Numerical experiments on the late night-early morning maximum of rainfall in the northeastern Bangladesh

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ABSTRACT

Numerical experiments over the Bengal region were conducted by using MM5. The experiments were performed during 14th - 21st June 1995 included the active period when the rainfall amount was above normal over Bangladesh. We focused on the northeastern Bangladesh where the late night-early morning maximum of rainfall was observed by using the data from rain gauges and radar in Dhaka.

At first, the diurnal variation of Ic (convective index) and 3 hourly precipitation of the model results were investigated to check the reliability of the model results. Ic had a peak around 06 LT - 15 LT which was about 3 hours later than that of precipitation. According to previous paper, this time lag between Ic and precipitation indicated that the model results agreed with Ic. The characteristics of the simulated precipitation and equivalent potential temperature (θ_e) from late night to early morning well agreed with those of squall line. Compared with the results without northern mountains, it's considered that the low θ_e area in the region framed in by northern and eastern mountains affects the lifecycle and movement of the precipitation system.

Keywords: Bangladesh, late night-early morning rainfall, diurnal variation, topography, squall line

1. Introduction

Bangladesh is one of the heaviest rainfall regions in South Asia. Climatic rainfall over Bangladesh is about 6000 mm during summer monsoon in some regions. Especially northeastern Bangladesh has much rainfall, where the late night-early morning maximum rainfall was observed by rain gauges and the radar in Dhaka. (Ohsawa et al., 2000, 2001; Terao et al., 2002; Islam et al., 2004). They suggested that the late night-early morning maximum is associated with the Shillong Plateau, east-west elongated mountainous range whose highest peak is about 2000 m located right in the north of the late night-early morning maximum rainfall region. Though the Shillong Plateau was suggested to work as a barrier to the southwesterly monsoon wind, the mechanism of the late night-early morning maximum rainfall is still not fully understood. The purpose of our study is to understand the mechanism of the late night-early morning maximum by using a numerical model.

2. Model

For numerical experiments, we used the PUS/NCAR mesoscale model (MM5). NCEP-Reanalysis2 data and NCEP weekly SST data were used for the input data. The model domains are indicated Fig. 1. Domain 1 was the mother domain, domain 2 was two-way nested with domain 1 and domain 3 was one-way nested with domain 2. The analyzed period was 16th - 21st June 1995 which included the active period when the rainfall amount was above normal over Bangladesh.

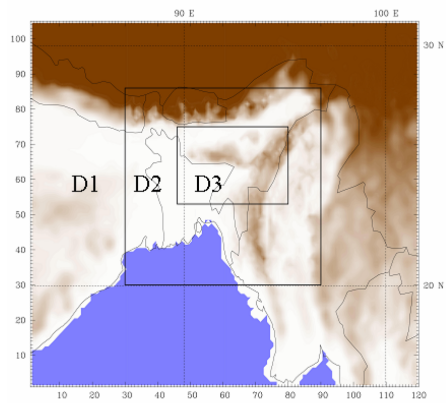

Fig. 1: Model domains

3. Results

Results of domain 3 are shown because we focused on the northeastern Bangladesh.

3.1 Diurnal variations of convective index and 3 hourly rainfall

In order to check the model result, the activities of deep convective clouds derived from hourly GMS IR1 Tbb data was used. We used the following index Ic defined by

$$
\begin{aligned}
Ic &= 230 - Tbb &&: Tbb \leq 230\ \mathrm{K}\\
&= 0 &&: Tbb > 230\ \mathrm{K}.
\end{aligned}
$$

Mean diurnal variation of 3 hour averaged Ic was compared with 3 hourly rainfall of model results

Fig. 2 shows the mean diurnal variation of 3 hour averaged Ic. Looking at the southern foot of the mountain, Ic had a peak around 06 LT – 15 LT. Fig. 3 shows the mean diurnal variation of 3 hourly rainfall of the model results averaged above 3 mm/3 h. The peak of the rainfall in the southern foot of the mountain was around 03 LT – 12 LT. The time lag between Ic and 3 hourly rainfall was about 3 hours. Because Ic has a peak a few hours later than that of rain (Nitta and Sekine 1994)., the model result described above agreed with that of Ic in the southern foot of the mountain. The model well simulated the precipitation from late night to early morning found in the previous studies.

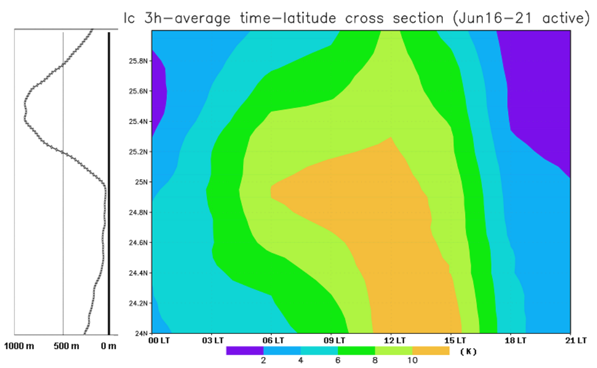

Fig. 2: Mean diurnal variation of 3 hour averaged Ic (time-latitude section). The values were averaged 16th - 21st June 1995 and from 90.5 E to 93.5 E. The left figure is the terrain averaged from 90.5 E to 93.5 E.

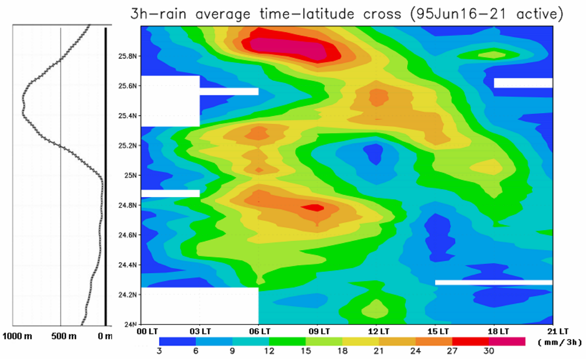

Fig. 3: Same as Fig. 2, except mean diurnal variation of 3 hourly rainfall of the model results averaged above 3 mm/3 h.

3.2 Hourly rainfall and equivalent potential temperature of the model results

Fig. 4 shows hourly rainfall from 00 LT to 07 LT 17th June 1995. Around midnight, precipitation appeared right south foot of Shillong Plateau. The intensity of the precipitation became stronger and the precipitation area became to a line form until around 03 LT. The precipitation area broadened southward and the south tip of the area formed an arc over early morning. The intensity of the precipitation weakened after 06 LT.

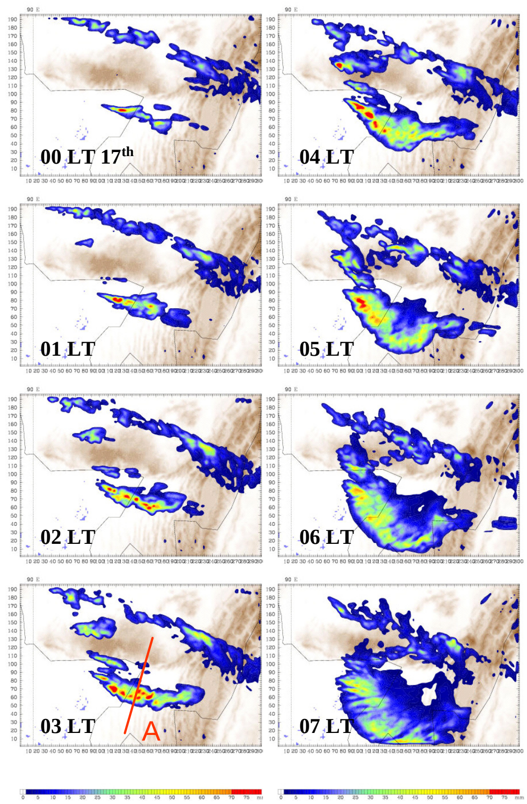

Fig. 4: Hourly rainfall of the model results from 00 LT to 07 LT 17th June 1995 (domain 3).

Fig. 5 shows the vertical cross section equivalent potential temperature (θ_e) cutting along line A in Fig. 4. In the vicinity of surface, a low θ_e area was found in the southern side of mountain. Low level high θ_e air ran into and advected upward on the low θ_e air. Strong upward flow existed in the boundary of these two air masses. In the north of the strong upward flow, downward flow with low θ_e air was simulated. It seems that the low θ_e area descended from middle level (around 7 km) to the surface. This downward flow divided into northward and southward at the surface. The boundary of the low and high θ_e moved southward about the speed of 10 m s^{-1} from 03 LT to 04 LT (not shown). These characteristics were consistent well with those of squall line.

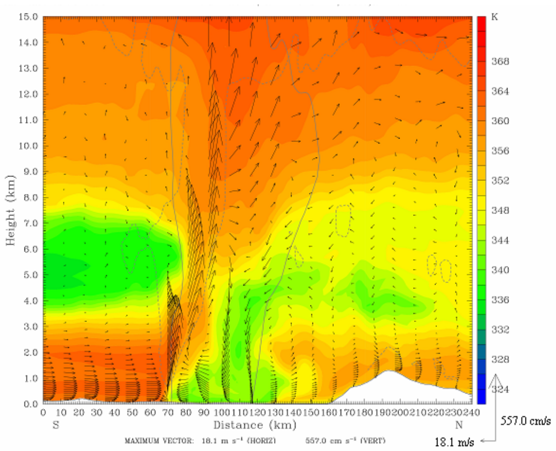

Fig. 5: Vertical cross section of θ_e averaged 20 km each side of line A in Fig. 4 at 03 LT 17th June 1995 (color contour). Vector shows wind in the direction of parallel to the cross section. The solid and dashed line shows 1g kg^{-1} of precipitation hydrometeor mixing ratio and 0.1 g kg^{-1} of cloud mixing ratio, respectively.

Fig. 6 shows horizontal cross section of θ_e at the altitude of 100 m. At 00 LT 17th June, before the precipitation area formed in a line, a low θ_e area existed in the south of the mountain. From 03 LT to 06 LT when the intensity of precipitation became strong, lower θ_e area appeared and broadened in the region framed in by northern and eastern mountains. Since a low virtual potential temperature area was well consistent with the low θ_e area, the cold air existed in this concave space when precipitation became heavier (not shown). At 09 LT when precipitation weakened, the contrast of high and low θ_e area became weak.

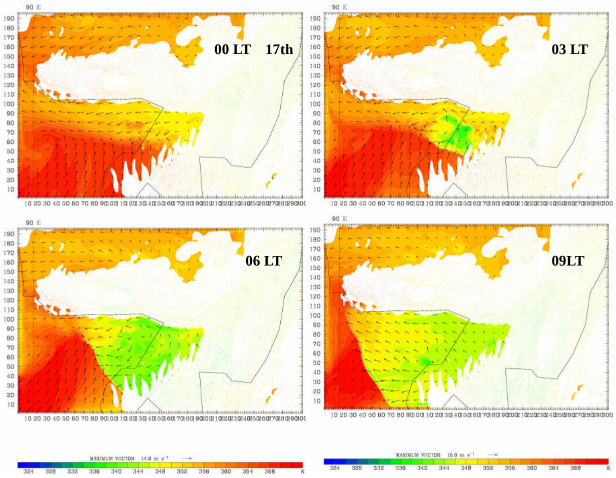

Fig. 6: Distribution of θ_e at the altitude of 100 m from 00 LT to 09 LT 17th June 1995

3.3 Sensitivity to the Shillong Plateau

To compare with the results of realistic terrain (control run), we ran the model using terrain taken off the Sillong Plateau. Fig. 7 shows hourly rainfall of the model result without Shillong Pleateau every 3rd hour. Precipitation existed around the northeastern Bangladesh-Indian border and moved southward similar to model results in the control run. The precipitation area was almost the same as that of control run at 06LT. The areas were, however, located in the north of the results of control run at 00 LT and 03 LT. This result indicated that Sillong Plateau plays an important role in the lifecycle and movement of the precipitation. The line shaped precipitation area was not clear in this no plateau case.

Fig. 8 shows the horizontal cross section of the θ_e at the altitude of 100 m. At 03 LT, the low θ_e was located almost the same place as the precipitation area, that was north of the control run. From 06 LT to 09 LT the low θ_e area stayed concave space as in Fig. 6 and also low virtual potential temperature area existed there (not shown). These characteristics indicate that the concave space has somewhat important role on the lifecycle and movement of the precipitation.

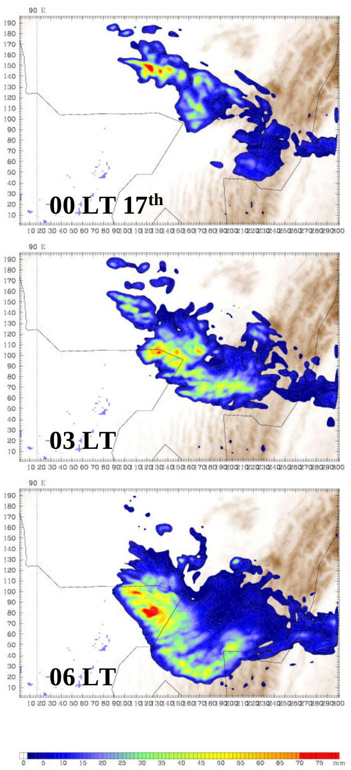

Fig. 7: Hourly rainfall of the model results without Shillong Plateau 00 LT, 03 LT and 06 LT 17th June 1995 (domain 3)

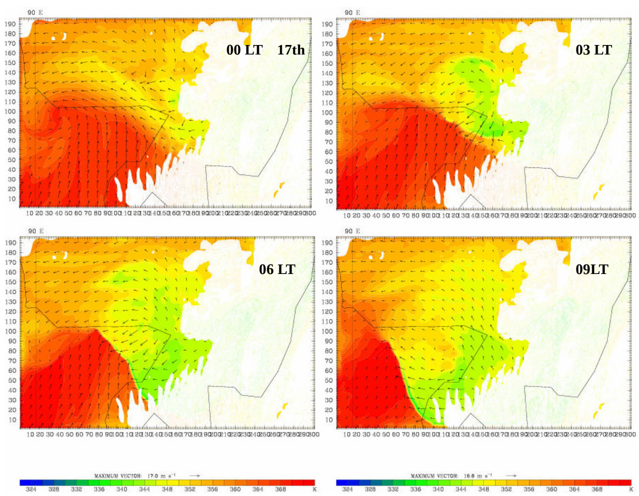

Fig. 8: Same as Fig. 6, except the results using the terrain without Shillong Plateau

4. Conclusion and discussion

Though the study using the radar in Dhaka (Islam, 2004) didn't suggested precipitation in the northeastern Bangladesh came from squall line, the simulated results indicated squall line system. The results of the radar were averaged over one month or one summer monsoon period, additionally time resolution was 3 hour (not observed 03 LT). Therefore the lifecycle and movement of the precipitation hardly recognized.

It is necessary to make a more frequent observation than one hour interval.

The model results successfully simulated the late night-early morning maximum rainfall. The simulated results agreed with Ic.

It is suggested from this study that

1) Squall line system produced the precipitation from late night to early morning in the northeastern Bangladesh (Fig. 4, 5).

2) Shillong Plateau and the concave space framed in by northern and eastern mountain possibly affect the lifecycle and movement of the precipitation (Fig. 6-8).

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