x 0.5 degree resolutions provided by JMA (the Japan Meteorological Agency). The daily SST products of 0.25 degree resolution, MGDSST (Merged satellite and in-situ data Global Daily Sea Surface Temperature) of JMA are utilized in the simulation (Sakurai, 2005). The model set up is furnished to get outputs at every 10 minutes interval.

The results of simulation have been verified by comparisons of available radar and rain-gauge data collected from BMD (Bangladesh Meteorological Department) and analysed to find out the features of the rainband of Sidr.

3. Results and Discussion

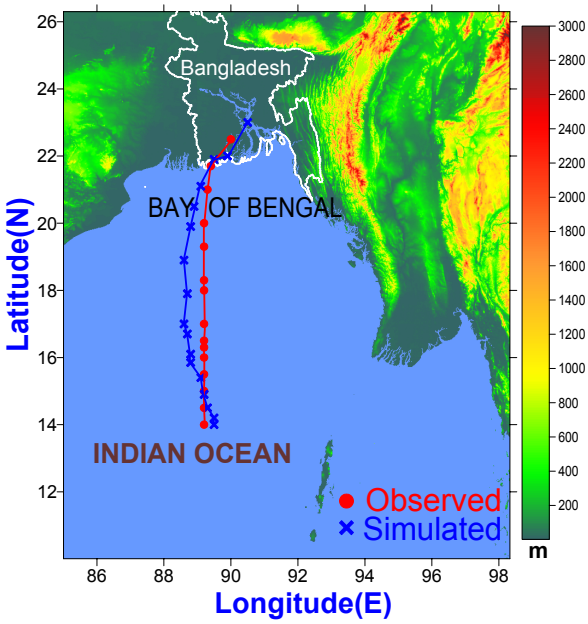

Fig. 1: Model domain with observed and simulated cyclone paths

The line indications shown in Fig. 1 illustrate the assessment of the simulation track of cyclone Sidr with the observed track. On the way of the cyclone path, little deviation occurs but both of them hit the land almost at the same point. The root mean square error (RMSE) of the simulated cyclone position with respect to the observed position is found 70.16 km. The structural comparison of rain fall distribution of Sidr between the simulation and the radar image is displayed in Fig. 2 for the time of 1200 UTC of 15 Nov. 2007.

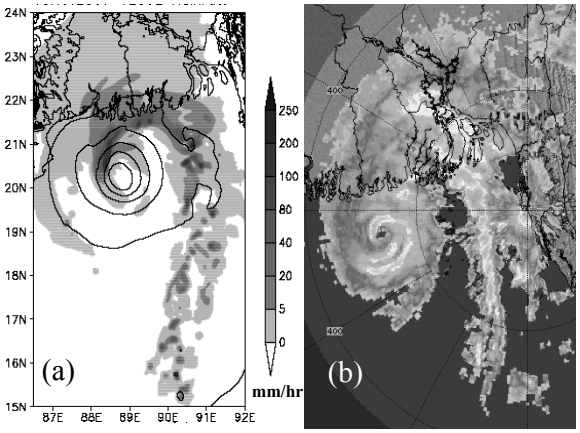

Fig. 2: Rainfall distribution of (a) simulation and (b) radar image at 1200 UTC of 15 Nov. 2007

The figures demonstrate the same configuration of rainband with long tail. Also the averaged rain rate (mm/hr) at 31 rain-gauge stations and the simulated outputs extracted from the same stations are estimated numerically for the period of 0000 UTC of 15 Nov. to 0000 UTC of 16 Nov. 2007 (Fig. 3). Their correlation co-efficient is found as 0.707 which indicates a good level of consistency.

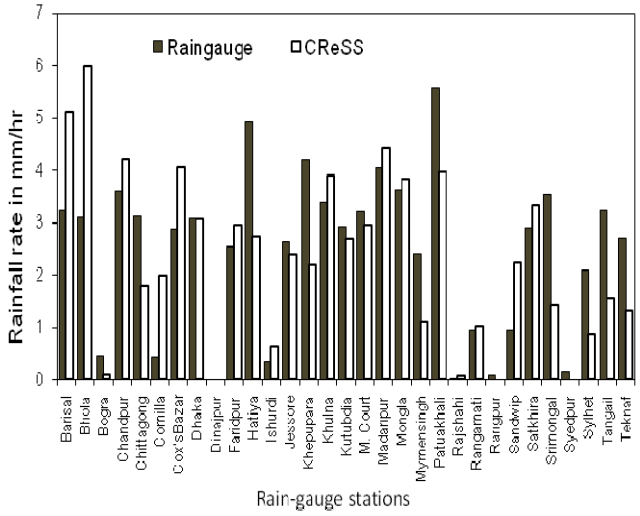

Fig. 3: Comparison of rain rate between 31 rain-gauges and model outputs for the same stations

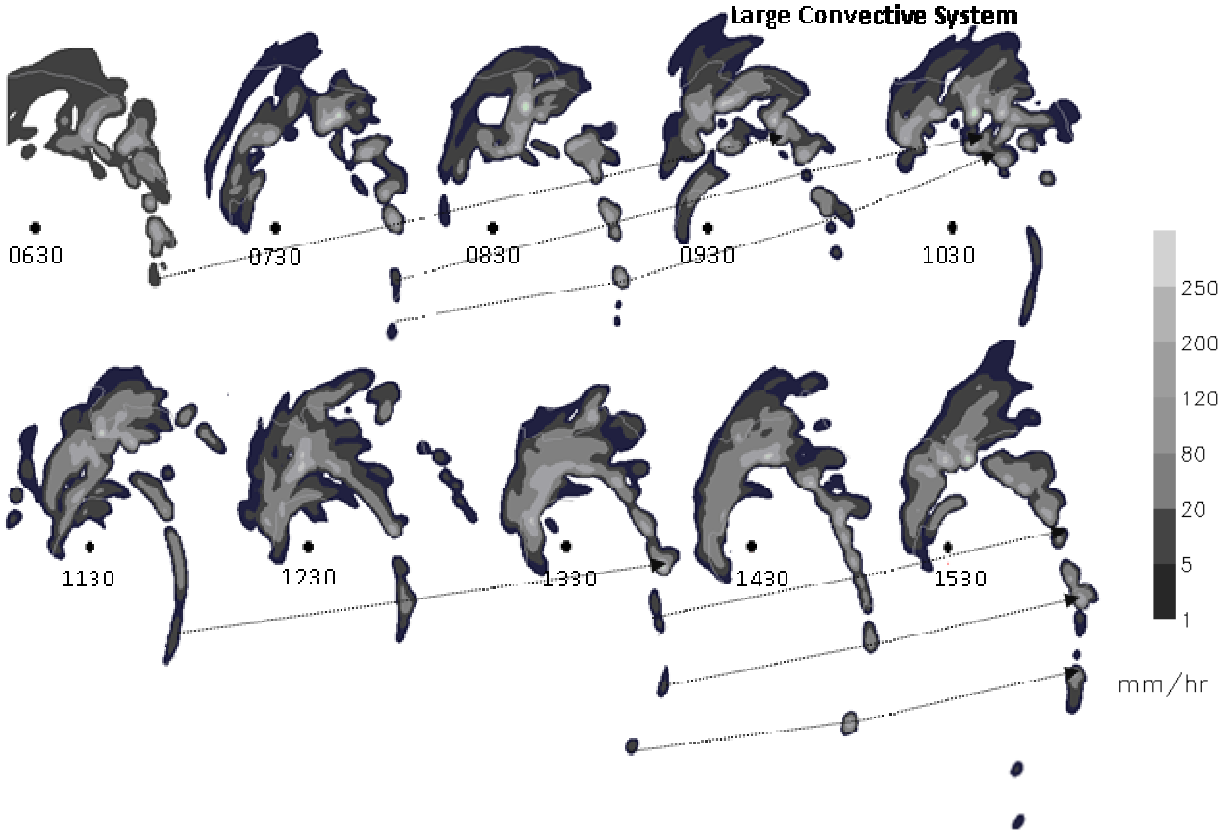

Fig. 4: Simulated rainband at one hour interval from 0630 UTC to 1530 UTC of 14 Nov. 2007

The pattern of the rain band of sidr is found to be different from usual shape. It does not follow properly the shape of the logarithmic or modified logarithmic spiral (Senn *et al*., 1957) of rainband in the tropical cyclone. The formation process and characteristics of the rainband of Sidr having the straight extended tail have been examined in this study.

The simulated rainband of Sidr is analyzed at 10 minutes intervals. Fig. 4 displays some pictures of rainband at one hour interval for convenient which exhibits the features about the rainband of Sidr. That is, this long band consists of a number of convective cells. New convective cells are formed in different location of rainband with respect to time. After formation cells are moving towards the north to join to the large system at north of the band. Band length is also increased with time on the south till landfall.

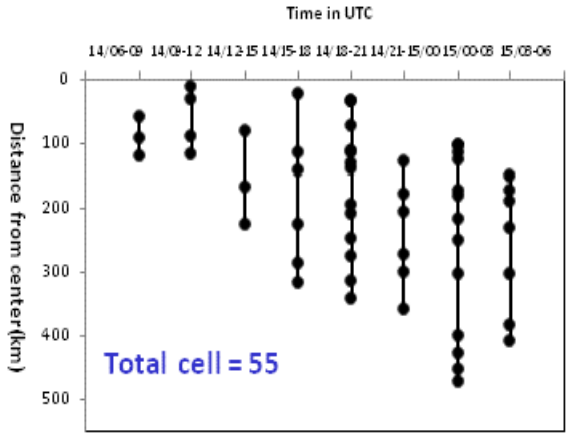

Fig. 5: Rate of cell productions and their positions of formation with respect to center of the cyclone

The formation of cells in the rainband is caused by the convergence of moist southerly with storm motion. This intensifies convective instability in the region of convergence and as a result convective cells are produced. The production rate of these cells and their relative positions of formation with respect to the center of cyclone are observed for 24 hr from 0600 UTC 14 Nov. to 0600 UTC 15 Nov. 2007. Within this 24 hours period of simulation a total of 55 cells are produced. Fig. 5 expounds the rate of cell productions and the relative positions of formation which are irregular and intermittent i.e. they are not produced regularly by time or by place. Most of the cases, the relative positions of formation are found to be shifted away from the center. For the same observation period the speeds (m/s) of the cells are found positive with respect to center of cyclone as displayed in Fig. 6. Hence they move upwards overtaking the eye and finally join up to the large precipitation system to the north of the cyclone center.

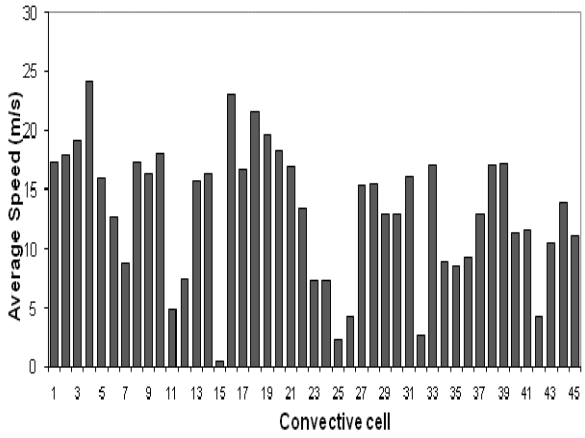

Fig. 6: Average speeds of the cells

Therefore, the movement of the cells to the north makes the elongation of rainband impossible but the production of new cells and their relative positions of formation increase the length of the rainband of Sidr.

4. Conclusion

The socio-economic structure of Bangladesh is severally affected by the furiousness of cyclone Sidr of 2007. Sidr has been simulated by the numerical model CReSS to make out the characteristics and formation process of rainband. In this study, the validations of simulation are found quite well with comparison of the available observed data. In the rainband of Sidr, irregular formations of convective cells with respect to time and place are caused by the effect of the convergence of moist southerly. Even though these cells are found to move northward the length of rainband is elongated over the time towards the south. This happens because of the subsequent productions of cells and their relative positions of formation which are produced far away from the center with time. As a whole, the cell production, their locations and their speeds make a straight longer rainband of Sidr.

Acknowledgements

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