The Effect of the Variable Component of 10.7 cm Solar flux on the Thunderstorm frequency over Kolkata and its Relation with Ozone Depletion Mechanism.

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ABSTRACT

A critical analysis on the effect of the variable component of 10.7 cm solar flux on the pre-monsoon thunderstorm frequency over Kolkata (22°32′N, 88°20′E) and its relation with the ozone depletion mechanism by photo dissociation of nitrous oxide is being established for the period 1997-2008. A study has been made and important results have been obtained which are as follows:

a) The pre-monsoon thunderstorm frequency is maximum at the solar peak phase of the 23rd solar cycle and then decreases. A similar trend is also observed with the variable component of 10.7 cm solar flux.

b) The pre-monsoon thunderstorm frequency increases with the increase in the variable component of 10.7 cm solar flux.

c) The increase in atmospheric nitrous oxide, causing ozone depletion, is also related with the increase in the frequency of the pre-monsoon thunderstorm over Kolkata.

d) A possible explanation is also presented based on chemical kinetics.

(Keywords: 10.7 cm solar flux, pre-monsoon, thunderstorm, solar cycle, ozone depletion).

INTRODUCTION

Thunderstorms, resulting from vigorous convective activity, are one of the most spectacular weather phenomena in the atmosphere. It is a mesoscale weather phenomenon with space scale varying from a few kilometers to a couple of 100 kilometers and time scale varying from less than an hour to several hours. A common feature of the weather during the pre-monsoon season (March–May) over the Indo-Gangetic plain and Northeast India is the outburst of severe local convective storms, commonly known as 'Nor'westers' or 'Kal-baishakhi'.

Nor'westers are the mesoscale convective systems which can develop under the large-scale envelope of the seasonal, low-level trough over the West Bengal–Bihar–Jharkhand belt, with a possible embedded low-pressure area. These severe thunderstorms associated with thunder, squall lines, lightning, torrential rain and hail cause extensive loss in agriculture, damage to property, and also loss of life.

Thunderstorm development is dependent on three basic components: moisture, instability, and some form of lifting mechanism. As air near the surface is lifted higher in the atmosphere and cooled, available water vapor condenses into small water droplets which form clouds. As condensation of water vapor occurs, latent heat is released making the rising air warmer and less dense than its surroundings. The added heat allows the air (parcel) to continue to rise and form an updraft within the developing cloud structure.

Air masses and advection are the prime sources of moisture. Instability is the tendency for air parcels to accelerate when they are displaced from their original position, especially the tendency to accelerate upward after being lifted. It is a pre-requisite for severe weather - the greater the instability, the greater the potential for severe thunderstorms. Lift is needed to overcome convective inhibition, sometimes referred to as a "cap." The cap is a layer of relatively warm air usually 10-15 kft aloft and forms under a large upper level ridge where the air gradually sinks and warms from compression. When the air sinks to roughly 10-15 kft, it is warmer than the air just below it (a stable condition), forming a "capping inversion." Lift is needed to push developing updrafts through the inversion if thunderstorm development is to occur. The weaker the capping inversion, the less amount of lift is needed to overcome it [3]. The casualties reported due to lightning associated with thunderstorms in this region are among the highest in the world. The strong wind produced by the thunderstorm downdraft after coming in contact with the earth's surface spreads out laterally and is referred to as downburst, which is a real threat to aviation [4].

The sun emits radio energy with slowly varying intensity. The radio flux, which originates from atmospheric layers high in the sun's chromosphere and low in its corona, changes gradually from day to day in response to the number of spot groups on the disk. Solar flux from the entire solar disk at a frequency of 2800 MHz is a measure of the solar radio flux density per unit frequency at a wavelength of 10.7 cm, near the peak of the observed solar radio emission. It represents a measure of diffuse, non-radiative heating of the coronal plasma trapped by magnetic fields over active regions, and is an excellent indicator of overall solar activity levels. Midya and Saha [8] also showed in the literature an insignificant co-variation between rate of change of Total Column Ozone (TCO) and summer monsoon rainfall with the increasing variable component of 10.7 cm solar flux.

By comparing the ozone depletion potential–weighted anthropogenic emissions of N_2O with those of other ozone-depleting substances, N_2O emission currently is the single most important ozone-depleting emission and is expected to remain the largest throughout the 21st century [10].

A significant result for airglow emission lines of mixed atmospheric region with the variation of variable component of 10.7 cm solar flux was obtained [9]. The variable component of 10.7 cm solar flux also plays important role on 6300 A^0 which is created mainly by the dissociative recombination of oxygen atom in the higher altitude level of the ionosphere [5]. The purpose of this paper is to present the variation of pre-monsoon thunderstorm frequency on the variable component of 10.7 cm solar flux and O_3 depletion phenomenon. Chemical kinetics are also presented to explain our study.

DATA AND METHODOLOGY

The data for thunderstorms over Kolkata ($22^0$32′N, $88^0$20′E) during pre-monsoon season for the period 1997- 2008, used in the present study are collected from the India Meteorological Department. The daily data for the relative sunspot number and 10.7 cm solar flux, adjusted to 1 AU (March ─ May) are taken from the official website of the US National Oceanic and Atmospheric Administration (NOAA), http://www.ngdc.noaa.gov/ngdc.html for the above-mentioned period.

The variable component of 10.7 cm solar flux is calculated by plotting the relative sunspot number against the 10.7 cm solar flux (Figure 1). Extrapolating to zero sunspot area, the line of the most probable relation between 10.7 cm solar flux and relative sunspot number, the basic component is obtained and it is the quiet sun emission. The emission above the base level is called the variable component of 10.7 cm solar flux. The variable component of 10.7 cm solar flux is computed from daily value of 10.7 cm solar flux, adjusted to 1 AU. The thunderstorm occurrences are divided into three categories in our study ─ severe (wind speed > 64 km/ hr), ordinary (wind speed ≤ 64 km/ hr), and total (severe and ordinary) thunderstorm. The thunderstorm frequencies of the above each are plotted against the variable component of 10.7 cm solar flux and also the pre-monsoon variation of the severe, ordinary and total thunderstorm frequencies over Kolkata is found for the period 1997- 2008 (Figure 2 and Figure 3).

RESULTS AND DISCUSSION

From the analysis of Figures 2 (a)-(c) it is seen that the pre-monsoon thunderstorm frequency has been maximum during the solar peak phase of the 23rd solar cycle. It also holds true for the variation of total thunderstorm frequency over Kolkata during pre-monsoon season with the variable component of 10.7 cm solar flux. It is due to the fact that on the solar peak phase the solar irradiation gets maximized, as a result percent relative humidity increases.

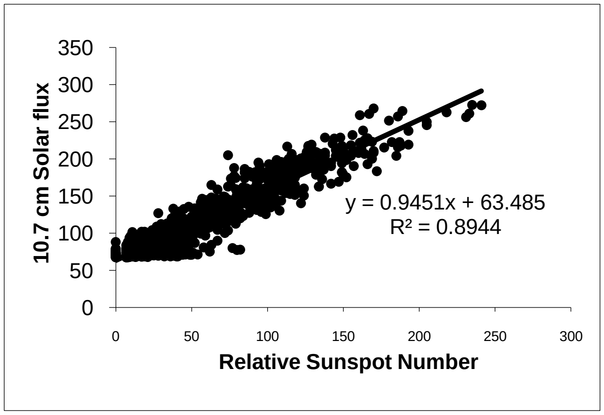


Figure 1. Calculation of Variable Component of 10.7 cm Solar Flux during the Pre-Monsoon Season for the Period 1997- 2008.

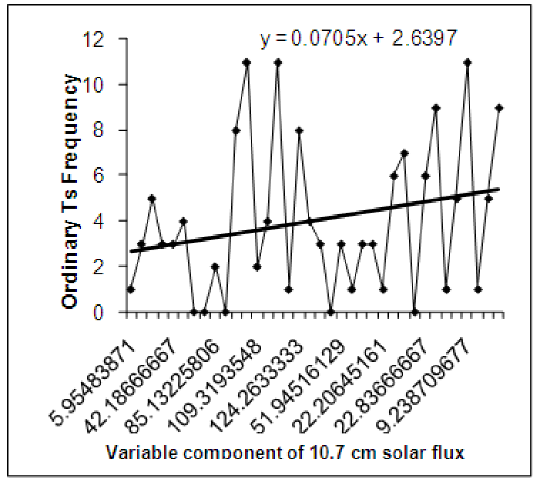


Figure 2(b) (i)

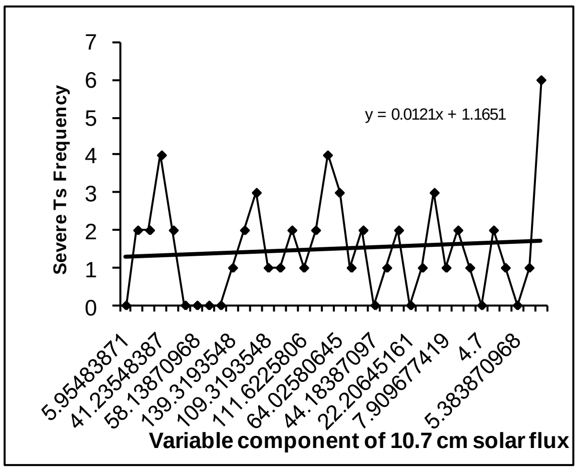
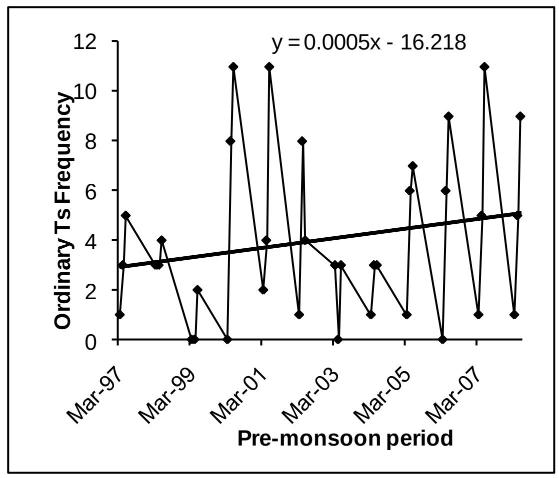


Figure 2(a) (i)



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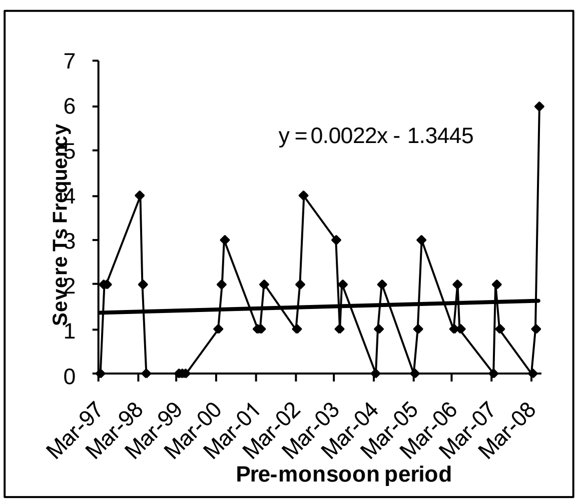

Figure 2(a) (ii)

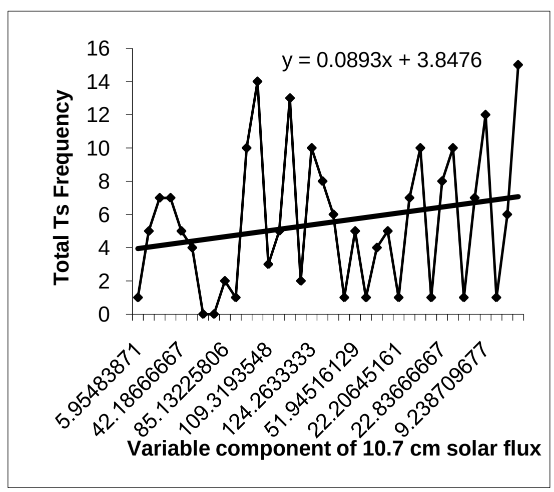

Figure 2(c) (i)

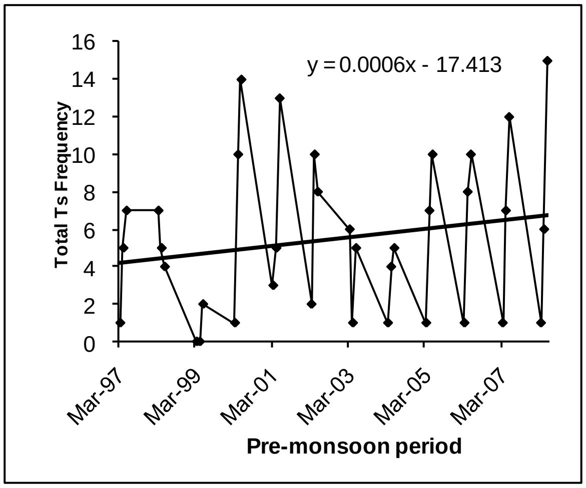

Figure 2(c) (ii)

Figure 2 (a)-(c): Comparison and Variation of (a) Severe, (b) Ordinary, and (c) Total Thunderstorm Frequency with the Variable Component of 10.7 cm Solar Flux during the Pre-Monsoon Season for the Period 1997- 2008.

Warm air has a lower density than cool air, so warm air rises within cooler air. Clouds form as relatively warmer air carrying moisture rises within cooler air. As the moist air rises, it cools causing some of the water vapor in the rising packet of air to condense. When the moisture condenses, it releases energy known as latent heat of fusion which allows the rising packet of air to cool less than its surrounding air, continuing the cloud's ascension.

If enough instability is present in the atmosphere, this process will continue long enough for cumulonimbus clouds to form, which support lightning and thunder. Generally, thunderstorms require three ingredients to form: (1) moisture, (2) an unstable air mass, and (3) a lifting force. Thus, the frequency of pre- monsoon thunderstorm increases during the solar peak phase. So it is also expected the increase of the pre-monsoon thunderstorm frequency (severe, ordinary and total) with the variable component of 10.7 cm solar flux increases as obtained in Figure 3 (a)-(c).

It is observed that O_3 is depleting over Kolkata with smaller amount [7]. The production of ozone-depleting gases is regulated under UN 1987 international agreement known as the “Montreal Protocol on Substances that Deplete the Ozone Layer” and its subsequent Amendments (London 1990, Nairobi 1991, Copenhagen 1992, Bangkok 1993, Vienna 1995, Montreal 1997 and Beijing 1999) and Adjustments that is now ratified by over 180 nations, establishes legally binding controls on the national production and consumption of Ozone Depleting Substance (ODS). The success of these international agreements has already been observed. As a result of the Montreal Protocol, the total abundance of ODSs in the atmosphere has begun to decrease in recent years. And as a result the concentration of ozone is increasing slightly to some extent.

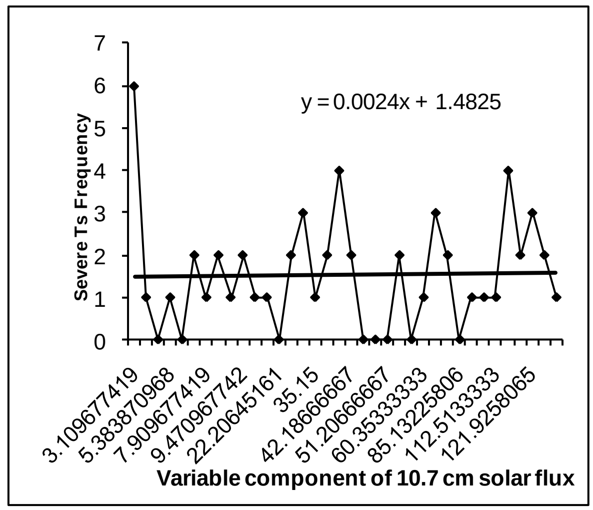

Figure 3(a)

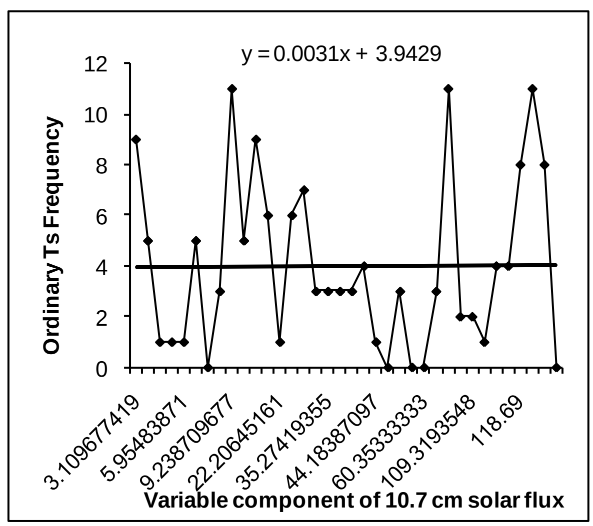

Figure 3(b)

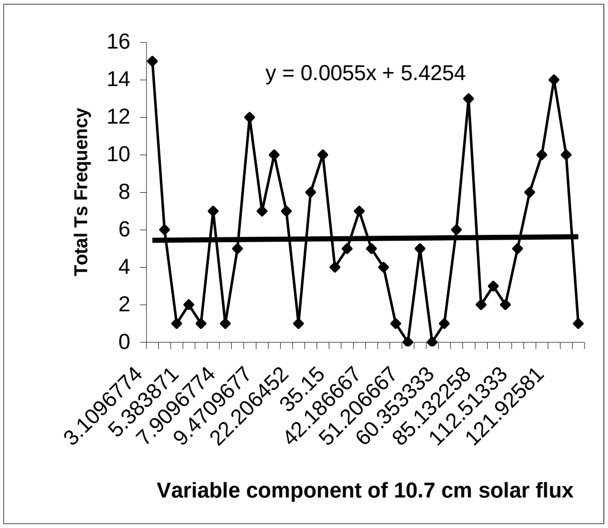

Figure 3(c)

Figure 3 (a)-(c): Increase of Severe, Ordinary and Total Thunderstorm Frequency with the Increase of Variable Component of 10.7 cm Solar Flux.

Figure 4 clearly indicates that the frequency of pre-monsoon thunderstorm over Kolkata is also in an increasing stage in the last few years. Recent research has revealed that the tiny pollutants can either inhibit thunderstorms or make them stronger depending on wind shear conditions.

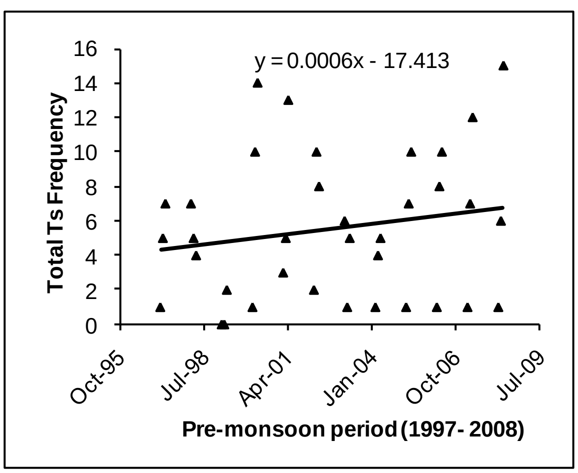

Figure 4: Increase in Total Pre-Monsoon Thunderstorm Frequency over Kolkata during the period 1997- 2008.

Wind shear occurs when wind begins to change velocity and direction along a wind stream. It is involved in forming storms, tornadoes, and other weather phenomena. Airplanes and jets often experience turbulence when there are changes in wind shear. When wind shear conditions are strong, aerosol pollution impedes the formation of thunderhead clouds. When wind shear is weak, the pollutants actually increase thunderhead development and cause storms to be stronger. The interaction between aerosol pollution and the formation of clouds has long been a mystery to scientists and climatologists.

Current research suggests that the microscopic, man-made particles may be severely altering the hydrological cycle. There may be limiting rainfall in some areas while increasing it in others. In another literature it is also shown that N_2O plays important role on depletion of ozone [6]. A model of nitrous oxide production by corona discharge in lightning appears able to quantitatively account for both storm cloud and laboratory observations of nitrous oxide enhancements if the N_2O yield from collisions between $N_2(A^3\ \Sigma)$ and O_2 molecules is large.

Global estimates of nitrous oxide production by lightning and by point discharges beneath thunderclouds are only of the order of thousands of tons of nitrous oxide per year; however, estimates of global production of N_2O by electrical, high voltage, power line coronas are from 1 to 2 orders of magnitude larger than by lightning [2]. This nitrous oxide is the dominant ozone depleting substance emitted in the 21st century [9]. On photo dissociation of N_2O, it yields nitric oxide (NO) as:

$$N_2O + h\upsilon \rightarrow NO + N$$

Depletion mechanism of O_3 as given by Crutzen [1], 1970 is given below:

$$NO + O_3 \rightarrow NO_2 + O_2$$
$$NO_2 + O \rightarrow NO + O_2$$
$$\overline{\hspace{5em}}$$
$$O_3 + O \rightarrow 2\ O_2$$

Thus, as the production of atmospheric N_2O increases, the depletion of O_3 occurs at a high rate. With the depletion of O_3 concentration, energetic solar UV ray passes through the stratosphere and falls on troposphere. It decomposes H_2O molecules and forms atomic oxygen and tropospheric bad ozone which acts as greenhouse gas. Besides these, due to industrial development at Kolkata, concentration of greenhouse gases increase. As a result, solar radiation is obstructed to reach the surface of earth. It decreases the evaporation rate and hence the frequency all types of the pre-monsoon thunderstorm increases.

CONCLUSION

It is concluded that the pre-monsoon thunderstorm frequency over Kolkata attains its maximum during solar peak phase of the 23rd solar cycle and it is due to the increase of solar activity. All types of pre-monsoon thunderstorm frequencies increases after the solar maximum due to the depletion of O_3 concentration and increase of greenhouse gases over Kolkata.

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