SIMULATION OF CHARACTERISTICS OF PRECIPITATION SYSTEMS DEVELOPED IN BANGLADESH DURING PRE-MONSOON AND MONSOON

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ABSTRACT

In Bangladesh (88.05–92.74°E, 20.67–26.63°N) arc- and scattered-type systems dominate during pre-monsoon and monsoon periods respectively. Due to lack of observational data simulation is one of the ways to reveal the characteristics of precipitation systems. An arc-type system of 26 April 2002 is simulated. In this study National Center for Atmospheric Research Mesoscale Model (NCAR MM5) is used to simulate precipitation systems. The model is set for three domains of horizontal grid resolution 45km, 15km and 5 km. Radar observed characteristics such as shape, length, propagation speed and direction of pre-monsoon arc-type system is simulated well. Simulation shows that the precipitation system is asymmetric squall line type of length 535 km and speed 8 m/s, and propagates south-eastward at the mature stage. Younger and more intense cells are formed at the south-western end of the system. The cells move north-eastward becoming stratiform. The north-eastern end of the system moves faster than south-western end due to cold pool which is formed in the stratiform region. Simulation of monsoon scattered-type system is yet not succeeded. Reasons of the failure to simulate monsoon scattered-type system are discussed.

Keywords: *Characteristics of precipitation systems, Bangladesh, Pre-monsoon, Monsoon, Simulation, Radar data.*

1. INTRODUCTION

Bangladesh (88.05–92.74°E, 20.67–26.63°N) receives heavy rainfalls causing flood and about one fourth to one third of the country is flooded each year for long periods during the monsoon season. The development mechanisms of the precipitation systems that bring heavy rainfall to this region are very important for understanding the variation of characteristics of monsoon precipitation systems associated with climate change. A precise understanding of the distribution and characteristics of precipitation systems is also helpful for disaster prevention and water management for agriculture-dependent countries such as Bangladesh.

Statistical analysis of six years (2000-2005) Bangladesh Meteorological Department's radar data revealed that fast moving arc-type precipitation system dominates in pre-monsoon and slow moving scattered-type system dominates in monsoon period (Rafiuddin et al., 2007). The arc-type system is usually associated with severe thunderstorm and produces intense rain and strong wind over small areas mainly in pre-monsoon, which sometimes results severe damage. Scattered-type system produces light rain over a wide area for long time. This type of system contributes a large amount of the accumulated rain during monsoon period which sometimes results flood or flash flood. It is well known that precipitation system has high spatial and temporal variation. Since this radar operates one hour in only single elevation angle with two hours pause and dose not operate at late night. So due to lack of continuous radar observational data the characteristics of precipitation systems are still unexplored in Bangladesh, which are also essential for disaster prevention, flood forecasting and water management. Numerical simulation is an effective process to study the characteristics of precipitation system. Mesoscale models have been developed with flexibility in terms of altering horizontal and vertical resolutions, nesting domains and choosing appropriate options for different physical parameterization schemes. By selecting some important parameters appropriately, these models can be used in a wide range of applications, including the characteristics of precipitation systems.

To know the characteristics of the precipitation systems simulation is made by using Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) mesoscale model (MM5) with finest horizontal grid increment of 5 km.

2. MODEL

The PSU/NCAR mesoscale model (MM5) (Dudhia, 1993) was used to simulate the precipitation systems. The MM5 is a nonhydrostatic, fully compressible three dimensional primitive equation model with a terrain following sigma (non-dimensional pressure) vertical coordinate, and Arakawa-B horizontal grid staggering. The MM5 uses a split semi-implicit temporal integration scheme and contains prognostic equations for the three wind components, temperature and water-vapor mixing ratio. Japanese 25-year Reanalysis (JRA-25) data of resolution 1.25 degree and NCEP Reynolds week mean SST data were used for initial and boundary conditions of PSU/NCAR mesoscale model (MM5) simulation. MM5 run was made for 3 domains (D1, D2 and D3, Fig. 1) with the horizontal grid increment of 45 km, 15 km and 5 km respectively. The vertical resolution was 23 sigma levels. Lambert Conformal (LAMCON) projection is used in Grell (Grell, 1993) scheme convective parameterization with shallow cloud option. The explicit moisture scheme was simple ice (Dudhia, 1989) and Medium Range Forecast (MRF) for Planetary Boundary Layer (PBL) (Hong and Pan, 1996) was used. MM5 simulation started at 0000 LST of April 26, 2002 and continued for 42 hours.

To represent the system in time series a line of leading edge of a system is drawn at the outer boundary of reflectivity. The propagation speed of the system is calculated from the movement of the leading edge at the mature stage. A line is drawn along the leading edge between two subsequent times greater than 30 minutes. A perpendicular line is drawn for the minimum distance between the lines. Latitude and longitude measurements of two intersection points are used to calculate the exact distance and direction of propagation using the formula of Bowring (1996).

3. RESULTS AND DISCUSSION

Simulation is done for pre-monsoon arc- and monsoon scattered-type system. The pre-monsoon arc-type system is simulated well by model whereas monsoon scattered-type is not succeeded. In this article simulation results of finest model domain (D3) for pre-monsoon is discussed in details.

An arc-type precipitation system developed in the north-western part of Bangladesh on 26 April 2002 is selected for analysis. Radar plan position indicator (PPI) shows that the system is developed at 1400 LST and propagates south-eastward. The system is identified until 2350 LST from radar PPI after then radar is not operated. The shape, length and propagation speed and direction are simulated well by model though there are about couple of hour's time delay and location shift of the system.

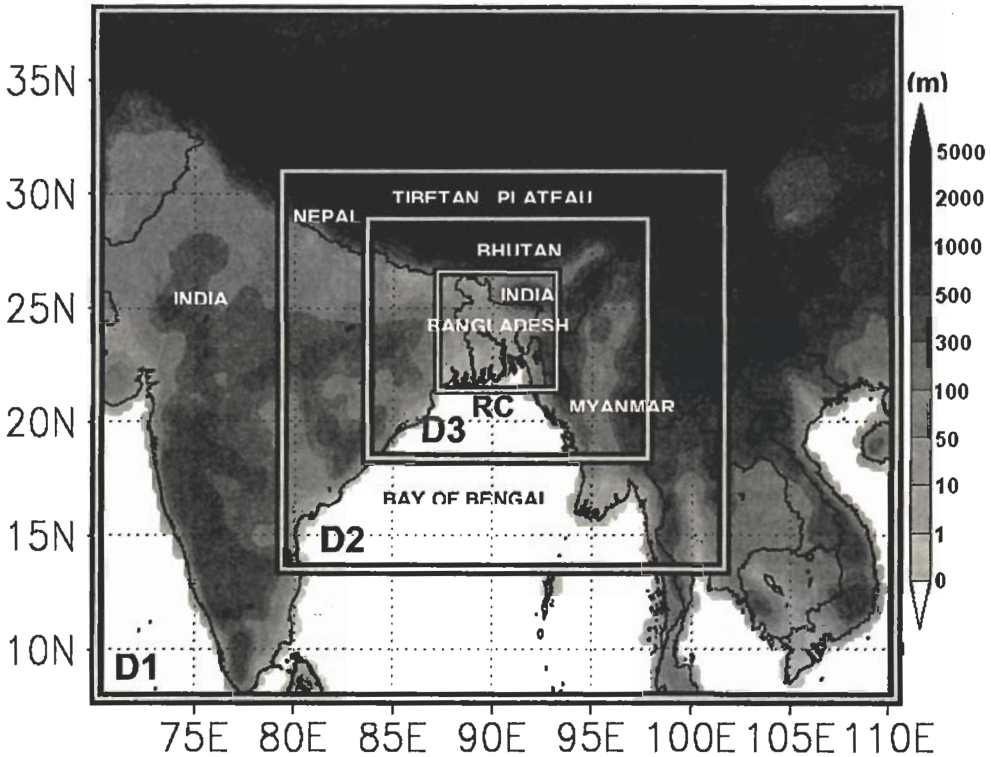

Figure 1: Model domains. D1, D2, D3 and RC indicate areas of domain 1, 2, 3 and radar coverage respectively. Gray shade indicates the topography.

Figure 2 shows the radar observed rain rate and the model simulated reflectivity at initial-, mature- and decaying-stage. From this figure it is clear that model simulates overall horizontal structure of the system. Simulation shows that the characteristics of the precipitation system are similar as that of the asymmetric squall line type introduced by Houze (1993). The system is oriented south-west to north-east direction. The younger and more intense cells are formed at the south-western edge of the system. The decaying cells which becoming stratiform are found in the north-eastern side of the system. This type of system is associated with severe thunderstorm and produces intense rain and strong wind over small areas. Severe weather in the form of hail and tornadoes is more common with asymmetric systems, in which new cell formation is preferred on one (typically south) end of the line, and decaying cells accompanied by a larger stratiform region are found on other (Jewett et al., 1998). The relative humidity ahead of the leading edge of system is very high throughout its life time (not shown). This humidity is carried by the low level south-westerly wind from Bay of Bengal. The relative humidity behind of the system is less and its area extended as system progress from initial to decaying stage (not shown).

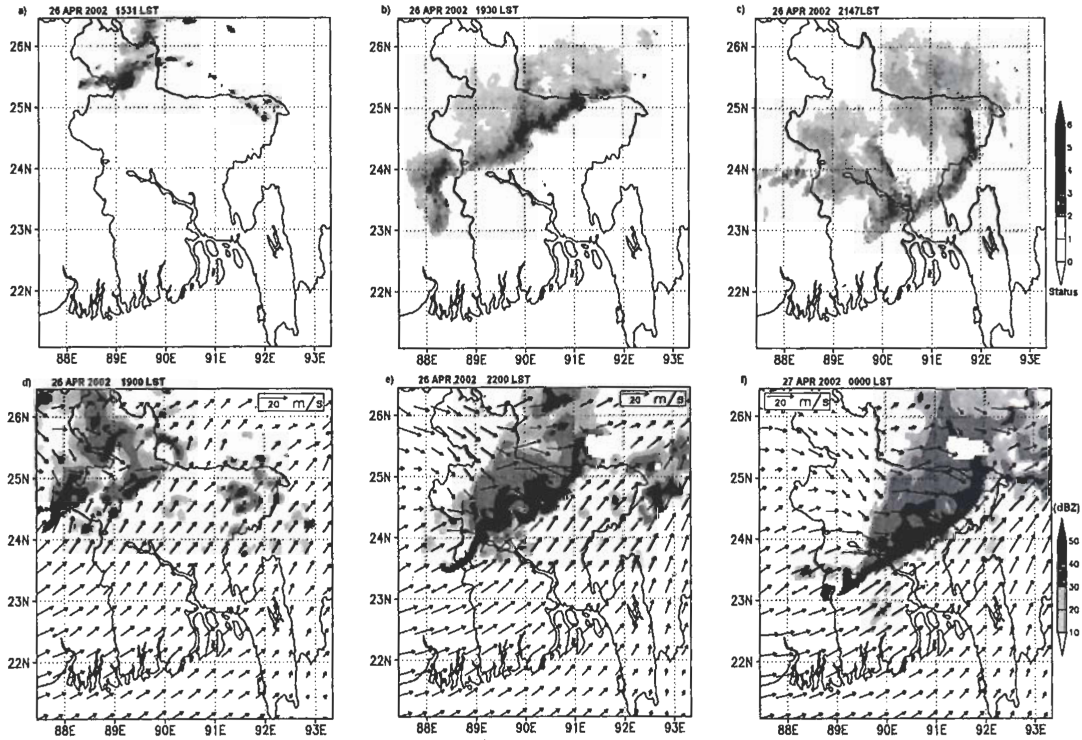

Figure 2: The upper panel shows the radar observed arc-type precipitation system on 26 April 2002 at a) 1531 LST (initial stage), b) 1930 LST (mature stage) and c) 2147 LST (decaying stage). The lower panel shows the model simulated reflectivity (shade) and wind (vector) at a) 1900 LST (initial stage), b) 2200 LST (mature stage) and c) 0000 LST of 27 April 2002 (decaying stage). The reflectivity and wind are at 850 hPa level.

Figure 3 shows the time series of the leading edge of precipitation system. The simulated system's propagation direction and area coverage throughout its life time are close to radar observation. The north-eastern end of system moves faster than south-western end. The characteristics such as length, propagation speed and direction of mature stage are shown in Table 1.

Table 1: Radar observed and simulated characteristics of the precipitation system

Characteristics	Radar	MM5
Propagation speed	8.0 m/s	8.0 m/s
Length	543 km	535 km
Propagation direction	South-East	South-East

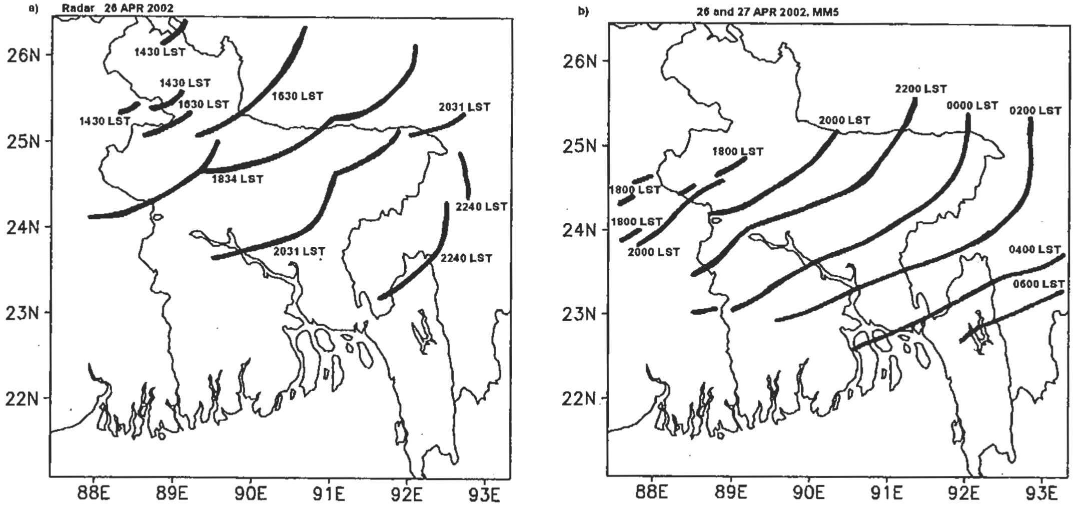

Figure 3: a) Radar observed time series (two hours interval) of leading edge of the system and b) same as a) for model. The lines are drawn at the outer boundary of leading edge of the system.

Figure 4 shows model simulated temperature and wind distribution. In this figure contour represent the reflectivity (above 45 bBZ only) of system at the same time. The temperature in south-western side is higher than that of north-eastern side on both time at 2200 LST of 26 April 2002 and 0000 LST of 27 April 2002. The low temperature area is extended at 0000 LST of 27 April 2002 (Fig. 4b) especially behind of the system in north-eastern end compared to 2200 LST of 26 April 2002. The stratiform area is extended and temperature falls at the north-eastern end of system with progress of time. Due to this reason the cold air mass at this end pushes strongly and the end moves faster than of its south-western end.

Pre-monsoon arc-type system is usually developed due to interaction of hot dry air and worm moist air in presence of strong vertical wind shear at the north, north-western part of Bangladesh. The low level south-westerly wind carries this warm moist air from Bay of Bengal and hot dry air comes from India. The cold air mass is formed behind of the system due to formation of cold pool. The cold air pushes the system to propagate south-eastward. This arc-type system usually does not reach coastal region of the country due to low level south-westerly wind. The stratiform area is extended in the north-eastern side which helps for clock wise rotation of the system. The arc-type system is tall and fast moving and usually associated with severe thunderstorms known as "Kal-baishakhi" or "Nor'westers" in Bangladesh. These types of system produce intense rain and strong winds over small areas, which can result in severe damage.

During monsoon abundance moisture is supplied by monsoonal wind and not well organized scattered-type system is developed in presence of little or no vertical wind shear. In presence of very high humidity and very weak convergence, systems are formed due to very small disturbance during monsoon. Model can not generate system in such conditions. Scattered-type system contributes a large amount of the accumulated rain during the monsoon period. This type of system generally has a low rain rate but covers a wide area, moves slowly, and persists for a long time. To explain details about the formation and development processes high resolution model is necessary. High resolution model has the capability to well reproduce the dynamical and thermodynamical atmospheric processes.

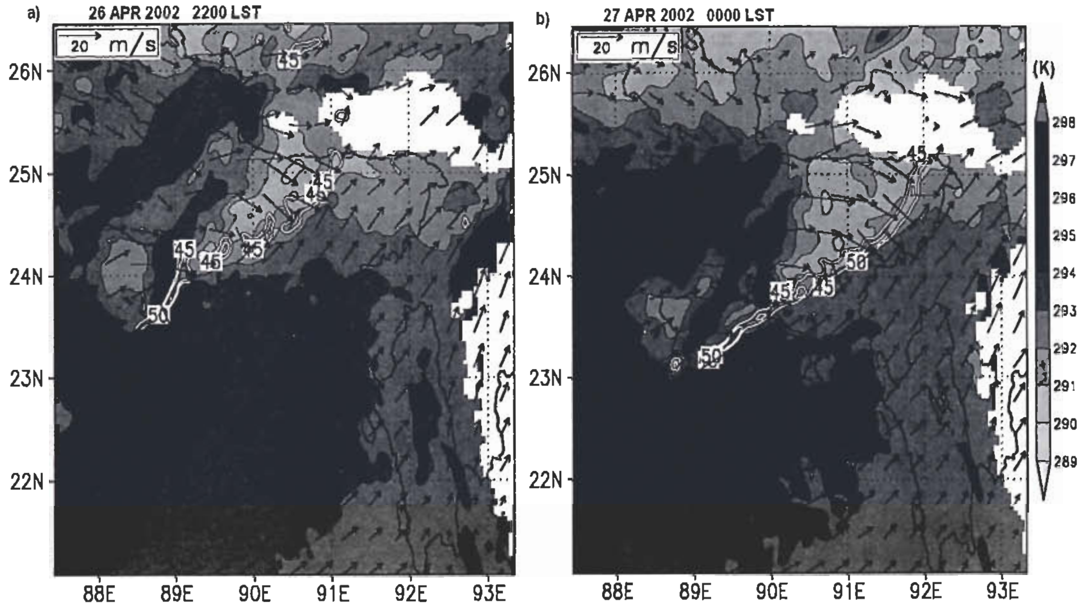

Figure 4: The model simulated temperature (shade), wind (vector) and reflectivity (contour, above 45 dBZ) on a) 26 April 2002 at 2200 LST and b) 27 April 2002 at 0000 LST. The temperature at 925 hPa level and wind and reflectivity at 850 hPa level.

4. CONCLUSIONS

The radar observed pre-monsoon arc-type system of 26 April 2002 in Bangladesh is simulated well by MM5. The simulated characteristics such as shape, length, propagation speed and direction are very close to radar observation. The new and intense cells of the asymmetric squall line are developed in the high temperature south-western region. The low level south-westerly wind brings warm moist air from Bay of Bengal help to develop new cells. The dying cells extended their areas and become stratiform in the low temperature north-eastern region. The north-eastern end of the system moves fast due to the strong rear to front cold flow from the extended stratiform region.

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