Diurnal variation of the atmospheric vertical structure over Bangladesh region observed by rawin sonde intensive observation

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ABSTRACT

Diurnal variations of convective activity and the atmospheric vertical structure were investigated using BMD (Bangladesh Meteorological Department) radar and intensive rawin sonde observation which was specially designed to resolve the diurnal variation. From the radar image in 2001 summer (16-18 July), clear and systematic diurnal variation was found in the convective activity over this country. In these two days, the evolution of convective activity was strikingly similar to each other. From the rawin sonde observation, averaged pattern of diurnal variation of the atmospheric vertical structure was obtained. The water vapor in the lower troposphere tended to be maximum in the midnight and be minimum in the daytime, while the temperature tended to be maximum in the late afternoon. The lower layer wind direction observed by rawin sonde was consistent with the location of the diurnal movement of convective activity.

1 Introduction

In the boreal summer monsoon season, South Asia is one of the heaviest rainfall region in the world. Especially over the norther part of Bay of Bengal and Meghalaya-Assam region, extraordinary large amount of rain falls (Matsumoto, 1988). This rainfall produces huge diabatic heating which induce the Asian summer monsoon circulation(Luo and Yanai, 1983). It is important to clarify the mechanisms of the rainfall over this region.

One of the most essential features of the rainfall over this region is the diurnal variation. Ohsawa et al. (2001) investigated the diurnal variations of convections over various Asian summer monsoon regions. Over the northeastern Bangladesh region, rainfall maximum is observed in the midnight at about 03BST, while it is afternoon at about 14BST over the southwestern part of the country.

Recently in 2000, two more radars installed at Dhaka and Rangpur which cover central to northeastern and northern part of this country, respectively, provide us good information on the evolution of convective activity over this area. In **2**, using these radar data, a typical example of the diurnal variation of convective activities will be shown.

It is needless to say that seeking the origin of the water vapor should be a key to understand the south Asian monsoon rainfall. Over the Bangladesh and Meghalaya-Assam region, water vapor inflow from the Bay of Bengal can be an important source.

To clarify the physical process of the diurnal variation, the upper layer observation resolving the diurnal variation is essentially important. However, usually the operational rawin sonde observation at Dhaka is only once a day. Therefore, from 1999, we have been performing 4 to 8 times daily rawin sonde observations at Dhaka in the summer monsoon season. In the present study, the diurnal variation of the atmospheric vertical structure will be shown with 2000 and 2001 data. Preliminary results of analysis using 1999 data have already been mentioned in Terao et al. (2000). In **3**, the intensive upper layer observation over Dhaka is analyzed.

Local time at Bangladesh (BST) is mainly used in this presentation. It advances 6 hours than GMT.

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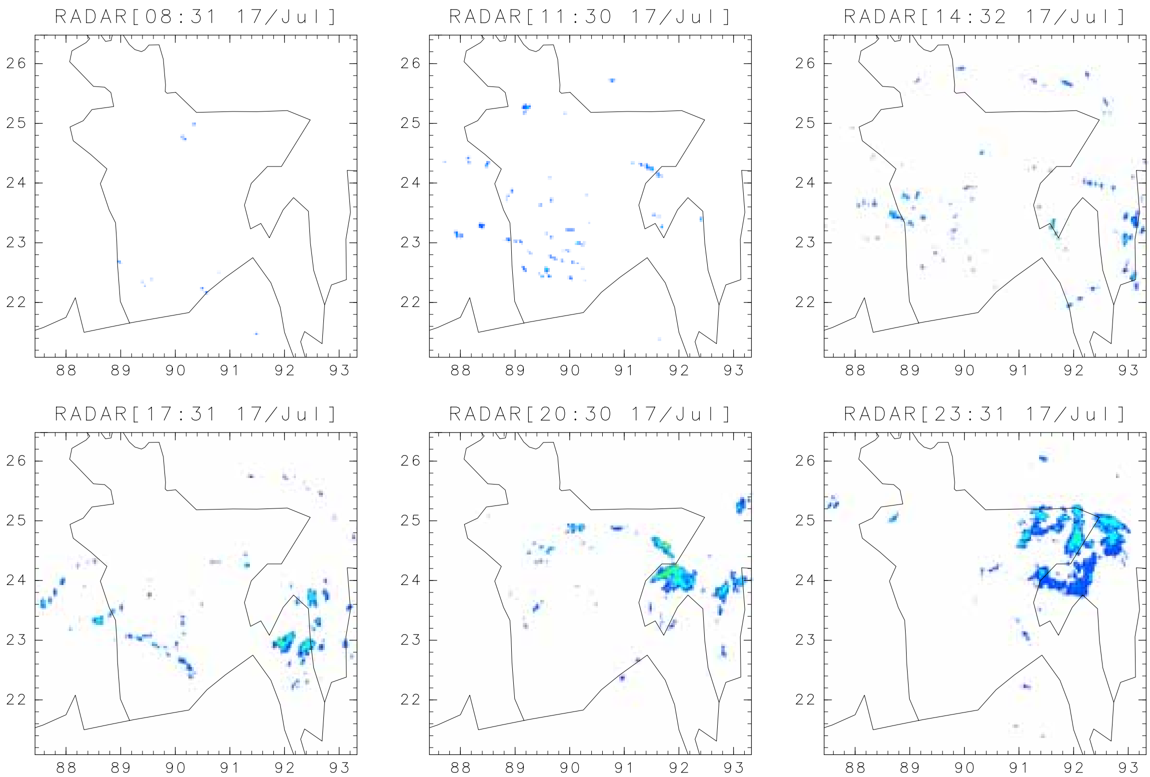

Fig. 1: Almost three-hourly BMD Dhaka radar images for 17 July 2001. Local times of observation are indicated on the top of each figure. Coast lines and border lines are indicated by thin lines. Vertical and Horizontal axes are the latitude and longitude, respectively.

2 Diurnal variation of the convective activity

In this section, a typical example of the diurnal variation of the convective activity over the Bangladesh region will be shown with data obtained from Dhaka radar. The radar is installed in spring 2000. Usually it is performed for one hour in every three hours like this; from 5 to 6, from 8 to 9, from 11 to 12, ... and from 23 to 24 in BST. It scans at about every three minutes.

Figures 1 and **2** show typical cases of diurnal variations appeared in radar images. The pattern of the temporal evolution of radar echo in these two days are strikingly similar to each other.

At 8:30 in the morning, few echoes are found in these radar images. From 11:30 to 17:30, over the region from the West Bengal in India to western part of Bangladesh covered by scattered small radar echoes. They seem to be organized gradually, and decay in the evening before 20:30.

On the other hand, over the eastern part of the image, some large organized disturbances tend to develop from afternoon to midnight. Some scattering echoes appear 14:30. It rapidly organized into two large echoes over the Rangamati region in the southeastern hilly part of Bangladesh (23°N, 92°E) at 17:30. The location and shape of these echoes are almost the same for these two different days. Three hours later (20:30), other organized convections appear over north to northeastern part of the country. This disturbance is characterized by rain-band-like shape oriented west to east. It locates about 50km south of the Meghalaya mountains (25-26°N, 90-93°E), and the band seems to be along the topography. At the midnight (23:30), radar echo is intensified and spreads over the area in the northeastern most part of this country (24-25°N, 91-93°E). Over the Meghalaya mountains, some echoes develop mainly only in the afternoon (14:30).

This diurnal variation over the Bangladesh is consistent with the result shown by Ohsawa et al. (2001) using rain gauges and IR images of GMS. Radar data shows that, over the southwestern part of the country, scattering echoes appear mainly from late morning to the afternoon. This corresponds to the maximum convection time detected by Ohsawa et al. (2001) over the southwestern part of Bangladesh and West Bengal. Just south of the Meghalaya mountains, strong radar echoes are found after late evening until midnight. Ohsawa et al. (2001) also pointed out that the maximum convections are found midnight over

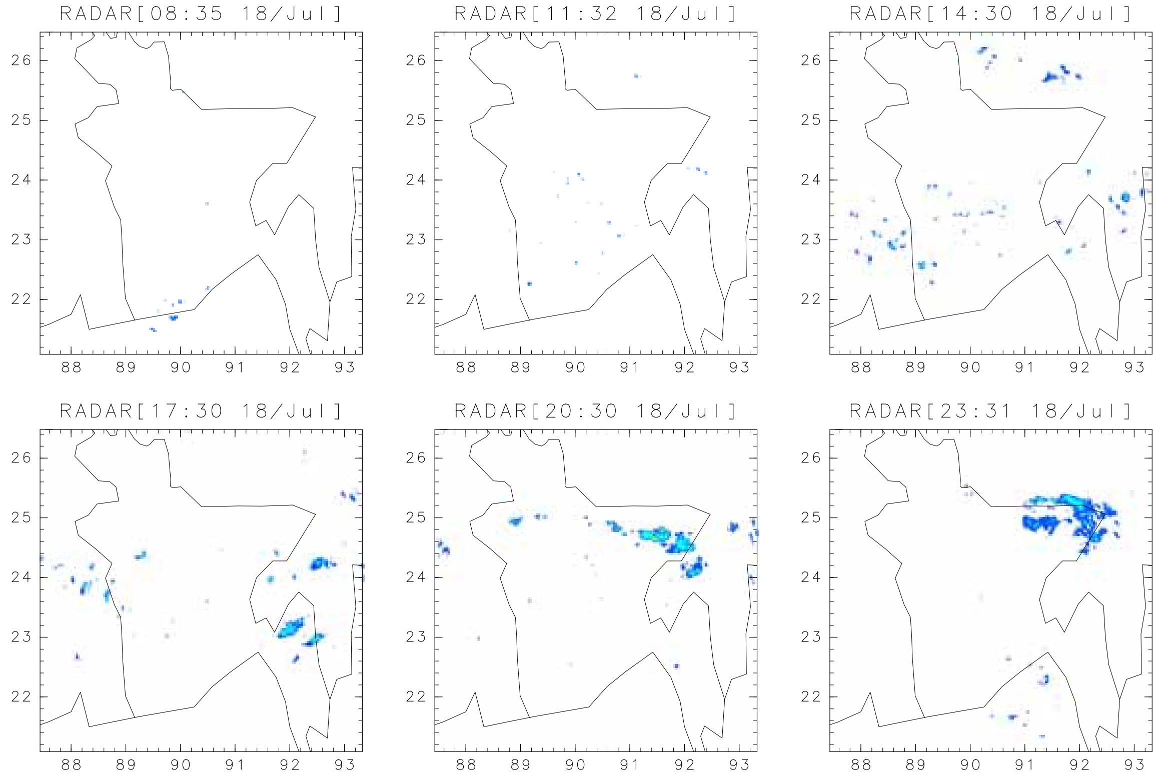

Fig. 2: Same as **Fig. 1** except for 18 July.

this region.

It should be emphasized again that the patterns of the radar echoes are strikingly similar to each other for these two days. Although the figures are not shown here, the evolution of radar echo is almost the same in 16 July also. This result shows that these patterns appear under some physical inevitability. We must clarify the physical processes through which these evolutions of convection occur. We have conducted 4-times daily rawin sonde observation at Dhaka for 17 to 18 July. Furthermore, we have gathered 3-hourly surface observations at several stations of Bangladesh Meteorological Department. The result of analysis using these available data will also be shown in the presentation.

In this period, monsoon rainfall was relatively weak (break phase). In the active phase of the monsoon rainfall, the pattern may quite be different. It is important to find some different diurnal evolution patterns of convection through the radar echo analysis.

3 Diurnal variation of the atmospheric vertical structure

Usually, in Bangladesh, operational rawin sonde observations are conducted only at 00GMT (06BST). We cannot investigate the diurnal variation of upper layer atmosphere only by using these data. There are some objective analysis whose time intervals are 6 hours. However, it is not clear whether the diurnal variations derived from such dataset are reliable or not. Therefore, we performed extra rawin sonde observations at Dhaka stations in summer monsoon season from 1999 to 2001. Three extra sondes are ascended at 06GMT, 12GMT and 18GMT. Together with operational observation, they consist 4-times daily observation. In this report data in 2000 and 2001 are used. These 4-times daily observations are conducted in days listed in **Table 1**. In this section, the diurnal variations derived from this dataset are shown.

First of all, the diurnal variation of the vertical thermal structure (potential temperature (θ) and equivalent potential temperature (θ_e)) for 2001 is shown in **Fig. 3**. Near the surface, equivalent potential temperature goes up to 350K. In the middle troposphere, it falls to about 340K. There, prominent diurnal variations are seen mainly in θ_e profile. This indicates that the changes in the humidity is important for the middle troposphere.

In **Fig. 4**, we can see clear diurnal variation of wind. In the diurnal variation in the zonal wind, we

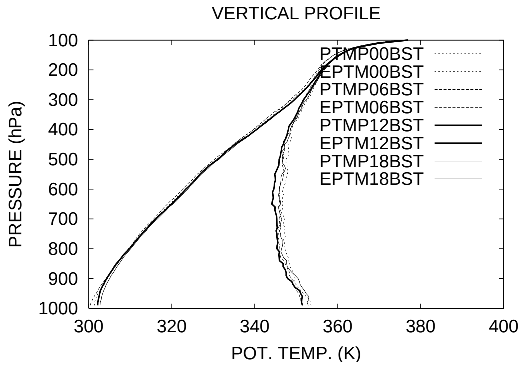

Fig. 3: Averaged vertical profiles of potential temperatures and equivalent potential temperatures for 2001.

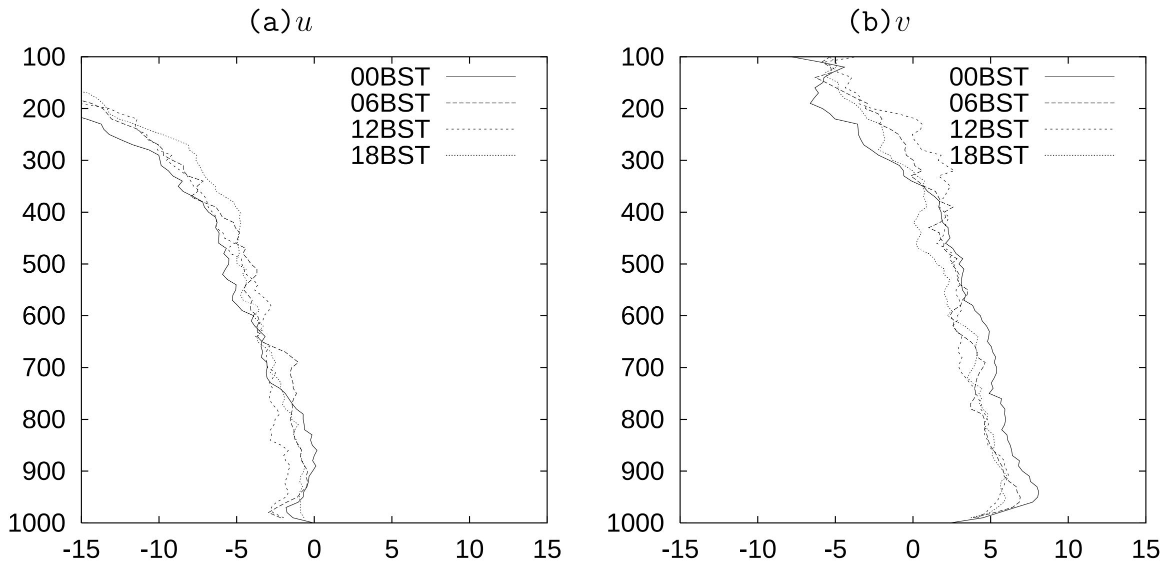

Fig. 4: Averaged vertical profiles of (a)zonal and (b)meridional wind velocities for 2001.

can see clear node at about 600hPa level. In the diurnal variation of zonal wind in 2000 also (figure is not shown) there is a node-like structure near 600hPa.

In **Fig. 5**, the diurnal variations for various parameters for 2001 are shown. Basically, thermodynamic

Table 1: List of 4-times daily rawin sonde observations conducted in 2000 and 2001 summer at Dhaka. Asterisks (*) denotes that in these days some of the wind observation were not obtained. Therefore, we did not use these data for calculation of the diurnal variation of the wind. The numbers of 4-times daily observation are indicated for each year. Those of days for which we could calculate wind diurnal variations are shown in parentheses.

year	month	day
2000	June	29
	July	6, 8*, 12-13, 14*, 18, 19*, 20*, 25, 26*, 27*
total: 12days(5days)		
2001	June	28, 29
	July	4, 9*, 10-11, 17*-18, 21-22, 26-27, 30-31*
	August	1, 5, 14*-15
total: 18days(14days)		

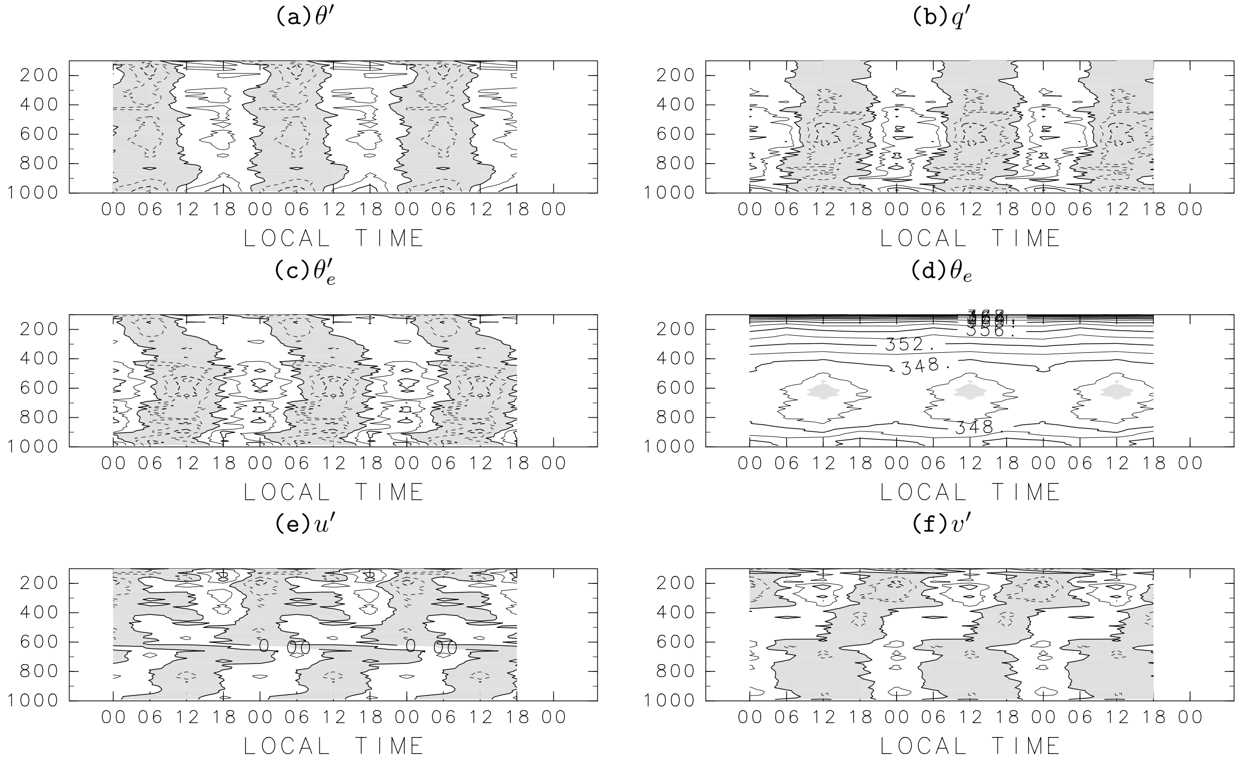

Fig. 5: Time-pressure cross sections showing averaged diurnal variations of vertical profiles for (a)potential temperature, (b)specific humidity, (c), (d)equivalent potential temperature, (e)zonal and (f)meridional wind velocities in 2001 summer. For (a)-(c), (e) and (f), anomalies from the daily averages are shown, and negative values are shaded. For (d), the averages for each local time are shown, and values less than 345K are shaded. Horizontal and vertical axes indicate local time and pressure, respectively. Contour intervals are 0.4K, 0.2g/kg, 0.5K, 2K, $1\mathrm{ms}^{-1}$ and $1\mathrm{ms}^{-1}$, respectively.

fields are vertically in phase. The tropospheric temperatures attain their maximum in the evening (18BST), while maxima of the specific humidities appear noon (12BST). In the middle troposphere, the diurnal variations of equivalent potential temperatures mainly reflects those of specific humidities.

It can be assumed that it is daytime when water vapor is actively provided from the lower boundary through the upward latent heat flux near the ground. The thermodynamic energy also increases during the daytime by the insolation. However, the results shown above exhibit different diurnal variation. The minimum of the specific humidities is found at noon (**Fig. 5b**). In **Fig. 5c**, the minimum of the equivalent potential temperatures is found in the day time. This also shows that the thermodynamic energy in the atmospheric column over the Bangladesh continues decreasing after sunrise.

The diurnal variations of wind are shown in **Fig. 5e** and **Fig. 5f**. Below the 600hPa level, a clear diurnal variation is found. From the view point of the sea-land breeze, we can expect that the wind blows from south during daytime and from north during night. However, wind anomaly is southwesterly and northeasterly in the daytime and night, respectively. This is opposite of what is expected.

However, as has been shown in **2**, or in Ohsawa et al. (2001), convection tends to be active early afternoon over southwestern part of Bangladesh. Over the northeastern part, on the other hand, strong convection prevails mainly in the midnight. Dhaka is located in the middle of this country. Therefore, at noon, strong convections are located to south of the Dhaka observatory. In the midnight, the convection moves to the north of Dhaka. If we assume that the wind blows toward the convection in the lower layer, the wind direction observed at Dhaka can be explained.

Meanwhile, in the lower layer, **Fig. 5b** and **Fig. 5e, f** are basically in phase with each other. That is, in the midnight, southwesterly wind anomaly prevails and the specific humidity increases. On the other hand, in the daytime, wind anomaly is northeasterly and the humidity decreases. This result suggests that the horizontal gradient of specific humidity directs southward and the southwesterly wind anomaly provides more water vapor.

4 Summary

Diurnal variations of convective activity and the atmospheric vertical structure were investigated using BMD (Bangladesh Meteorological Department) radar and intensive rawin sonde observation which was specially designed to resolve the diurnal variation. From the radar image in 2001 summer (16-18 July), clear and systematic diurnal variation was found in the convective activity over this country. In these two days, the evolution of convective activity is strikingly similar to each other. In the daytime, scattering radar echoes dominated over southwestern part of this country. On the other hand, in the midnight, strong radar echoes were seen just south of Meghalaya mountains. The diurnal variation of convective activity shown by Ohsawa et al. (2001) is consistent with this radar echo pattern, showing that the diurnal variation described in the present study may be rather typical.

From the rawin sonde observation, averaged pattern of diurnal variation of the atmospheric vertical structure was obtained. The water vapor in the lower troposphere and the thermodynamic energy tend to be maximum in the midnight and be minimum in the daytime, while the temperature tend to be maximum in the evening. The lower layer wind direction observed by rawin sonde was consistent with the location of the diurnal movement of convective activity. Terao et al. (2000) has investigated the diurnal variations of the potential temperature and the equivalent potential temperature using 1999 data only. Their results were largely the same as those of the present study.

The water vapor flux from the land surface also can be a dominant water source for the cloud formation. It is well known that severe flood disasters attack the land of Bangladesh frequently. In the rainy season, many large seasonal ponds (haols) appear in the northeastern part of this country. Thus, extraordinary wet and hot situation which can be compared to the Tropical sea surface dominates over this country. Therefore, it is also important to investigate how this land surface affect the water budget over this region.

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