Dhaka Univ. J. Sci. 59(2): 187-191, 2011 (July)

An Investigation of Tropospheric Energetics for Pre-monsoon Nor'westers for Selected Cases in Bangladesh During 2008.

Nasrin Sultana, Sujit Kumar Debsarma and Sultana Shafee *

SAARC Meteorological Research Centre (SMRC), Agargaon, Dhaka-1207, Bangladesh

**Department of Physics, Dhaka University, Dhaka-1000, Bangladesh*

Received on 26. 12. 2009. Accepted for Publication on 17. 04. 2011

Abstract

Attempts have been made to study the different energy components of the atmosphere prior to the occurrence of Nor'westers over Dhaka in Bangladesh during the pre-monsoon season. Three Nor'westers of higher speed have been investigated for the Nor'westers occurring in April and May, 2008. Different dates as mentioned in the text at 00 UTC for the standard isobaric heights from 850 hPa to 100 hPa levels have been utilized to study the energy components of the troposphere on the date of occurrence of Nor'westers and have been compared with the non-occurrence days. The study of the various parameters, the mean sea level pressure and satellite images show the favourable condition for the occurrence of Nor'westers.

Key Words: Nor'westers, Pre-monsoon, Isobaric height, Troposphere, Vertical Profile.

I. Introduction

A natural disaster affects human activities. Human vulnerability leads to financial, environmental or human losses provoked by the lack of planning or appropriate emergency management. The resulting loss depends on the capacity of the population to support or resist the disaster, their resilience. The location of Bangladesh being the biggest contributing factor, where it is one of the most disaster-prone countries in the world. Because of the geographical location of Bangladesh a common, though short lived, destructive type of weather hazard is Nor'wester. Nor'wester thunderstorms, often blow over Bangladesh in April-May from a northwesterly direction, are locally called "Kalbaishakhi" as they occur during Bengali month Baishakh [1].

II. Different Aspects of Nor'westers and Climatological Features

The term severe weather is usually used to refer to severe thunderstorms and related phenomena, such as tornadoes, hail, hurricanes, cyclones, downbursts and snowstorms, ice storms, blizzards and huge winds also refer to severe weather.

In Bangladesh two transition periods between southwest and northwest monsoons over the sub continent are characterized by local severe storms. Usually these transition periods are known as pre-monsoon (March-May) and post- monsoon (October-November) period.

The direction and their time sequences are not always the same for Nor'westers. Usaully, the majority of Nor'westers starts in West Bengal and Choto Nagpur area in the early afternoon and proceeds in NW-SW direction. Depending on the synoptic situations there could be some variation with respect to the origin of Nor'westers to a certain extent**.** The usual speed of travel of Nor'westers varies between 33-80 knots i.e. 62-150 km/hr. They may develop within half an hour to three hours.

III. Synoptic Study of Local Severe Storms

Suitable synoptic features are responsible for causing local severe storms. These features are required to be in existence both at the surface and the upper levels. These can be easily identified in the weather charts, which are analyzed in a forecasting office [2].

Lightning is the key ingredient that defines a thunderstorm since lightning is needed to create thunder. Thunderstorms come in all shapes and size with some cells only a few miles in diameter and some clusters of storms that span hundred of miles.

The thunderstorms that we see are composed of one or more individual convection cells. Individual thunderstorm cells have many variations in growth and behavior. Typically they go through three stages of development and decay. These are Cumulus, Mature, and Dissipating stages.

Nor'westers are mainly products of highly unstable atmosphere. A number of factors, which are responsible for the formation and development of Nor'westers in Bangladesh, are given below:

a). Suitable synoptic condition to cause low level convergence and upper level divergence which will act as trigger and release the instability present in the air mass.

b). A layer of moist air of moderate thickness near the earth's surface surrounded by deep layer of dry air with steep lapse rate.

c). Ascent of moist air to higher levels by upper level divergence.

d). Presence of convective instability with Showalter Index having a value lower than -3°C and total index having a value greater than 44°C.

e). Presence of sharp low-pressure troughs at or near the area of occurrence.

f). Presence of low pressure zone at the north-west or north-east of West Bengal and Bangladesh or surrounding area (at 1000 mb, 850 mb, 700 mb, 500 mb) [2].

IV. Theoretical Frame Work

The total atmospheric energy is given by $E = C_p T + gz + Lq + \frac{V^2}{2}$ or, $E = E_1 + E_2 + E_3 + E_4$

Where $E_1 = C_p T$, the sensible heat energy per unit mass; $E_2 = gz$, the potential energy per unit mass; $E_3 = Lq$, the latent heat energy per unit mass; and $E_4 = \frac{V^2}{2}$, the kinetic energy per unit mass. The computations of these components are described below (Karmakar 1984) [3]: The Sensible Heat Energy (SHE) is obtained as follow: $E_1 = C_p T = 0.24(t + 273) \times 4.186$ joule/gm; where, $C_p = 0.24 \times 4.186$ joule/gm/°k and t is in °C. The Potential Energy (PE) is computed by using:

$$E_2 = gz = \frac{981 \times z \times 100}{10^7} \text{ joule/gm}$$

where z is the geo-potential height and its unit is geo-potential meter.

The Latent Heat Energy (LHE) is given by $E_3 = Lq$ where q is the specific humidity and is determined from $q = \frac{0.62197e}{P - 0.37803e}$ gm/gm (Saucier, 1955) [4]; where e is the actual vapor pressure.

Latent heat is:

$L = [597.3 - 0.556(T - 273)] \times 4.186$ joule/gm.

Where T is the temperature of the air parcel in °k. Generally, the wind is expressed in Knots is meteorological observation. The Kinetic Energy (KE) per unit mass is given by: $E_4 = \frac{V^2}{2}$ When V is in Knots or,

$E_4 = 1.3250493 \times 10^{-4} \times V^2$ joule/gm.

V. Data Collection

The data of dry bulb temperature, dew point temperature, geo-potential height, wind speed and wind direction at 00 UTC of 850 hPa, 600 hPa, 500 hPa, 400 hPa, 200 hPa, 150 hPa and 100 hPa pressure levels for Agortola, Kolkata, Gauhati, Ranchi, Dhaka, Bogra and Chittagong stations have been collected from Bangladesh Meteorological Department (BMD). The data for three Nor'westers occurring on 17th April, 1st May and 10th May 2008 with were higher speeds have been collected. The data were collected for the dates before and after the dates of occurrence of Nor'westers.

VI. Results and Discussion

The energy components of the Sensible heat energy, Potential energy, Latent heat energy, Dry static energy, Moist static energy and Total energy per unit mass in the atmosphere have been calculated by using mentioned data. The vertical profiles of these energy components have also been calculated to see their changes on the dates of occurrence, and before and after the dates of occurrence of Nor'westers. Results are given below:

Sensible Heat Energy (SHE): The vertical profiles of SHE over Dhaka on the occurrence day (17/4/08) and before and after the date of occurrence of Nor'westers are illustrated in figure 1. It shows that SHE from 295.36 joule/gm to 280 joule/gm on the date of occurrence lay in between the values of the day before and after the occurrence from 850 hPa to 750 hPa levels. From 750 hPa to 450 hPa levels, the SHE up to 270.24 joule/gm on the date of occurrence is slightly greater compared with the other two days, and then it overlapped with from 450 hPa to 400 hPa levels. The SHE on the date of occurrence, is slightly lower than on the other two days from 400 hPa to 300 hPa levels. From 350 hPa to 240 hPa levels the SHE after the date of occurrence is slightly greater than on other two days.

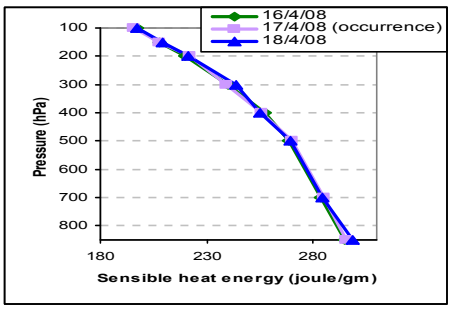

Fig. 1. Vertical Profiles of the Sensible heat Energy over Dhaka at 00 UTC on Different Dates.

From 240 hPa to 100 hPa levels the approximate value of SHE from 230 joule/gm to 195.90 joule/gm overlapped and decreased rapidly in the upper troposphere. This case shows similarity with the other two cases of 01/05/08 and 10/05/08.

Potential Energy (PE): The vertical profiles of PE over Dhaka on the occurrence day (17/04/2008) and before and after the date of occurrence of Nor'westers are illustrated here. Figure 2 shows the vertical profiles of the difference in PE curves between on the date of occurrence on 17th April, 2008 and on before and after the date of occurrence.

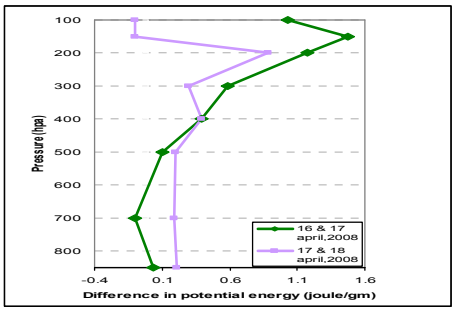

Fig. 2. Vertical Profiles of the Difference in Potential Energy over Dhaka at 00 UTC on Different dates.

This figure shows that the curve of the difference in PE from 0.039 joule/gm to 0.09 joule/gm between on the date of occurrence and on the date before occurrence decreased slowly from ground surface up to 700 hPa levels. After that it has an increasing trend up to 150 hPa levels, and decreased sharply. But the curve of the difference in PE

from 0.20 joule/gm to 0.19 joule/gm between on the date of occurrence and on the date after occurrence remained constant from ground surface up to 500 hPa pressure levels and then the curve from 0.19 joule/gm to 0.39 joule/gm slightly increased up to 400 hPa levels and again decreased up to 100 hPa levels. After that, it fluctuates slowly in the upper troposphere. The whole trend matches with the other two cases of 01/05/08 and 10/05/08.

Latent Heat Energy (LHE): The vertical profiles of the LHE on the date of occurrence (17/04/08) and before and after the date of occurrence of Nor'westers are illustrated here. In figure 3 the LHE was from 2.65 joule/gm to 3.06 joule/gm on the day of occurrence. Before and after the date of occurrence it increased slowly from ground surface up to 700 hPa pressure levels and the LHE on the date of occurrence lay in between the values of the other two days up to 200 hPa levels. From 700 hPa levels the values in three curves decreased slowly up to 400 hPa levels and the LHE from 2.12 joule/gm to 2.14 joule/gm on the date of occurrence remained constant from 400 hPa to 300 hPa levels, then LHE on the date of occurrence at 2.29 joule/gm decreased significantly up to 100 hPa levels. The figure shows that the LHE on the date of occurrence overlaps with that after the date of occurrence from 150 hPa to 100 hPa levels with increasing trend. The cases of 01/05/08 and 10/05/08 are approximately show the same result.

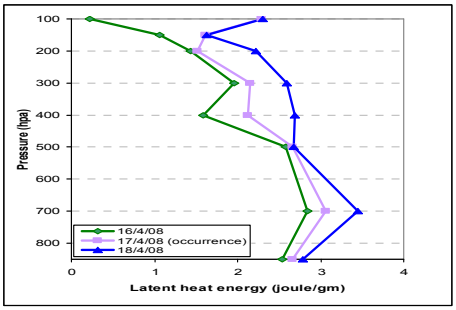

Fig. 3. Vertical profiles of latent heat energy over Dhaka at 00 UTC on different dates.

Dry Static Energy (DSE): The vertical profiles of the occurrence day (17/4/2008) and before and after the occurrence day of Nor'westers are studied here. Figure 4 shows that the value of DSE from 309.76 joule/gm to 315.88 joule/gm on the occurrence day of Nor'wester , which is less than the value of it before and after the date of occurrence from ground surface up to 700 hPa pressure levels. Then DSE from 309.76 joule/gm to 327.34 joule/gm on the occurrence day increased slowly in comparison with the other two curves from 850 hPa to 500 hPa after that the curve from 315.88 joule/gm to 358.36 joule/gm lay in between the values of the day before and after the date of occurrence from 700 hPa to 150 hPa pressure levels. The values in DSE curve after the date of occurrence of Nor'wester were higher than in other two curves from 700 hPa to 150 hPa pressure levels. The study of 01/05/08 and 10/05/08 reveals the same result.

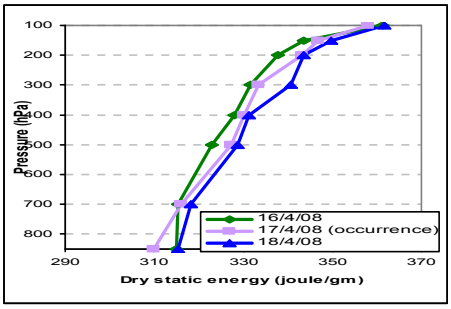

Fig. 4. Vertical Profiles of dry Static Energy over Dhaka at 00 UTC on different dates.

Moist Static Energy (MSE): The MSE per unit mass of the troposphere on the occurrence day (17/4/08) and before and after the date of occurrence of Nor'westers under study have been computed. The vertical profiles in figure 5 show that the values of MSE from 312.42 joule/gm to 318.94 joule/gm on the date of occurrence.It is lower than that of the values in the day before and after the occurrence from ground surface to 700 hPa pressure levels. The curve on the occurrence day shows an increasing trend up to 100 hPa pressure levels. But from the pressure level 400 hPa of 335.38 joule/gm and 220 hPa of approximately 340 joule/gm for MSE on the occurrence day shows lower value than that of the curve after the occurrence day. From 220 hPa to 150 hPa levels MSE on the occurrence day overlapped with the curve after the occurrence day. Three curves show almost the same pattern from 150 hPa to the upper troposphere. The three cases of 17/04/08, 01/05/08 and 10/05/08 show almost similar results.

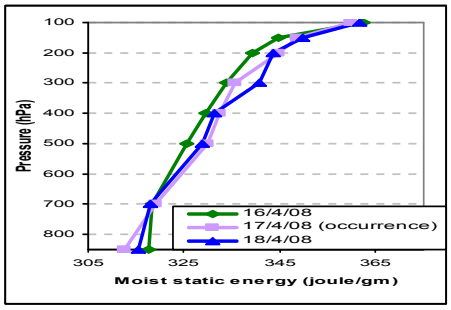

Fig. 5. Vertical profiles of moist static energy over Dhaka at 00 UTC on different dates**.**

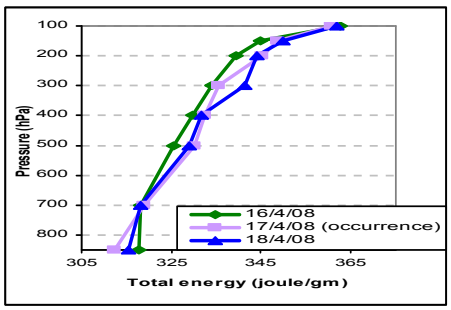

Fig. 6. Vertical Profiles of total Energy over Dhaka at 00 UTC on Different dates.

Total Energy (TE): The vertical profiles of the TE over Dhaka at 00 UTC on the date of occurrence (17/4/08) and before and after the date of occurrence of Nor'westers under

study have been computed in figure 6. It is found that the contribution of the KE into the TE was very small. Therefore, the behaviour of the curve of the TE was almost similar to that of the MSE.

Synoptic Chart Study at Mean Sea Level

The distribution of mean sea level pressure at 00 UTC on the date of occurrence on April 17, 2008 is shown in figure 7a.

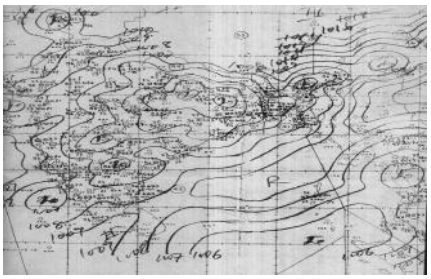

Fig. 7a. Distribution of mean sea level pressure at 00 UTC on 17th April, 2008 in Bnagladesh and its surrounding areas.

This figure shows that there is a low pressure area over Bihar and adjoining West Bengal. A trough line extends from Uttar Pradesh to Assam across Bihar, West Bengal, and central part of Bangladesh. At 12:00 UTC mornings low pressure area moved and lightly eastwards and lay over West Bengal, and adjoining area. A trough line extended from Nepal to West Bengal thence to Tripura across central part of Bangladesh.

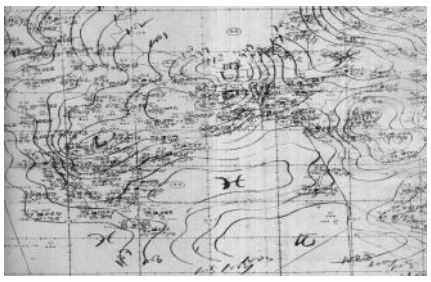

Fig. 7b. Distribution of mean sea level pressure at 12:00 UTC on 17th April, 2008 in Bangladesh and its surrounding areas.

Satellite Picture Analysis: Satellite pictures had been collected from the Storm Warning Center of Bangladesh Meteorological Department (BMD). Satellite Images of cloud on the dates of occurrence of Nor'westers on 17th April, 2008 and 1st and 10th May, 2008 over Bangladesh were collected.

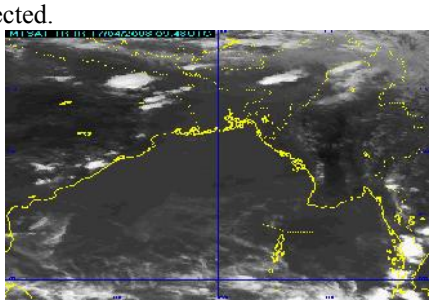

Fig. 8a. IR image of MTSAT satellite at 09:43 UTC of 17th April, 2008.

Only the Satellite picture of the Nor'wester occurring on 17th April, 2008 has been analyzed.

Satellite imageries in figure 8a-d show that at 09:43 UTC on 17th April, 2008 a cell developed over Bihar and West Bengal and adjoining area

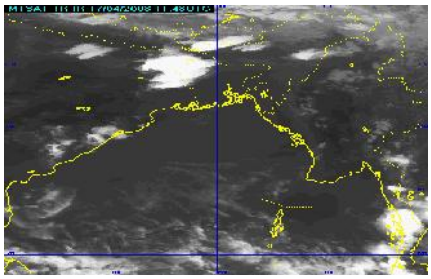

Fig. 8b. IR Image of MTSAT Satellite at 11:43 UTC of 17th April, 2008.

of India. At 11:43 UTC on 17th April, 2008 Nor'wester was taking place over Bogra and Ishurdi regions.

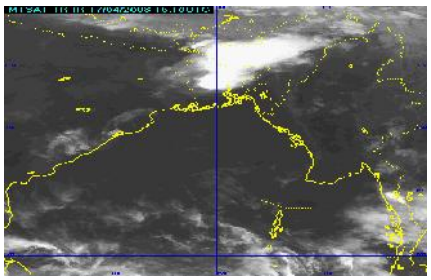

Fig. 8c. IR image of MTSAT satellite at 15:10 UTC of 17th April, 2008.

More dense cloud accumulation occurred over north-eastern part of Bangladesh at 15:10 UTC. At 17:43 UTC the previous cloud system over north-eastern Bangladesh and Assam moved eastwards of Bangladesh.

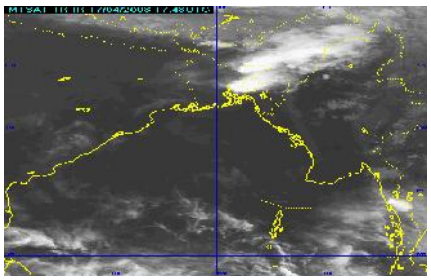

Fig .8d. IR image of MTSAT satellite at 17:43 UTC of 17th April, 2008.

VII. Conclusion

The following conclusions may be drawn:

a) The SHE on the date of occurrence of Nor'wester and before and after the date of occurrence of Nor'wester varies in the mid-troposphere.

b) The PE difference decreases in the lower troposphere, increases in the middle troposphere and then decreases.

c) The LHE per unit mass of the atmosphere increases from ground surface up to 700 hPa pressure levels and decreases up to 500 hPa pressure levels and fluctuates in the upper troposphere for the Nor'wester occurring in April and 10th

May, 2008. But the LHE of the atmosphere shows exceptional behaviour in the lower troposphere for the Nor'wester occurring in the early May.

d) The DSE of the atmosphere increased slowly from ground surface to upper troposphere for the Nor'wester in April and May. But the Nor'wester occurring in early May shows slight different behaviour from 400 hPa to 200 hPa pressure levels with respect to DSE.

e) The MSE increases significantly from ground surface to upper troposphere for the Nor'wester in April and May.

f) It is found that the contribution of KE into the TE is almost negligible.

Acknowledgement

Our sincerest thanks to Ms. Arjumand Habib, Director of Bangladesh Meteorological Department (BMD), Mr. S. M. Quamrul Hassan, Assistant Meteorologist, BMD and the staff of Bangladesh Meteorological Department (BMD) and SAARC Meteorological Research Centre (SMRC), and to Department of Physics for help and cooperation they had extended to us.

.....

1. Karmakar, S., 2005, "Study of nor'westers and development of prediction techniques in Bangladesh during the pre-monsson seasons," Ph.D. Thesis, Department of Engineering and Technology (KUET). 3-7.
2. Israt Jahan , 2008, Masters Thesis, "A study of the tropospheric conditions for three Pre-monsoon Nor'westers over Dhaka in 2008", Dept of Physics, University of Dhaka. 12, 19.
3. Karmakar, S., 1984, "Some Aspects of Tropospheric Energy and its Fluxes over Bangladesh and neighborhood during the Withdrawal Phase of Southwest Monsoon", M S. thesis, dept. of Met. and Ocean, University of Philippines, Diliman. 14-19.
4. Saucier, W. J. (1955): "Principles of Meteorological Analysis", Univ, of Chicago Press. 438.

Dhaka Univ. J. Sci. 59(2): 187-191, 2011 (July)