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Rate of change of total column ozone and monsoon rainfall - A co-variation with the variable component of 10.7 cm solar flux during pre-monsoon period

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सार – इस शोध पत्र में वर्ष 1997–2005 की अवधि में अलग–अलग मौसमों में 10.7 सै. मी. सौर फल्क्स के परिवर्तनशील घटकों से पश्चिमी बंगाल के गांगेय क्षेत्र में मानसून की कुल वर्षा और दमदम (22° 38´ उ. 88° 26´ पू.) में कुल कॉलम ओज़ोन (टी. सी. ओ.) की परिवर्तनशीलता की दर की परिवर्तिता पर एक गहन विश्लेषण किया गया है। इसमें मानसून पूर्व और मानसून की अवधि में टी. सी. ओ. के परिवर्तन दर के साथ परिवर्ती घटक के मध्य सहसंबंध प्रतिकूल पाया गया है और मानूसन के बाद तथा शीत ऋतु में यह सहसंबंध उल्लेखनीय रूप से सकारात्मक पाया गया है। इस अवधि में अलग–अलग ऋतुओं के दौरान परिवर्ती घटक और कुल मानसून वर्षा के मध्य पूर्णतया नगण्य रूप से सकारात्मक सहसंबध पाए गए हैं। मानसून पूर्व ऋतु के दौरान इस अध्ययन की पूरी अवधि में 10.7 सै. मी. सौर फल्क्स के परितर्वी घटक में वृद्धि सहित सहपरिवर्तिता पाई गई है। संभावित विवरणों को भी इस शोध पत्र में प्रस्तुत किया गया है।

ABSTRACT. A critical analysis is done on the variation of the rate of change of Total Column Ozone (TCO) over Dum Dum (22° 38′ N, 88° 26′ E) and Total Monsoon Rainfall over Gangetic West Bengal with the variable component of 10.7 cm solar flux during different seasons for the period 1997- 2005. An anti-correlation is observed between the variable component with the rate of change of TCO during the pre-monsoon and monsoon period and significant positive correlations during the post-monsoon and winter seasons. Quite insignificant positive correlations are observed between the variable component and Total Monsoon Rainfall during different seasons for this period. A co-variation is observed with the increase in the variable component of 10.7 cm solar flux throughout the period of study only during the pre-monsoon season. Possible explanations are also presented.

Key words – TCO, 10.7 cm Solar flux, Pre-monsoon, Correlation.

1. Introduction

Ozone is one of the most important constituents in the atmosphere and is the only gas that absorbs solar radiation at the ultraviolet end of the spectrum strongly. Stratospheric ozone protects the Earth's surface from harmful solar ultraviolet radiation (especially UV-B) and plays an important role in controlling the temperature structure of the stratosphere (Ghude *et al.,* 2005). Ozone is primarily formed by the photochemical action between solar UV-rays and oxygen molecules above tropopause to about 50 km with centre of mass at 25 km (Ghosh and Midya, 1994) and it plays important role to control the chemical kinetics of atmospheric constituents (Midya, 1994; Midya *et al*., 2001; Midya *et al*., 2002). At ground level, ozone is not in a stable state and is transformed into oxygen upon direct contact with organic materials and aerosols. Surface ozone concentration near the ground is maintained by the various factors involved in the transfer processes. The diurnal variation of surface ozone closely follows the diurnal variation of surface temperature (Tiwari and Sreedharan, 1973; Shreffler and Evans, 1982; Decker *et al.,* 1976; Evans *et al.,* 1983). Clubbed with this regular diurnal variation of surface ozone, different types of short term variations have also been observed. They are found to be associated with weather phenomena such as thunderstorms, vertical air currents and temperature inversions (Sreedharan and Tiwari, 1973; Guicherit and Dop, 1977; Sanhueza *et al.,* 1985; Broder *et al.,* 1981). Generally, the updrought associated with thunderstorms brings an ozone decrease, the following downdrought generates a prominent increase in ozone. During thunderstorms a two- to ten-fold increase in ozone has been reported from studies (Dobson *et al.,* 1956 and Vassy,1965). Monsoon season (June–September) rainfall is of great concern to the scientists in India because of its agricultural based economy. Several researchers have studied many aspects of monsoon season rainfall, *e.g.*, rainfall patterns (Vines,1986; Kulkarni *et al*., 1992), variability (Kripalani *et al*.,1995) etc.

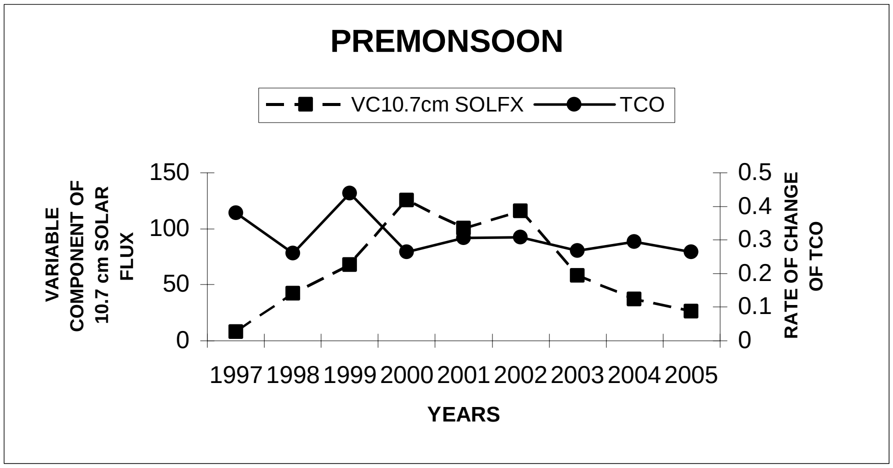


Fig. 1. Yearly variation of the pre-monsoon variable component of 10.7 cm solar flux (VC 10.7 cm SOLFX) and pre-monsoon rate of change of TCO over Dum Dum (1997- 2005)

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. 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 (Midya *et al.*, 1997). The variable component of 10.7 cm solar flux also plays important role on 6300 A° which is created mainly by the dissociative recombination of oxygen atom in the higher altitude level of the ionosphere (Midya and Chattopadhyay, 1996). The purpose of this paper is to present the variation of the rate of change of Total Column Ozone (TCO) over Dum Dum (22° 38′ N, 88° 26′ E) and total monsoon rainfall over Gangetic West Bengal with the variable component of 10.7 cm solar flux during different seasons for the period 1997- 2005.

2. Data and methodology

There are 306 precipitation observation stations equally distributed over about 90% of India. In addition, there are about 30 meteorological stations that began providing precipitation observations in every region since 1871. The ISMR sub divisional rainfall (Gangetic West Bengal) data set we used for this paper is from the Indian Institute of Tropical Meteorology (IITM), Pune taken from the website ftp://www.tropmet.res.in/pub/data/rain/iitm-subdivrf.txt.gz. The data set covers the time of the monsoon season, *i.e.*, from June to September of the years for 1997 through 2005. The ozone concentration over Dum Dum is taken from Earth Probe TOMS (Total Ozone Mapping Spectrometer) from the website http://jwocky.gfsc.nasa.gov/eptoms/data. The data set covers the different seasons for the period 1997-2005. As Dum Dum (22° 38′ N, 88° 26′ E) lies within Gangetic West Bengal, hence the monsoon rainfall data of this sub-division is collected. 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 NOAA, http://www.ngdc.noaa.gov/ngdc.html for the above-mentioned period. Daily value of 10.7 cm solar flux (adjusted to 1 AU) is plotted against daily value of relative sunspot numbers. A line of most probable relation between these two parameters is obtained. Extrapolating to zero sunspot area, the basic component or the quiet sun emission is obtained. The emission above the base level is the variable component of 10.7 cm solar flux. These values are calculated for pre-monsoon, monsoon, post-monsoon and winter periods separately and analyses for different periods are done.

3. Results and discussion

The yearly variation of the variable component of 10.7 cm solar flux with each of the pre-monsoon rate of change of TCO over Dum Dum and Total monsoon rainfall over Gangetic West Bengal has an anti-correlation (r = - 0.146) and a very poor correlation (r = 0.096) respectively (Fig. 1 and Fig. 2). The correlation coefficient

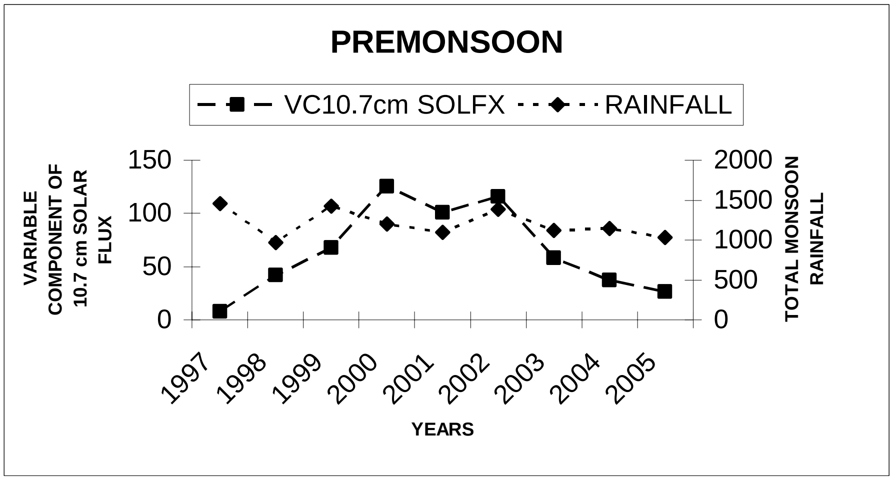
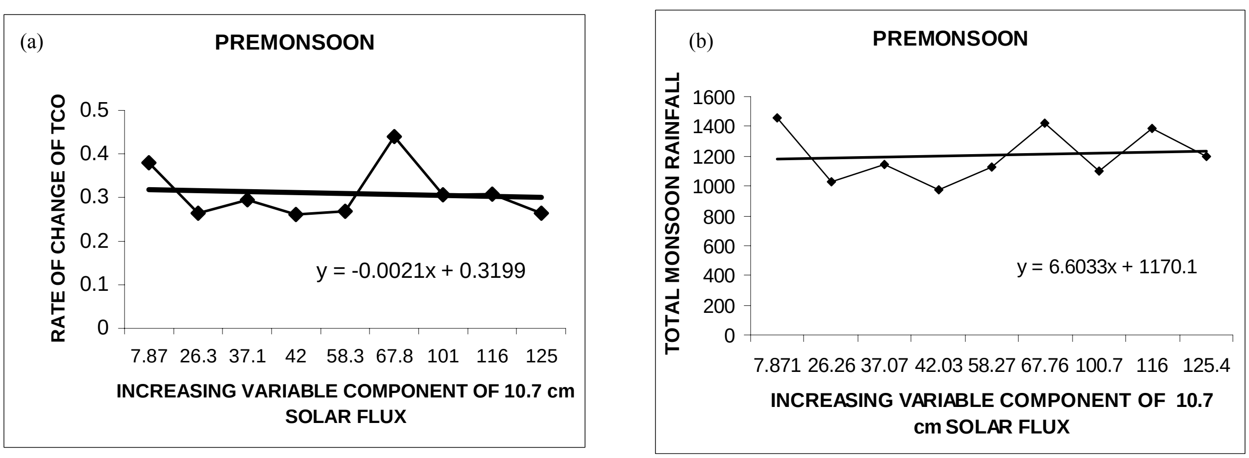


Fig. 2. Yearly variation of the pre-monsoon variable component of 10.7 cm solar flux (VC 10.7 cm SOLFX) and total monsoon rainfall over Gangetic West Bengal (1997- 2005)

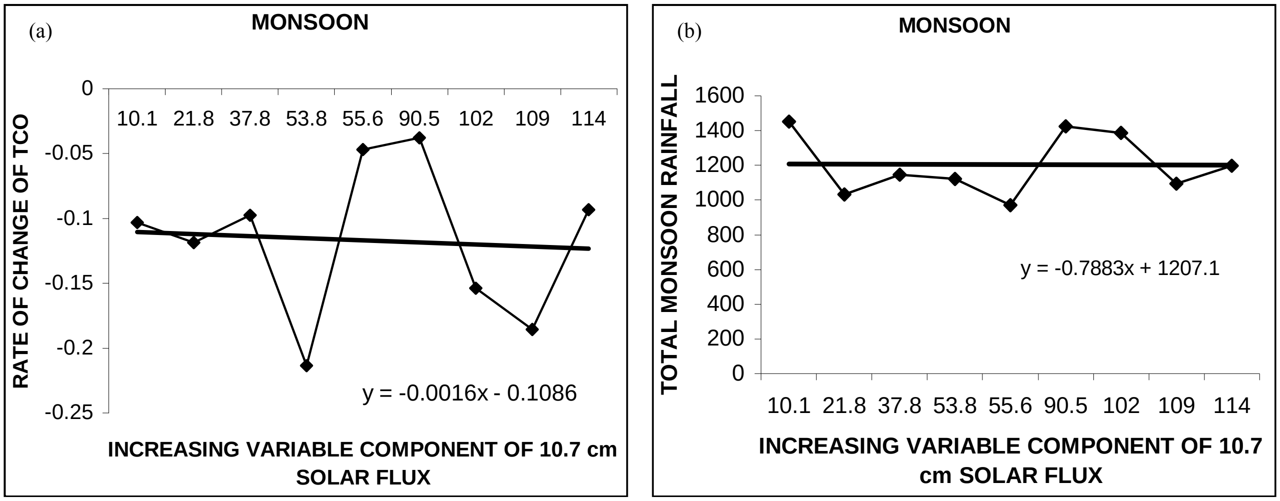


Figs. 3(a&b). (a) Variation of pre-monsoon rate of change of TCO over Dum Dum with the pre-monsoon increasing variable component of 10.7 cm solar flux throughout the period 1997- 2005 and (b) Variation of total monsoon rainfall over Gangetic West Bengal with the pre-monsoon increasing variable component of 10.7 cm solar flux throughout the period 1997- 2005

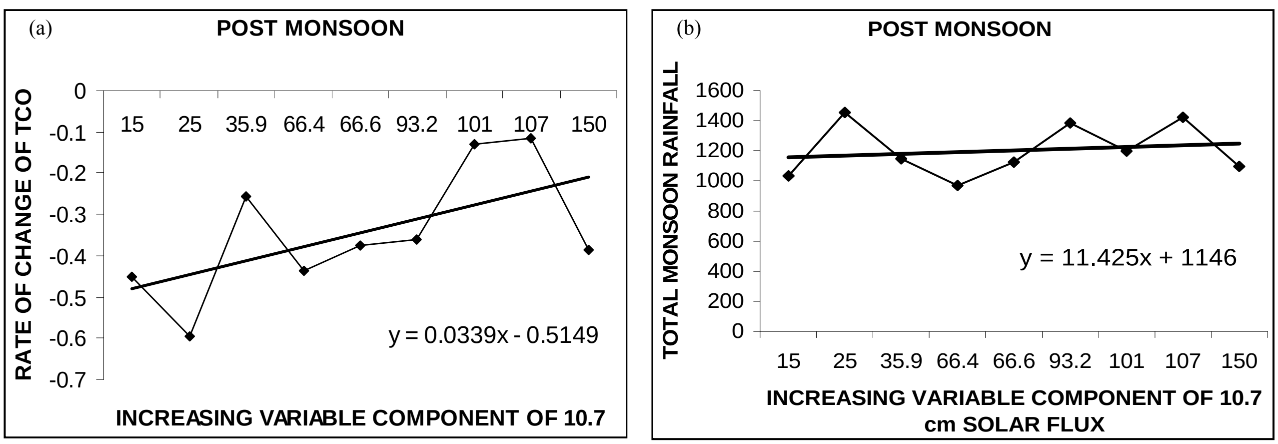
TABLE 1

Correlation coefficient between the variable component of 10.7 cm solar flux with the rate of change of TCO over Dum Dum and Total monsoon rainfall over Gangetic West Bengal during different seasons

Seasons	Correlation coefficient between the variable component of 10.7 cm solar flux with		Results with correlation coefficient between variable component of 10.7 cm solar flux with	
	Rate of change of TCO	Total monsoon rainfall	Rate of change of TCO	Total monsoon rainfall
Pre-monsoon	$r = -0.146$	$r = 0.096$	Anti-correlation	Very poor correlation
Monsoon	$r = -0.108$	$r = 0.103$	Anti-correlation	Poor correlation
Post-monsoon	$r = 0.483$	$r = 0.080$	Positive correlation	Insignificant correlation
Winter	$r = 0.500$	$r = 0.260$	Positive correlation	Positive correlation

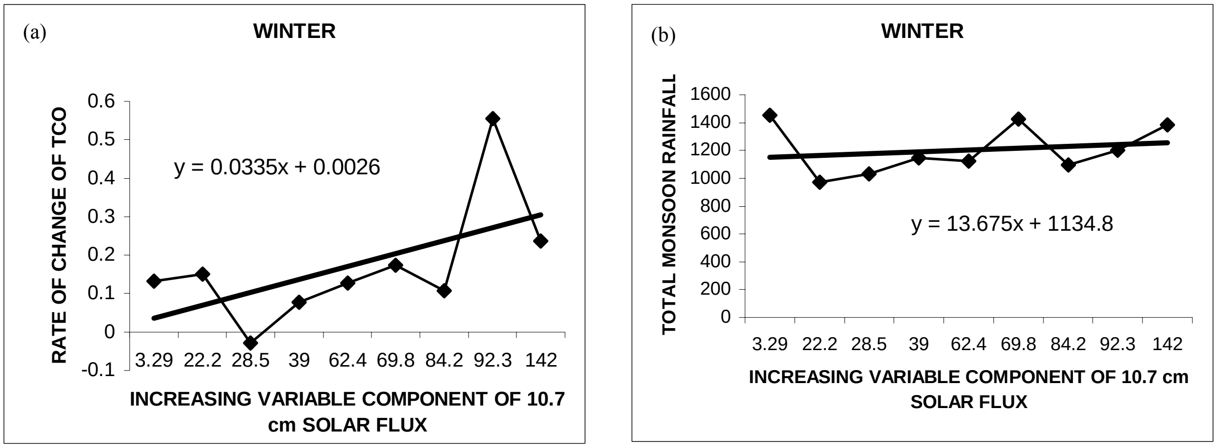


Figs. 4(a&b). (a) Variation of monsoon rate of change of TCO over Dum Dum with the monsoon increasing variable component of 10.7 cm solar flux throughout the period 1997-2005 and (b) Variation of Total monsoon rainfall over Gangetic West Bengal with the monsoon increasing variable component of 10.7 cm solar flux throughout the period 1997-2005



Figs. 5(a&b). (a) Variation of post-monsoon rate of change of TCO over Dum Dum with the post-monsoon increasing variable component of 10.7 cm solar flux throughout the period 1997-2005 and (b) Variation of Total monsoon rainfall over Gangetic West Bengal with the post-monsoon increasing variable component of 10.7 cm solar flux throughout the period 1997-2005

between the variable component of 10.7 cm solar flux with the rate of change of TCO and total monsoon rainfall for different seasons are presented in Table 1. The rate of change of TCO during pre-monsoon and monsoon season has a decreasing trend and an increasing trend during post-monsoon and winter seasons with the increasing variable component of 10.7 cm solar flux throughout the period of study and the total monsoon rainfall during pre-monsoon, post-monsoon and winter seasons has an increasing trend with the increasing variable component of 10.7 cm solar flux, except during the monsoon season which has a slight decreasing trend having insignificant correlation [Figs. 3(a&b), Figs. 4(a&b), Figs. 5(a&b) and Figs. 6(a&b)]. During pre-monsoon period, rate of formation of ozone predominates. Rate of formation of TCO is expected to decrease with the increase of variable component of 10.7 cm solar flux. India being a tropical country, solar radiation on Earth surface is maximum during the pre-monsoon and monsoon periods. Solar activity plays a major role on decomposition of ozone. So the nature of variation of rate of change of TCO *w.r.t.* variable component of 10.7 cm solar flux as shown in Fig. 3 (a) and Fig. 4 (a) is quite expected. Solar activity decreases during the post-monsoon and winter periods. So



Figs. 6(a&b). (a) Variation of winter rate of change of TCO over Dum Dum with the winter increasing variable component of 10.7 cm solar flux throughout the period 1997-2005 and (b) Variation of Total monsoon rainfall over Gangetic West Bengal with the winter increasing variable component of 10.7 cm solar flux throughout the period 1997-2005

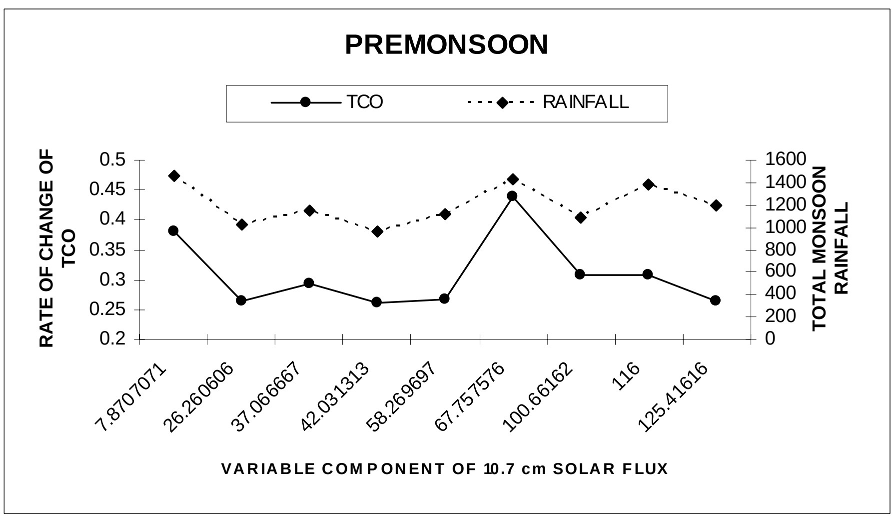


Fig. 7. Co-variation of the pre-monsoon rate of change of TCO over Dum Dum and Total monsoon rainfall over Gangetic West Bengal with the gradually increasing variable component of 10.7 cm solar flux (1997- 2005)

the nature of variation between the rate of change of TCO and variable component of 10.7 cm solar flux as shown in Fig. 5 (a) and Fig. 6 (a) is justified. Another study is that with the increasing pre-monsoon variable component of 10.7 cm solar flux, a co-variation is observed only between the pre-monsoon rate of change of TCO over Dum Dum and total monsoon rainfall over Gangetic West Bengal with statistically significant correlation coefficient, $r = 0.802$ (Fig. 7) but this co-variation is absent during the other seasons.

Monsoon rainfall is highly related with the amount of water vapor produced in the atmosphere. Due to the increase of solar activity, the rate of evaporation increases; as a result, the production of water molecules in vapour state increases. Hence, it is expected that the monsoon rainfall over Gangetic West Bengal increase with the increasing variable component of 10.7 cm solar flux during the pre-monsoon season, as shown in Fig. 3 (b). The same reason is valid for the other seasons [Fig. 5(b) and Fig. 6 (b)]. Due to the increase of cloud coverage in the monsoon season, the incoming solar activity is obstructed and hence the slight decreasing trend between Total monsoon rainfall and increasing variable component of 10.7 cm solar flux is quite expected [Fig. 4(b)].

4. Conclusion

During pre-monsoon season, it is expected that earth surface receives maximum amount of solar energy. As a result, evaporation rate increases. O_3 is created due to the decomposition of water molecules (Ghosh and Midya, 1994) as:

$$H_2O + h\upsilon \rightarrow OH + H \quad (1)$$

$$OH + h\upsilon \rightarrow O + H \quad (2)$$

$$O + O + M \rightarrow O_2 + M \quad (3)$$

$$O_2 + O + M \rightarrow O_3 + M \quad (4)$$

M is the third body which conserves energy and momentum of the reaction.

Rate of formation of water molecules in vapour state depends on variable component of 10.7 cm solar flux. Again monsoon rainfall mainly depends on the rate of evaporation of water molecules during pre-monsoon season. Evaporation rate is high during this season, so the co-variation between total monsoon rainfall and rate of change of TCO with the increasing variable component of 10.7 cm solar flux is justified (Fig. 7).

During monsoon period, solar radiation is obstructed to reach the ground due to cloud coverage. As a result, decomposition of H_2O molecules is affected and formation of TCO will be affected. Solar radiation reaching the Earth surface is also minimum during the rest of the seasons *w.r.t.* pre-monsoon period. For this reason, an insignificant co-variation between rate of change of TCO and summer monsoon rainfall with the increasing variable component of 10.7 cm solar flux is obtained.

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