Seasonal variation of Daily Total Column Ozone (TCO) and its Formation and Depletion Role on Surface Temperature and Average Rainfall over Dibrugarh, India (27°28'N,94°54'E).

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ABSTRACT

The purpose of the paper is to present the variation of total ozone concentration over Dibrugarh, Assam, where rainfall occurs to a large extent, during different seasons due to its special location. A critical analysis is done and following important results are obtained.

A. During winter and pre-monsoon period the total ozone concentration increases.

B. During monsoon and post-monsoon period the total ozone concentration decreases.

C. Rate of change of TCO decreases with surface temperature in an oscillatory manner during winter and monsoon periods.

D. Rate of change of TCO increases with surface temperature in an oscillatory manner during pre-monsoon and post-monsoon periods.

E. For the period of study (1997-2005) the overall ozone concentration over Dibrugarh shows a slightly decreasing trend.

F. Rainfall shows increasing trend with the increase of rate of change of TCO during all seasons throughout the period of our study.

G. Possible explanations are also presented.

(Keywords: TCO, O_3, depletion and formation)

INTRODUCTION

Orography provides necessary uplift to moisture and results in good rainfall activity. Dibrugarh is one of the most important stations which suffer maximum rainfall. Ozone is mainly found in the two regions of the atmosphere that are closest to the earth's surface. About 10 percent of the atmospheric ozone is in the lowest-lying atmospheric region, the troposphere. Most ozone (about 90%) resides in the next atmospheric layer, the stratosphere which begins from 15 kilometers above the earth's surface and extends up to about 50 kilometers. The ozone in this region is commonly known as the ozone layer. The total column ozone means both the tropospheric as well as stratospheric ozone over a specified region.

Ozone studies over India have already been done by different investigators (Chiplonkar 1939; Mani 1990; Ramanathan et al., 1949). From ground and satellite based measurements it has been shown that overall ozone concentration is declining globally (Stolarski et al.,1992). Seasonal variation of surface ozone over Athens, Greece was studied by Varotsos et al., 2000, 2001.Trend in total column ozone over Dumdum was studied by Jana et al., 2001, and its effect on summer monsoon rainfall over Gangetic West Bengal was reported by Midya and Saha, 2011.

This paper presents variation of the rate of change of ozone concentration over Dibrugarh in different seasons during the period 1997-2005. The nature of variation of rate of change of TCO with surface temperature during different seasons is also studied. Rainfall variations with the rate of

change of TCO for different seasons are also presented and possible explanations are also offered.

DATA AND ANALYSIS

Ozone data of Dibrugarh are taken from the Internet website: http://jwocky.gsfc.nasa.gov/ozone/ozone.html.

Surface temperature data are taken from: www.weather.uwyo.edu/upperair/sounding.html.

Rainfall data are taken from IITM, Pune.

The collected ozone data and surface parameter data were divided into the following four parts-
Pre- monsoon period- the months of March, April, May and up to 7th June.

Monsoon period- the months of June (8th onwards), July, August, September and October (upto 10th).

Post-monsoon period- the months of October (11th onwards), November and December.

Winter period- the months of January and February.

RESULTS AND DISCUSSION

Daily Variation of Ozone

The total ozone concentration is plotted against days in a scatter diagram for different time periods as mentioned above. The trends that were observed in the different time period are given below.

The trend indicating clearly an increasing tendency (i.e., the total column ozone concentration increases during winter and pre-monsoon period) as shown in Figures 1 and 2.

The reverse trend is observed during monsoon and post-monsoon period which is shown in Figures 3 and 4.

Rate of Change of TCO During Different Seasons

The general trend clearly shows positive gradient values in the pre-monsoon and winter periods and negative values in the monsoon and post-monsoon periods. In other words, it can be said that there is an increase in the ozone concentration during the months from January to 7th June (i.e., the Winter and Pre-Monsoon periods) and a decrease in the same from 8th June to December (i.e., Monsoon and Post-Monsoon periods).

Within the period of study, in the pre-monsoon period, a maximum positive value of the rate of change of TCO is observed in the year 1999. However, in the winter period the same is observed in the year 2000. The magnitude of the highest positive gradient is much greater during the pre-monsoon period (0.4147) than in winter (0.3822). Both in the monsoon and post-monsoon period negative gradient values are observed, with more negative values in the post-monsoon period as compared to the monsoon period. The highest negative value (-0.2659) in monsoon is found in the year 2003 and that (-0.4518) in the post-monsoon period is in the year 1997.

Variation of Depletion and Formation Rate of O_3 Concentration with Surface Temperature

The variation of formation and depletion of O_3 concentration with surface temperature over Dibrugarh during different seasons are shown in Figures 5-8, both at 00Z and 12Z. It is clear from Figure 6 that pre-monsoon rate of formation of ozone increases with the rise of surface temperature. During the monsoon period, the rate of depletion of ozone increases with the increase of surface temperature is shown in Figure 7. During the post-monsoon period, the rate of depletion of ozone decreases with increase of surface temperature (Figure 8). It is shown that average O_3 concentration is declining over Dumdum with smaller amount for short term ozone analysis (Ganda et al., 2010).

This paper confirms that during pre-monsoon and winter period O_3 trend is positive and rate of change of O_3 concentration is highly correlated with surface temperature at 12Z. During other seasons depletion rate of O_3 predominates. The average trend of O_3 concentration over Dibrugarh for the period 1997-2005 is shown in Figure 9.

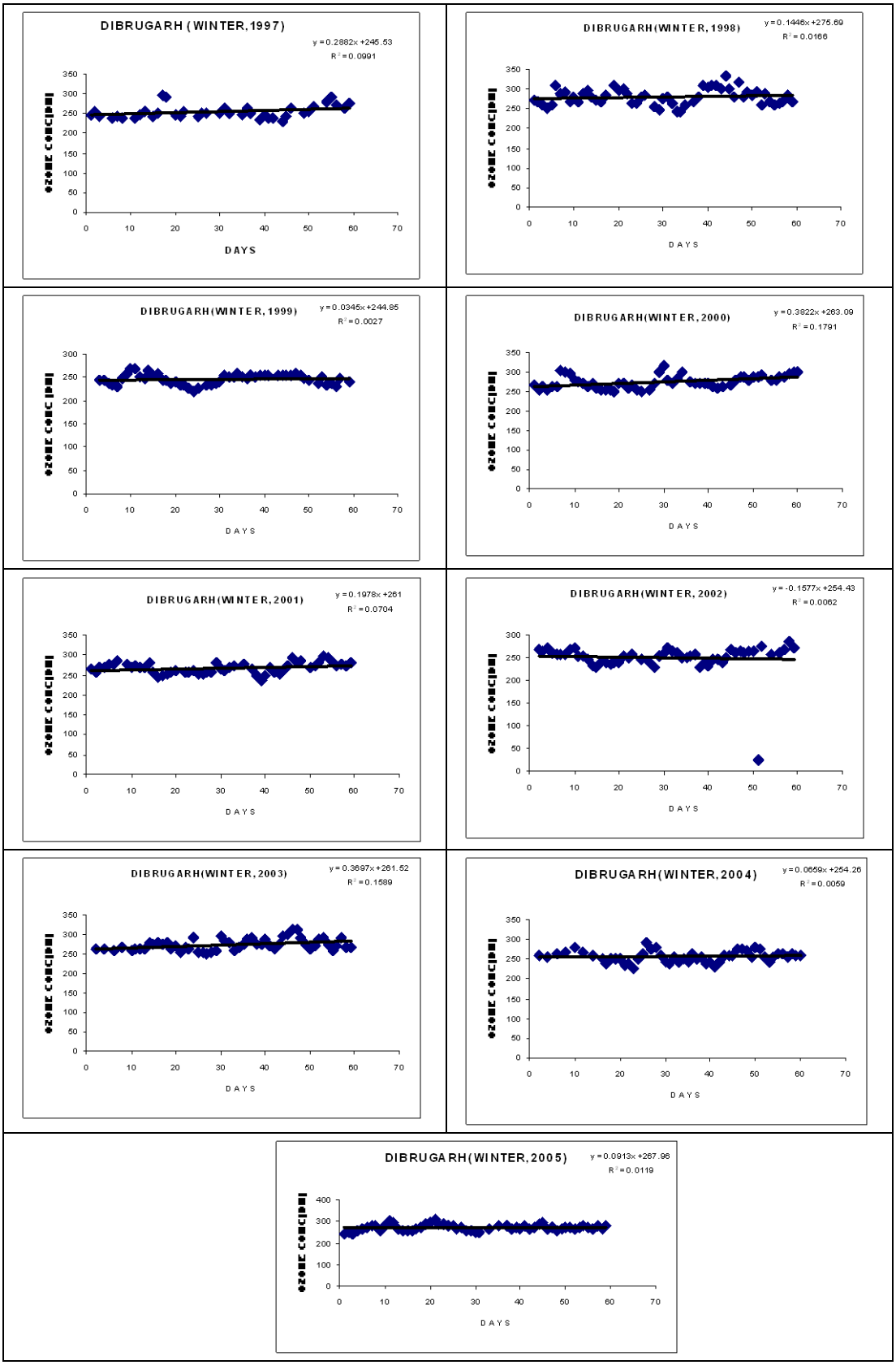

Figure 1: Daily Variation of Ozone during Winter Showing Increasing Trend During the Whole Period of Study.

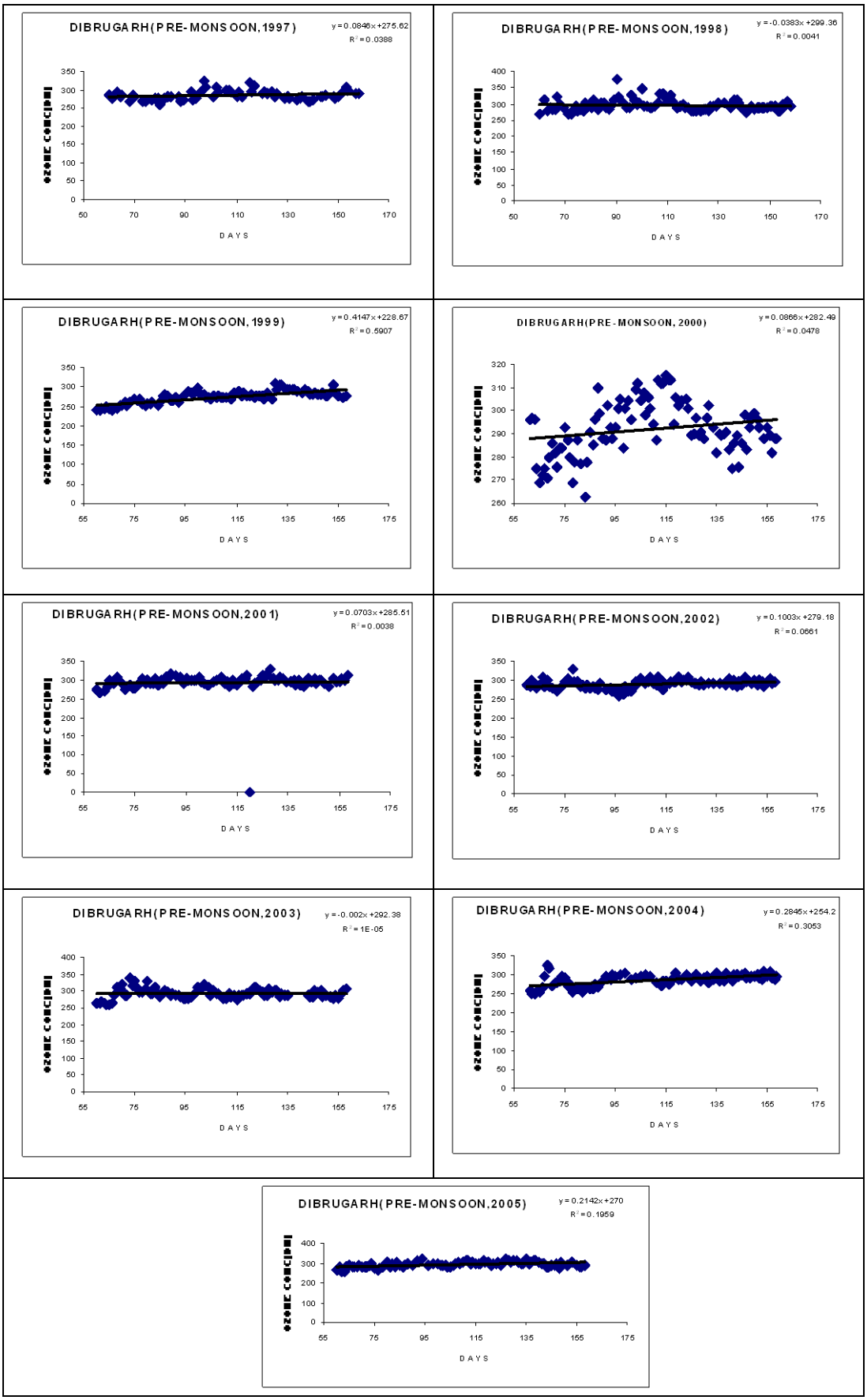

Figure 2: Daily Variation of Ozone during Pre-Monsoon showing Increasing Trend during the Whole Period of Study.

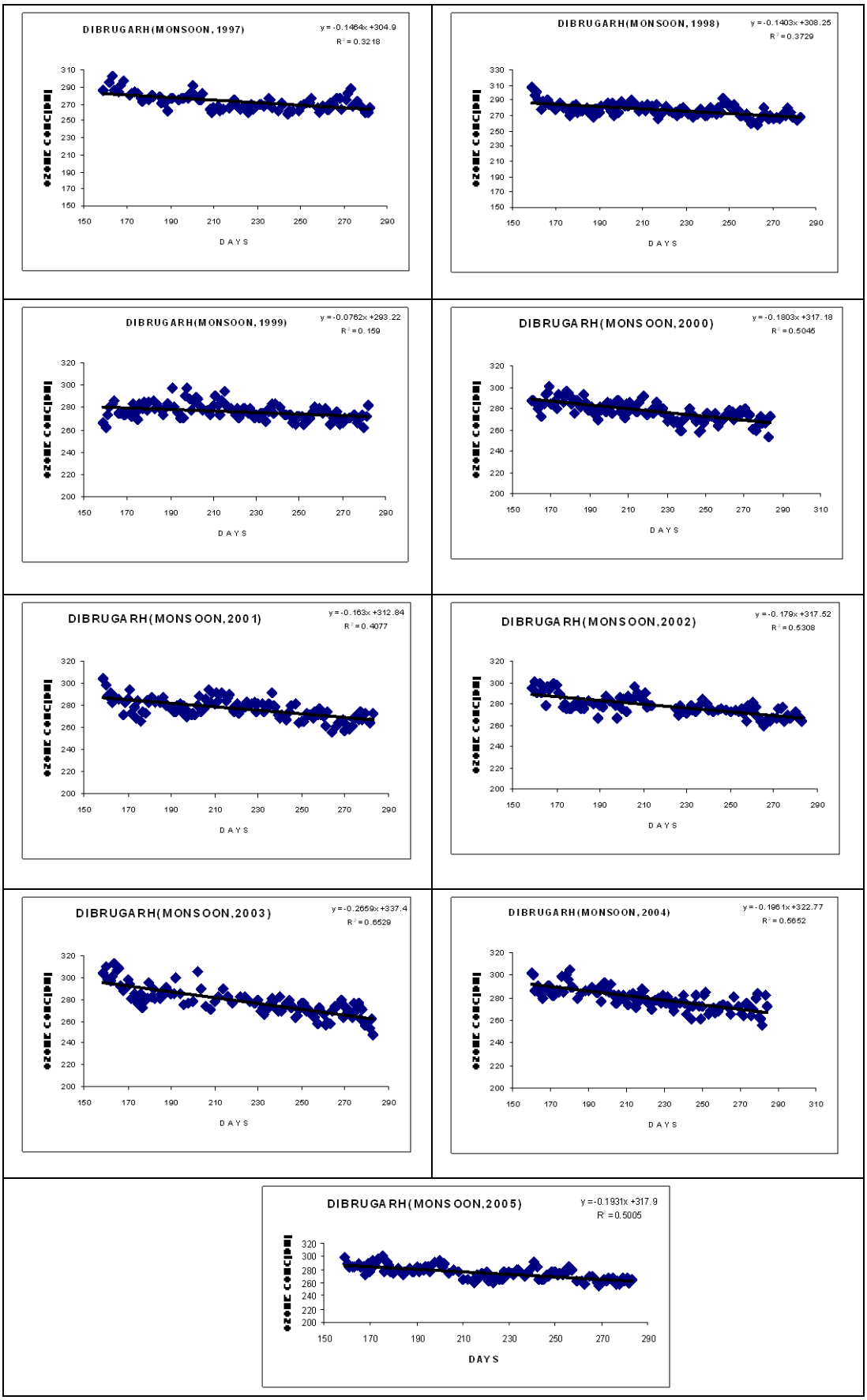

Figure 3: Daily Variation of Ozone during Monsoon Showing Decreasing Trend during the Whole Period of Study.

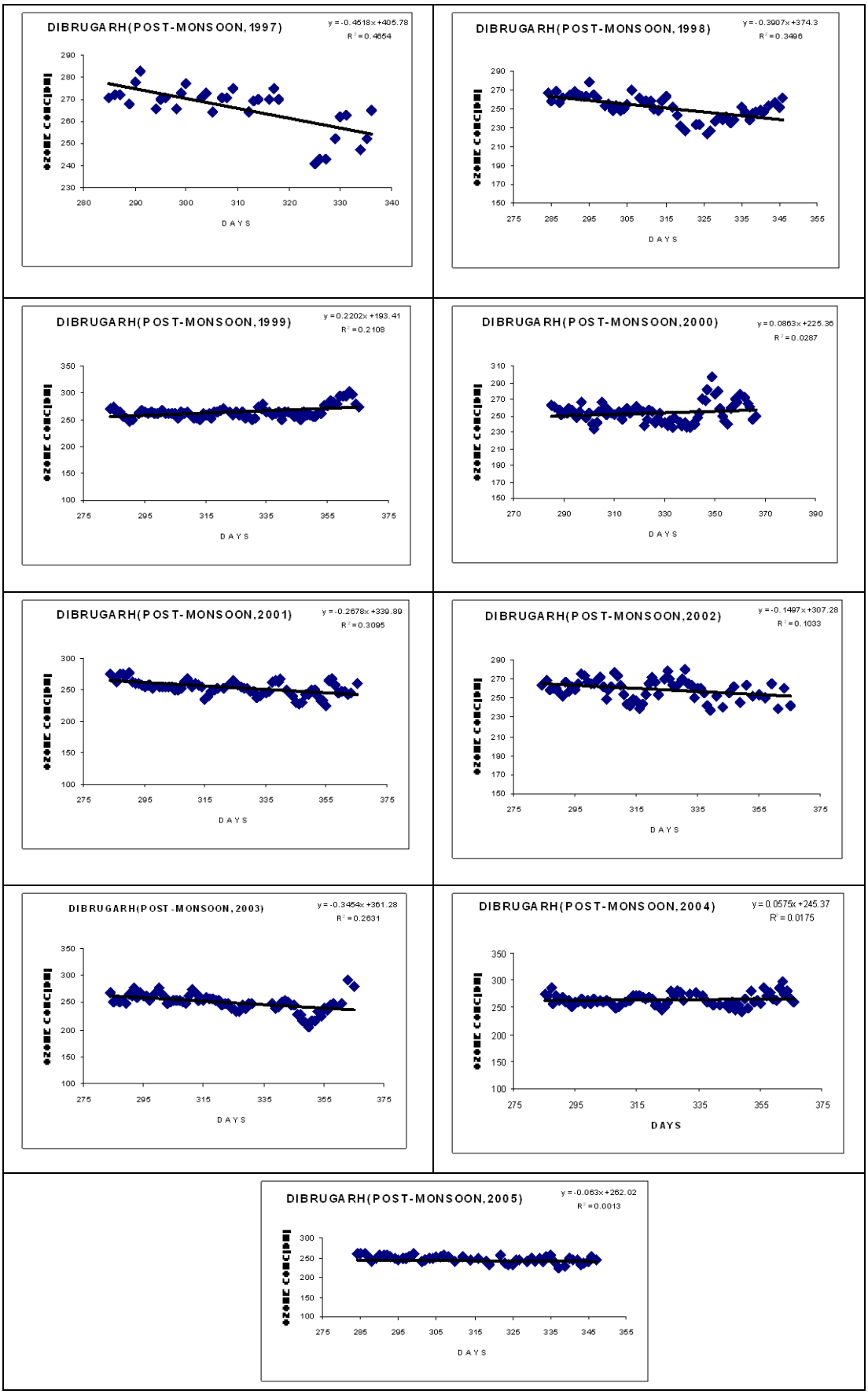

Figure 4: Daily Variation of Ozone during Post-Monsoon showing Decreasing Trend during the Whole Period of Study.

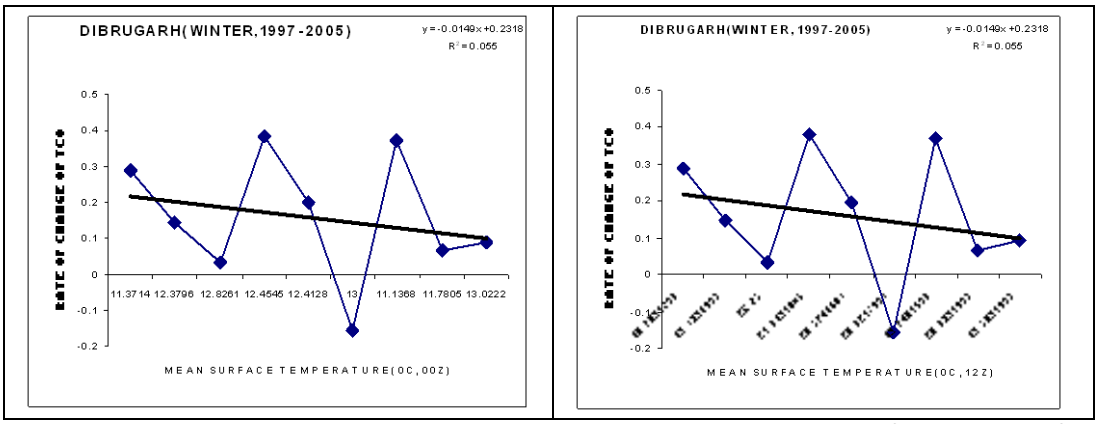

Figure 5: Variation of Rate of Change of TCO with Mean Surface Temperature (^{0}C, 00Z) and (^{0}C, 12Z) during Winter Period.

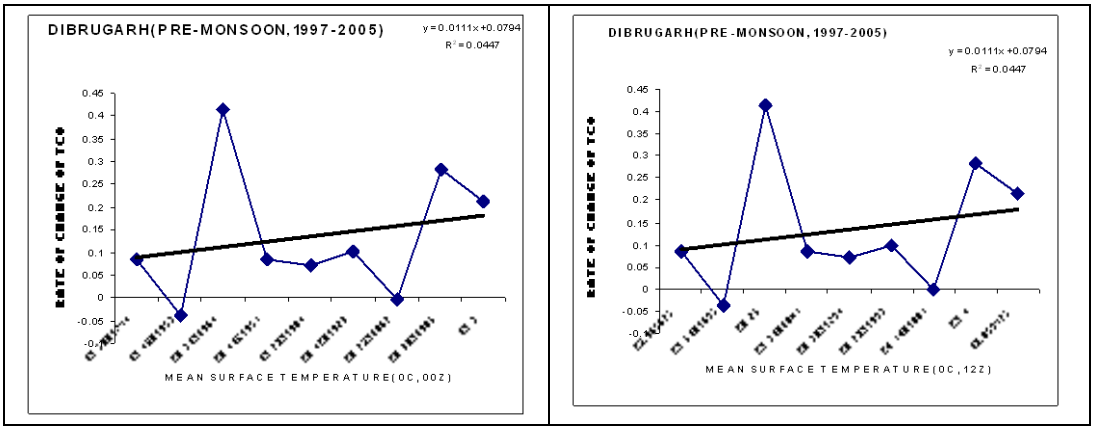

Figure 6: Variation of Rate of Change of TCO with Mean Surface Temperature (^{0}C, 00Z) and (^{0}C, 12Z) during Pre-Monsoon Period.

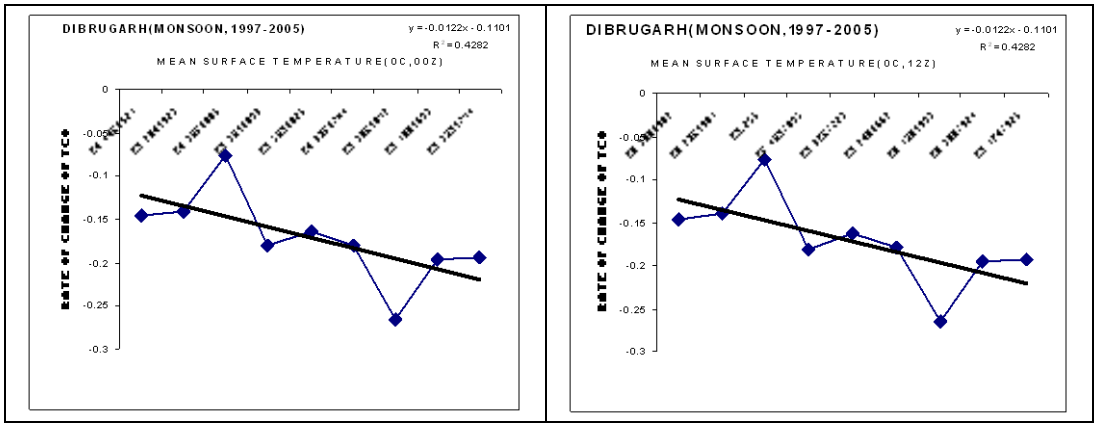

Figure 7: Variation of Rate of Change of TCO with Mean Surface Temperature (^{0}C, 00Z) and (^{0}C, 12Z) during Monsoon Period.

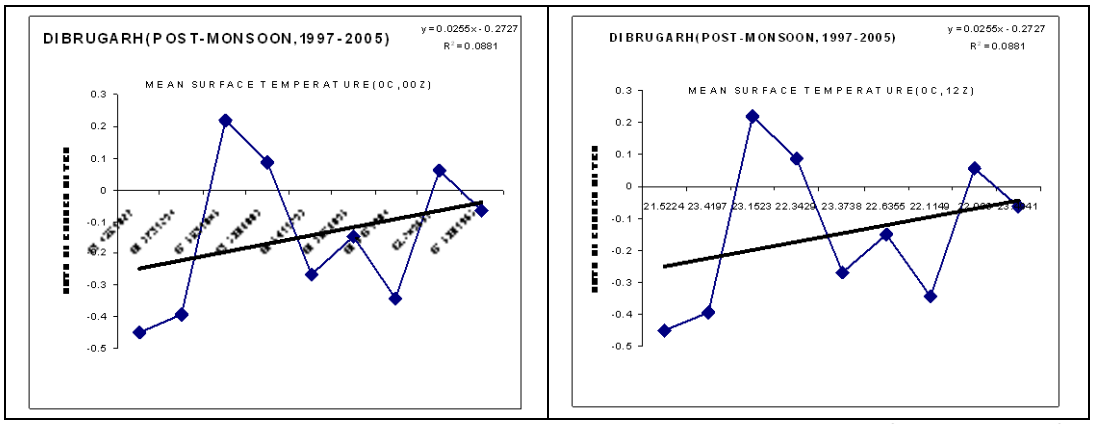

Figure 8: Variation of Rate of Change of TCO with Mean Surface Temperature (^{0}C, 00Z) and (^{0}C, 12Z) during Post-Monsoon Period.

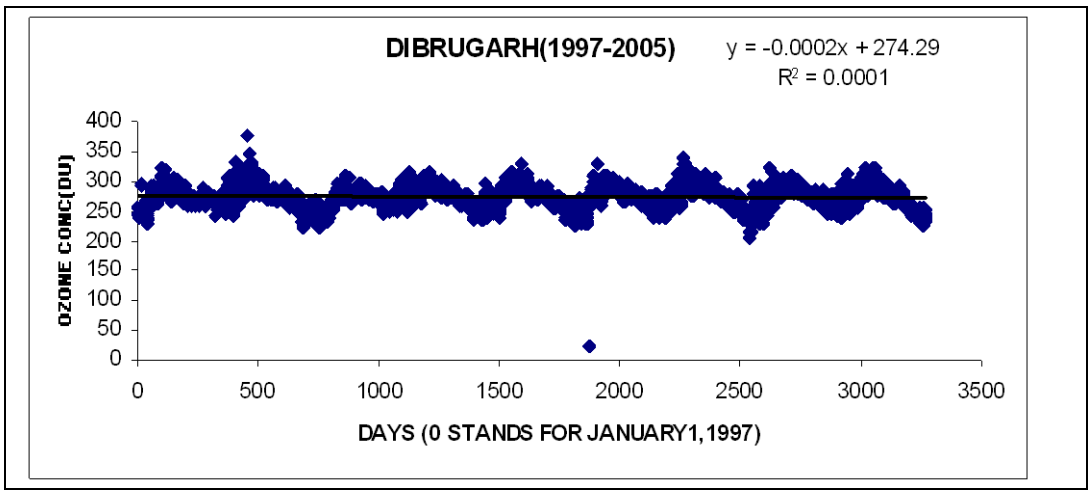

Figure 9: Variation of Ozone Trend over Dibrugarh for the Period 1997-2005.

It is clear that overall O_3 concentration shows slightly decreasing trend for the period of our study over Dibrugarh. Variations of mean rainfall with corresponding rates of change of TCO for different seasons are shown in Figure 10. Rainfall shows increasing trend with the increase of rate of change of TCO for all seasons.

Different formation and destruction processes of ozone are given below:

Reactions			Rate Constants
1. O_3+hv	$\xrightarrow{I_{abs}}$	O_3*	I_{abs}
2. O_3^*	$\xrightarrow{K_1}$	O_2+O	K_1
3. O+O_3	$\xrightarrow{K_2}$	$2O_2$	K_2
4. O+O^*_3	$\xrightarrow{K3}$	$2O_2$	K_3
5. O+O	$\xrightarrow{K_4}$	O_2	K_4
6. O+O_2	$\xrightarrow{K_5}$	O_3	K_5

An empirical equation of O_3 concentration with the concentrations of other atmospheric constituents is established (Midya et al., 1995). $[O_3]= \{K_5[O_2]/K_2\} - \{I_{abs}/K_2[O]\} - \{1/K_2[O]\}\exp[-K_2[O](K_{10}+t)]$.

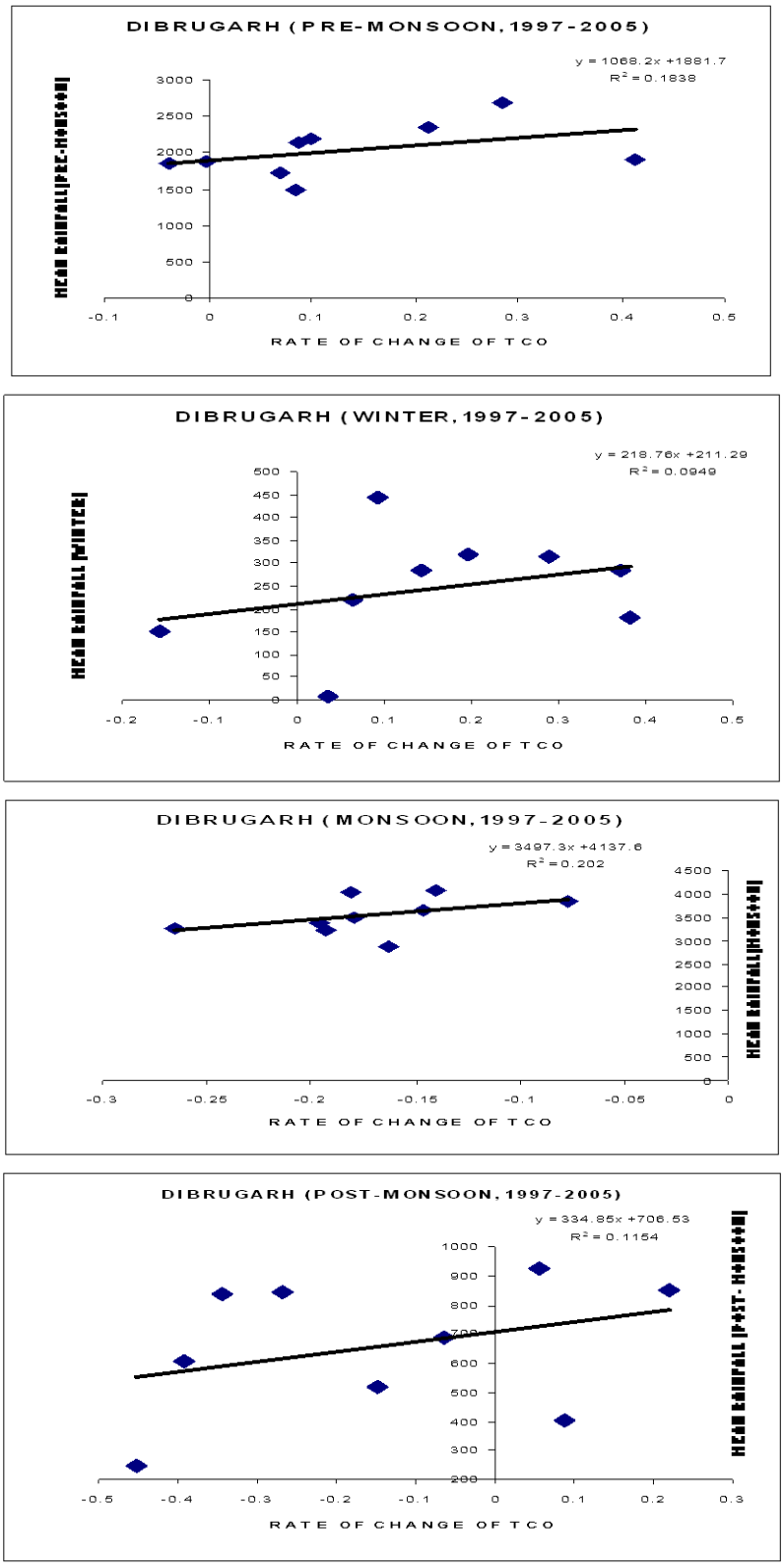

Figure 10: Variation of Total Rainfall with Rate of Change of TCO during Different Seasons over Dibrugarh.

$[O_3]$, $[O_2]$, and [O] are the concentrations of ozone, molecular oxygen and atomic oxygen, respectively. Iabs and all K values are the rate constants of different reactions and these values can be determined from chemical kinetics (Midya et al., 1995). The net reaction for the formation of ozone in stratosphere is given below:

$$O_2+O_2 \rightarrow O_2+O+O=O_3+O$$
$$\underline{O+O_2+M=O_3+M}$$
$$3O_2=2O_3$$

Ozone formation reaction is endothermic. So higher temperature will favor higher equilibrium concentration of O_3. Again if temperature decreases rate of formation of O_3 will also decrease. Thus it is quite expected that concentration of ozone decreases with the decrease of temperature. During pre-monsoon period, temperature of surface is higher. So in order to obtain higher concentration of ozone, rate of formation of ozone will be higher during pre-monsoon period and will increase with the increase of surface temperature. So the nature of variation as shown in Figure 6 is quite expected.

Depletion mechanism of O_3 as given by Bates and Nicolet, 1950 is given below:

$$OH+O_3 \rightarrow HO_2+O_2$$
$$HO_2+O \rightarrow OH+O_2$$
$$\overline{O_3+O \rightarrow 2O_2}$$

Again atomic and molecular oxygen are produced due to the decomposition of H_2O molecule in the troposphere. This is done by unabsorbed solar UV ray as given below (Ghosh et al., 1994).

$$H_2O \rightarrow H+OH$$
$$OH \rightarrow O+H$$
$$O+O+M \rightarrow O_2+M$$

During the monsoon period the probability of OH increases in the atmosphere. As a result depletion rate increases with the rise of temperature as probability of H_2O molecules in vapor state increases with the rise of temperature which is observed in Figure 7.

During the post-monsoon period the probability of H_2O molecules in vapor state decreases and as a result depleting rate of ozone gradually decreases during post-monsoon period which is observed in Figure 8. Rainfall depends on amount of H_2O molecules in vapor state. Due to special orographic location of Dibrugarh, water molecules in the vapor state are available throughout all seasons of the year. O_3 formation and destruction depends on H_2O molecules in the vapor state and OH radicals which are also obtained from water vapor. So increase of rainfall is quite expected with the increase of rate of change of TCO.

CONCLUSION

It is concluded that the rates of change of total ozone concentration over Dibrugarh are not the same for all seasons. It depends on the change of surface temperature for different seasons. It is also concluded that ozone concentration over Dibrugarh shows a slightly decreasing trend for the total period of our study. This type of variation is explained considering ozone destruction mechanism which was given by Bates and Nicolet., 1950. Increase of rainfall with the increase of TCO is also explained from the availability of H_2O molecules in the vapor state due to special location of Dibrugarh.

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