Inter-relation amongst the different Atmospheric Parameters to Estimate Summer Monsoon Rainfall over Gangetic, West Bengal: A Multiple Linear Regression Approach.

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ABSTRACT

A critical analysis for the inter-relation among some important atmospheric parameters affecting monsoon rainfall over Gangetic West Bengal is done and their seasonal variability is studied for the period 1997- 2005. A Multiple Linear Regression (MLR) method is also carried out to find out the percent dependence of those parameters affecting monsoon rainfall to estimate the summer monsoon rainfall over Gangetic, West Bengal during different seasons throughout the period of study. It is found that there is a strong inter-relation between El Nino Index with Solar Flare Index during the pre-monsoon season and with surface temperature of Kolkata ($22^0$30'N, $88^0$24'E) for the other seasons. MLR method clearly indicates that Total Column Ozone (TCO) plays an important role and has the highest contributing factor in the pre-monsoon season and surface temperature of Kolkata is the predominating factor for rest of the seasons to estimate the summer monsoon rainfall over Gangetic, West Bengal, India.

(Keywords: monsoon, MLR, El Nino, pre-monsoon, TCO, rainfall)

INTRODUCTION

Indian Summer Monsoon Rainfall (ISMR), a part of the Asian monsoon system, is well known for its influence on the socio-economic conditions of most of the population in the Indian subcontinent. More than 80% of annual rainfall over India comes as summer monsoon rainfall during the months of June to September. This rainfall is an important component of the climate system in South Asia and has huge effect on production and life in this region.

Rasmusson *et al*., (1983) and Loschnigg *at al*., (2000) made some studies which linked monsoon rainfall with sea surface temperature (SST) in the Pacific Ocean. In the Indian Ocean, studies have also been established by Clark *et al*., (2000), Li *et al*., (2001), and Zhang *et al*., (2000) which indicates a positive relation between monsoon rainfall over India and variability in the equatorial SST. Recently it is reported by Yang *et al.,* (2001) and Zhao *et al*., (2004) that monsoon rainfall is affected by snow deposition on the Tibetan plateau. Xiao *et al*., (2000) and Lihua *et al.* (2007) found that the rainfall in the Jiangnan region of China is possibly related to ISMR changes.

Some studies by Chattopadhyay *et al.*, (1995.), Parthasarathy *et al*., (1992)., Bansod *et al.,* (1995), Mooley *et al*., (1985) Nicholls *et al.,* (1995) and Gadgil *et al.,* (2004), show that the ISMR change relates to some meteorological parameters and phenomena, including surface temperature, surface relative humidity, sea level barometric pressure, El Nino/Southern Oscillation (ENSO) events. It is also well established by Lihua *et al.*, (2007) and Hiremath *et al.,* (2004) that Quasi Biennial Oscillation (QBO), Cloud condensation nuclei counter, aerosol concentration, relative sunspot number (SSN). Midya *et al.,* (2011a) reported that 10.7 cm solar flux play important role on ISMR. In another communication, Midya *et al.,*(2011b) reported that pre-monsoon rate of change of TCO has some role to forecast monson rain. It is also reported that rate of formation of TCO is maximum during pre-monsoon period and rain occurs only when TCO lies in a certain concentration level (Midya *et al.,* 2011c, *et al.,* and 2011d). Midya (1994) showed that the minor constituent O_3 plays important role to control the chemical kinetics of atmospheric constituents. It is recently reported by Ganguly (2007) that the ozone concentration on the Indian forest changes due to some special type of reactions and has significant role on rainfall over forest region. It is being enhanced by the increase in the NOx concentration either on the forests or in the cities, located in the proximity of these forests, suggesting a faster transportation of the NOx to the surroundings from its sources (Ganguly *et al.,* 2006). Here we consider only six parameters, namely Total Column Ozone (TCO), Surface Temperature (T) & Surface Relative Humidity (Rh) over Kolkata (22^{0}30'N, 88^{0}24'E), El Nino Index (EN), Solar Flare Index of Northern Hemisphere (SFI) and 10.7 cm Solar Flux (SF), affecting summer monsoon rainfall over Gangetic West Bengal. The purpose of this paper is to present the inter-relation among different atmospheric parameters affecting monsoon rainfall and to establish one important relation, which connect the Total Summer Monsoon Rainfall and the parameters affecting monsoon rainfall.

DATA AND METHODOLOGY

The data used in the complete study for the analysis of inter-relationship amongst different atmospheric parameters on the variability of summer monsoon rainfall over Gangetic West Bengal, India is listed below:

1. Daily Total Column Ozone concentration over Dum Dum of all the seasons for the period 1997-2005 is taken from Earth Probe TOMS (Total Ozone Mapping Spectrometer) from the website http://jwocky.gfsc.nasa.gov/eptoms/data.

2. Daily Surface parameter data containing Surface Temperature and Surface Relative Humidity over Kolkata during all the seasons for the period 1997- 2005 is taken from the website http://weather.uwyo.edu/upperair.

3. The three monthly running mean data for the El Nino Index is taken from National Climatic Data Center from the website http://www.ncdc.noaa.gov/enso.

4. Daily Solar Activity data such as Solar Flare Index and 10.7 cm Solar Flux is taken from Solar Geophysical Data Book from the website ftp://ftp.ngdc.noaa.gov.

5. 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 used for our study is from the Indian Institute of Tropical Meteorology, Pune (IITM). The data set covers the time of the monsoon period, i.e. from June to September of the years for 1997 through 2005.

The collected data were divided into the following four parts:

- **Pre-monsoon season**– the months of March, April, May and upto 7th June.
- **Monsoon season** – the months of June (8th onwards), July, August, September and October (up to 10th).
- **Post-Monsoon season** – the months of October (11th) onwards, November & December.
- **Winter season** – the months of January & February.

The different atmospheric parameters is plotted against Time (days), in a scatter diagram, for different seasons as mentioned above for the time period 1997- 2005 to obtain the rate of change of the parameters affecting Monsoon Rainfall over Gangetic West Bengal. Midya and Saha, 2011 show the pre-monsoon rate of change of TCO in another communication, given in Figure 1. Similar analysis is done with the other parameters during different seasons. Now the obtained rates of change of different atmospheric parameters affecting monsoon rainfall are plotted individually against themselves in a scattered linear plot for different seasons. The maximum inter related atmospheric parameter pairs are shown in Figures 2- 5. The plots of the rate of change of other parameters are similarly done. The obtained slopes for the strongly inter-dependent parameters are now considered to find out the percent-dependence on one another for all the seasons within 1997- 2005 (Figures 6- 9).

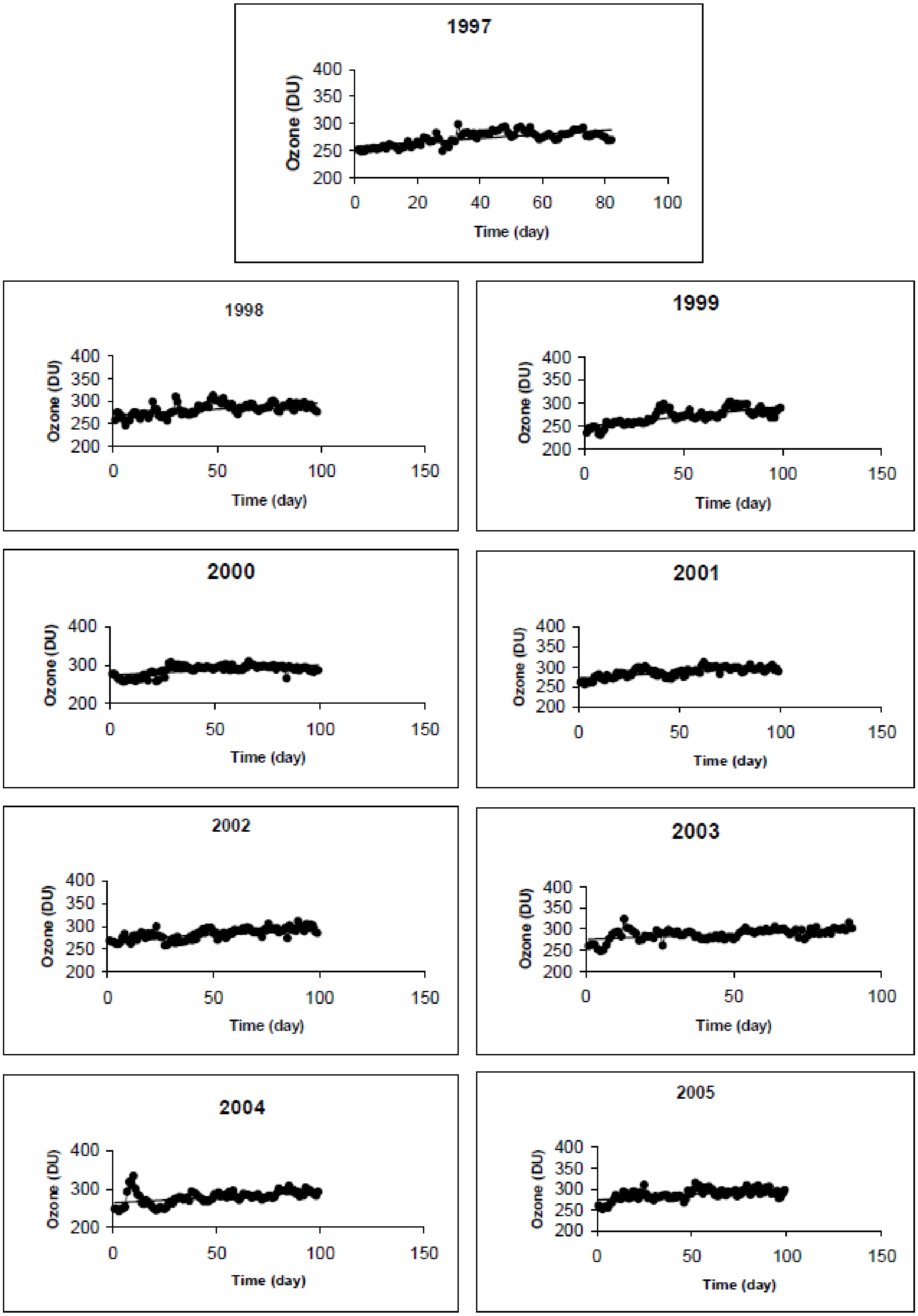

Figure 1: Pre-monsoon Daily Variation of TCO over Dum Dum for 1997-2005.

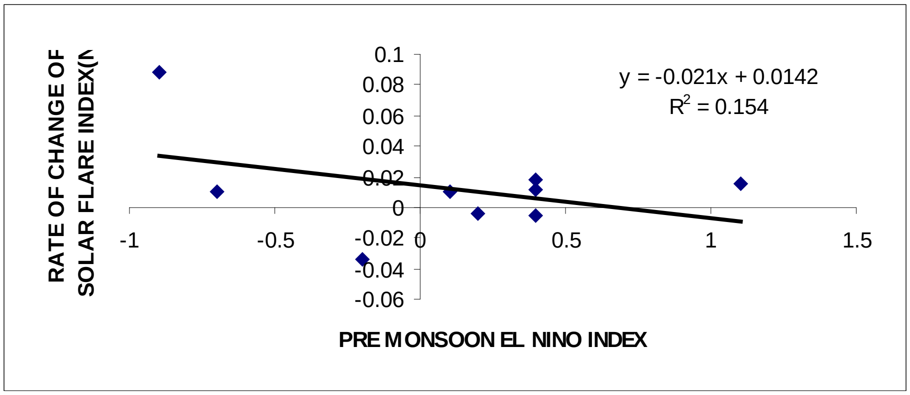

Figure 2: Pre-monsoon variation of El Nino Index with Solar Flare Index of the Northern Hemisphere for the period 1997-2005.

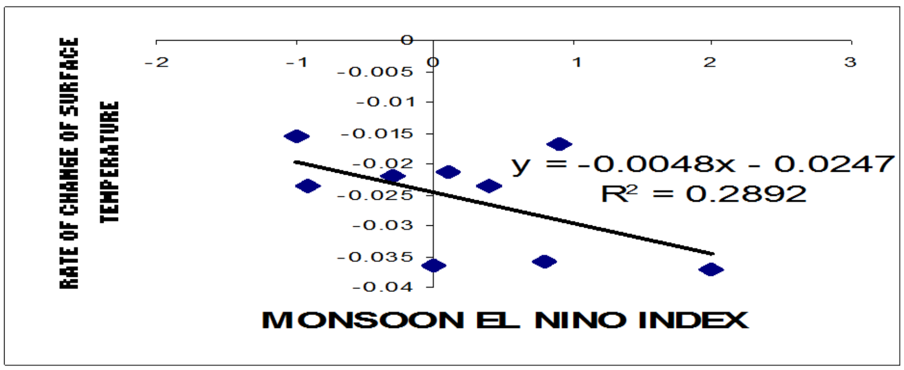

Figure 3: Monsoon variation of El Nino Index with Rate of change of Surface Temperature of Kolkata for the period 1997-2005.

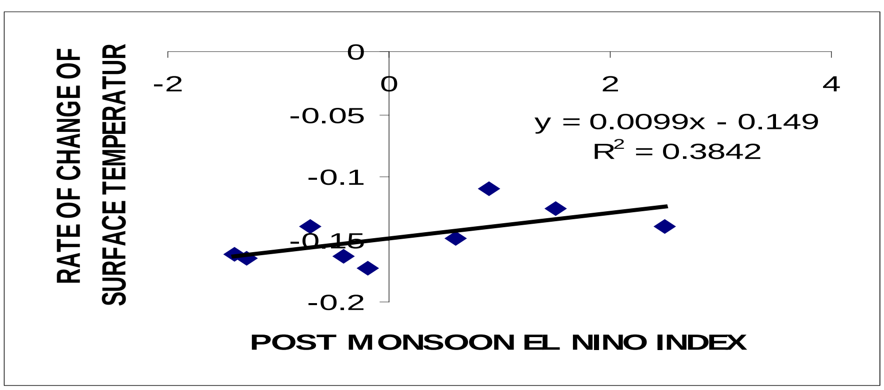

Figure 4: Post-monsoon variation of El Nino Index with Rate of change of Surface Temperature of Kolkata for the period 1997-2005.

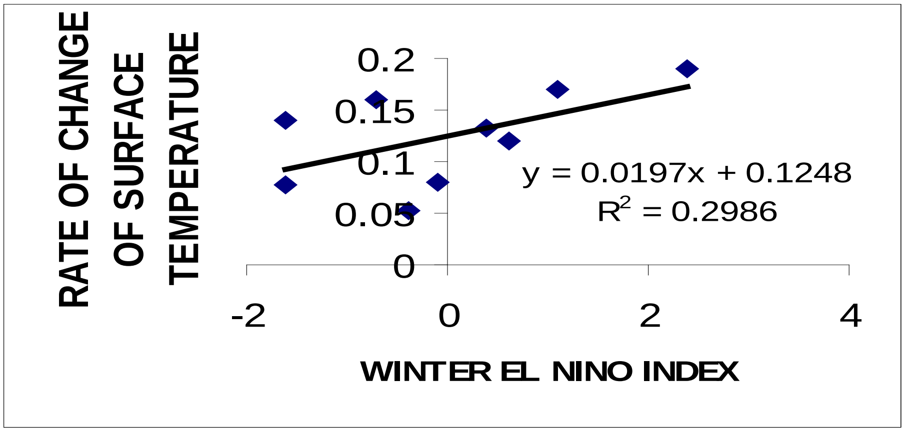

Figure 5: Winter variation of El Nino Index with Rate of change of Surface Temperature of Kolkata for the period 1997-2005.

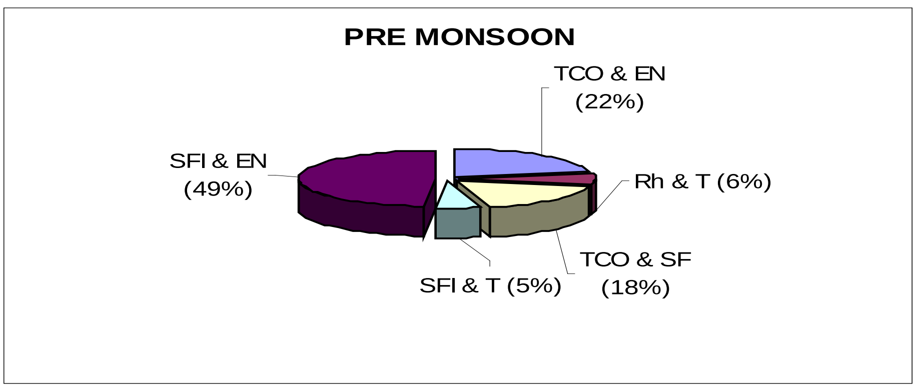

Figure 6: Percentage Inter-dependence between the Atmospheric Parameters during Pre-monsoon Season (1997-2005).

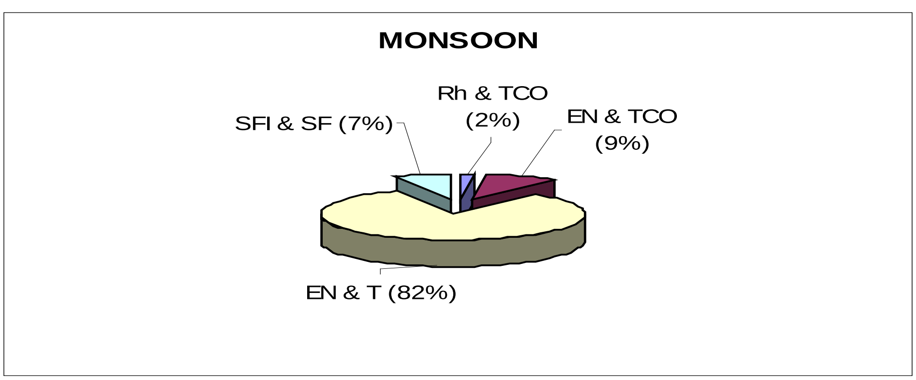

Figure 7: Percentage Inter-dependence between the Atmospheric Parameters during Monsoon Season (1997-2005).

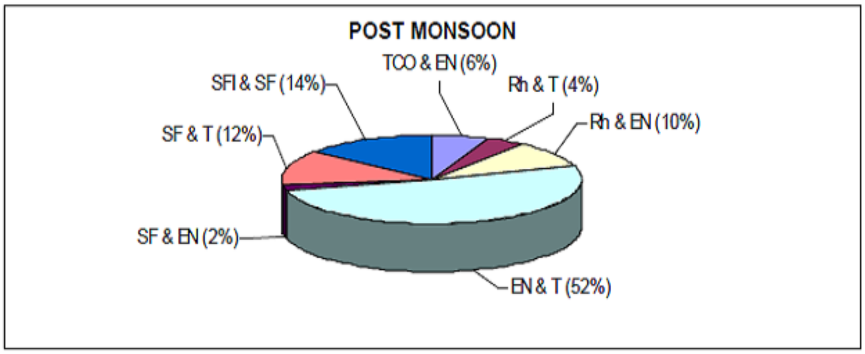

Figure 8: Percentage Inter-dependence between the Atmospheric Parameters during Post-monsoon Season (1997-2005).

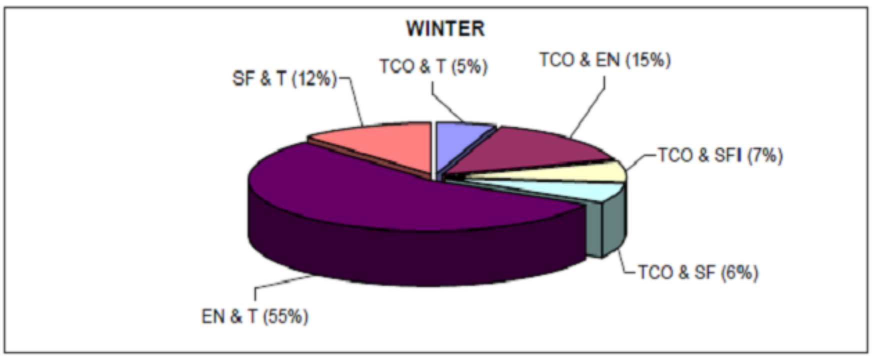

Figure 9: Percentage Inter-dependence between the Atmospheric Parameters during Winter Season (1997-2005).

A Multiple Linear Regression (MLR) method is adopted to estimate the total summer monsoon rainfall over Gangetic West Bengal in a given year using the percentage contribution of the different atmospheric parameters affecting monsoon rainfall.

RESULTS AND DISCUSSION

From the correlation coefficients (Table 1), it is clear that 5 pairs of the atmospheric parameters (TCO & EN, Rh & T, TCO & SF, SFI & T and SFI & EN) are strongly inter- related among themselves during pre-monsoon season. During the monsoon season, 4 pairs (Rh & TCO, EN & TCO, EN & T and SFI & SF); 7 pairs of parameters (TCO & EN, Rh & T, Rh & EN, EN & T, SF & EN, T & SF and SFI & SF) during post-monsoon season and in the winter season, 6 pairs of atmospheric parameters (TCO & T, TCO & EN, TCO & SFI, TCO & SF, EN & T and SF & T) affecting summer monsoon rainfall over Gangetic West Bengal are strongly interdependent on each other (Table1).

The pairs not considered for the individual seasons are either independent or insignificant to each other for those seasons throughout the period of study (1997- 2005). During the pre-monsoon season, the maximum percentage dependence is obtained for the Solar Flare Index and El Nino phenomenon (48.75 %) (Figure 6).

Table 1: Atmospheric Parameters Affecting Monsoon Rainfall over Gangetic, West Bengal.

(a) Correlation Coefficients among the rate of change of different atmospheric parameters affecting monsoon rainfall over Gangetic West Bengal during the pre- monsoon season for the period 1997- 2005.

	Total Column Ozone	Relative Humidity	Surface Temperature	El Nino Index	Solar Flare Index (N)	10.7 cm Solar Flux
Total Column Ozone	1.00	0.0563	0.0643	0.1131	0.0489	0.4656
Relative Humidity	0.0563	1.00	0.1441	0.0012	0.0895	0.0525
Surface Temperature	0.0643	0.1441	1.00	0.05	0.1382	0.0005
El Nino Index	0.1131	0.0012	0.05	1.00	0.154	0.0005
Solar Flare Index (N)	0.0489	0.0895	0.1382	0.154	1.00	0.0016
10.7 cm Solar Flux	0.4656	0.0525	0.0005	0.0005	0.0016	1.00

(b) Correlation Coefficients among the rate of change of different atmospheric parameters affecting monsoon rainfall over Gangetic West Bengal during the monsoon season for the period 1997- 2005.

	Total Column Ozone	Relative Humidity	Surface Temperature	El Nino Index	Solar Flare Index (N)	10.7 cm Solar Flux
Total Column Ozone	1.00	0.182	0.0035	0.1738	0.0007	0.0737
Relative Humidity	0.182	1.00	0.0039	0.0347	0.0393	0.0051
Surface Temperature	0.0035	0.0039	1.00	0.2892	0.0039	0.0517
El Nino Index	0.1738	0.0347	0.2892	1.00	0.0384	0.0703
Solar Flare Index (N)	0.0007	0.0393	0.0039	0.0384	1.00	0.4121
10.7 cm Solar Flux	0.0737	0.0051	0.0517	0.0703	0.4121	1.00

(c) Correlation Coefficients among the rate of change of different atmospheric parameters affecting monsoon rainfall over Gangetic West Bengal during the post- monsoon season for the period 1997- 2005.

	Total Column Ozone	Relative Humidity	Surface Temperature	El Nino Index	Solar Flare Index (N)	10.7 cm Solar Flux
Total Column Ozone	1.00	0.0196	0.0201	0.2979	0.065	0.0897
Relative Humidity	0.0196	1.00	0.3422	0.4016	0.0436	0.1288
Surface Temperature	0.0201	0.3422	1.00	0.3842	0.092	0.3158
El Nino Index	0.2979	0.4016	0.3842	1.00	0.0952	0.1462
Solar Flare Index (N)	0.065	0.0436	0.092	0.0952	1.00	0.7921
10.7 cm Solar Flux	0.0897	0.1288	0.3158	0.1462	0.7921	1.00

(d) Correlation Coefficients among the rate of change of different atmospheric parameters affecting monsoon rainfall over Gangetic West Bengal during the winter season for the period 1997- 2005.

	Total Column Ozone	Relative Humidity	Surface Temperature	El Nino Index	Solar Flare Index (N)	10.7 cm Solar Flux
Total Column Ozone	1.00	0.0328	0.1538	0.2438	0.2615	0.3381
Relative Humidity	0.0328	1.00	0.0028	0.0479	0.0569	0.0668
Surface Temperature	0.1538	0.0028	1.00	0.2986	0.011	0.1357
El Nino Index	0.2438	0.0479	0.2986	1.00	0.0345	0.0952
Solar Flare Index (N)	0.2615	0.0569	0.011	0.0345	1.00	0.0287
10.7 cm Solar Flux	0.3381	0.0668	0.1357	0.0952	0.0287	1.00

It is due to the fact that during the pre-monsoon (1st March to 7th June) period, the Indian region is marked by clear skies, which, coupled with intense as well as increased solar radiation, result in high temperatures. *El Nino* (or *La Nina*, depending on its phase) is characterized by warming or cooling of surface waters in the tropical eastern Pacific Ocean. When the warm oceanic phase (known as *El Nino*) is in effect, surface pressures in the western Pacific are high, and when the cold phase is in effect (*La Nina*), surface pressures in the western Pacific are low. El Nino's warm rush of nutrient-rich tropical water, heated by its eastward passage in the Equatorial Current, replaces the cold, nutrient-rich surface water of the Humboldt Current. During the last several decades the number of El Nino events increased, and the number of La Nina events decreased (Trenberth *et al*., 1996). The studies of historical data show that the recent El Nino variation is most likely linked to global warming. Federov *et al*., (2000) and Zhang et al., (2008) reported that even after subtracting the positive influence of decadal variation, shown to be possibly present in the ENSO trend, the amplitude of the ENSO variability in the observed data still increases, by as much as 60% in the last 50 years .

Flares increase the sun's UV radiation level by at least 16 percent Heath (1977). Ozone in the stratosphere absorbs this excess energy that causes local warming. The 70-mb polar vortex is displaced. This disturbance is propagated downward to the troposphere where it affects the intensity of the Hadley circulation. Hartley *et al.*, (1998) have shown that there is a dynamical link between stratospheric polar vortex distortions and meteorological events in the troposphere. As El Ninos are linked to trade winds and trade-winds to the Hadley cells that may be affected by circulation change in the stratosphere, it seems plausible that energetic solar eruptions could be the cause of this chain of links. The increase in solar radiation increases the solar activity, causing global warming and is thus related to El Nino phenomenon.

The maximum percentage dependence for the monsoon, post-monsoon and winter season is obtained for the El Nino and Surface Temperature pair (Figures 7- 9). In every case, the dependence- percentage is above 50% and is maximum for monsoon season (82.28%). The anomalous high value of TOC (Total Ozone Column) is found to coincide with the warmer temperature over the Indian subcontinent. The increase in surface temperature due to increased solar radiation quickly warm up the surface oceanic water and thus the warm current off the coastal waters off Peru and equatorial regions of South America enters the Indian Ocean where the pressures tended to be low causing extensive ocean warming and its economic impact to local fishing for an international market can be serious due to the occurrence of El Nino event.

ENSO events are the strongest source of variability in the global climate system and explain most of the global temperature anomalies as reported by Daly (1998). Thus, the surface temperature and El Nino Index is strongly inter-related for these seasons. The inter-relationship between El Nino and Surface Temperature needs investigation by the scientific community in greater detail.

The MLR equation after computation is given as:

For the pre-monsoon season,

$$M_{monsoon\ rainfall} = 300.6203839 + 3516.892235\,[TCO] - 3245.93369\,[T] + 268.151933[Rh] + 102.9544029\,[EN] + 1960.58043\,[SFI] - 320.4424856\,[SF] \quad \textbf{(1)}$$

For the monsoon season,

$$M_{monsoon\ rainfall} = 1726.778236 + 1791.18235\,[TCO] + 13802.58584\,[T] + 539.4548373[Rh] + 222.8014627\,[EN] + 114.6964703\,[SFI] - 250.4907149\,[SF] \quad \textbf{(2)}$$

For the post-monsoon season,

$$M_{monsoon\ rainfall} = -\,103.9636902 + 1925.023075\,[TCO] - 14119.76148\,[T] + 98.43824685[Rh] + 322.4277247\,[EN] + 114.6964703\,[SFI] - 250.4907149\,[SF] \quad \textbf{(3)}$$

For the winter season,

$$M_{monsoon\ rainfall} = 1593.131667 - 334.1332967\,[TCO] - 2563.61324\,[T] + 161.812971[Rh] - 47.59748975\,[EN] + 1246.428808\,[SFI] - 23.34978855\,[SF] \quad \textbf{(4)}$$

It is found after MLR computation that TCO contributes the maximum percentage in the pre monsoon season (37.36%) whereas during the monsoon, post-monsoon and winter season, Surface Temperature over Kolkata contributes the highest percentages to estimate the summer monsoon rainfall over Gangetic West Bengal (Figures 10- 13).

CONCLUSION

From the analysis, it is concluded confirmedly that during the pre-monsoon season, El Nino Index is strongly inter-related with the Solar Flare Index of the Northern Hemisphere and Total Column Ozone contributes the maximum percentage to estimate the Total Monsoon Rainfall over Gangetic West Bengal.

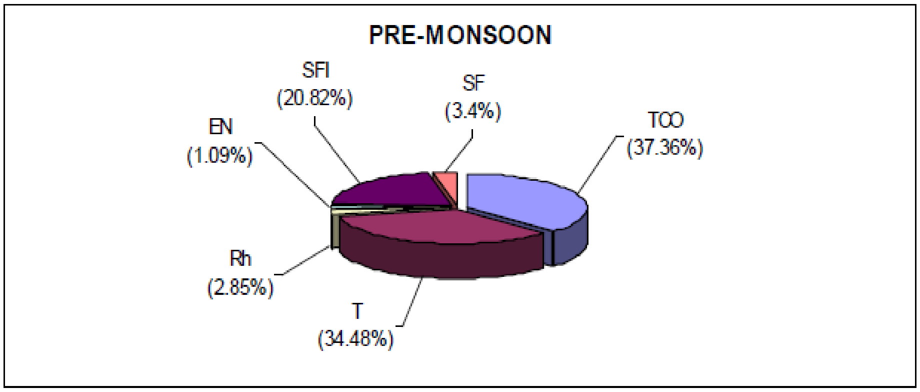

Figure 10: Percentage Dependence of the Parameters during Pre-monsoon Season to Estimate Monsoon Rainfall over Gangetic, West Bengal.

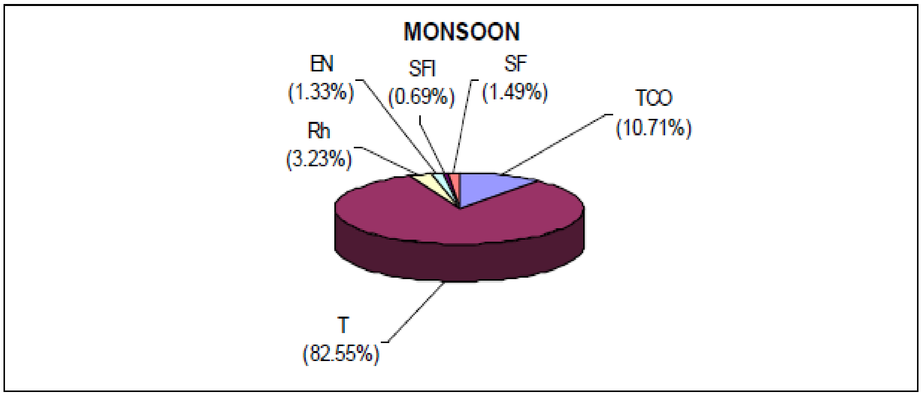

Figure 11: Percentage Dependence of the Parameters during Monsoon Season to Estimate Monsoon Rainfall over Gangetic, West Bengal.

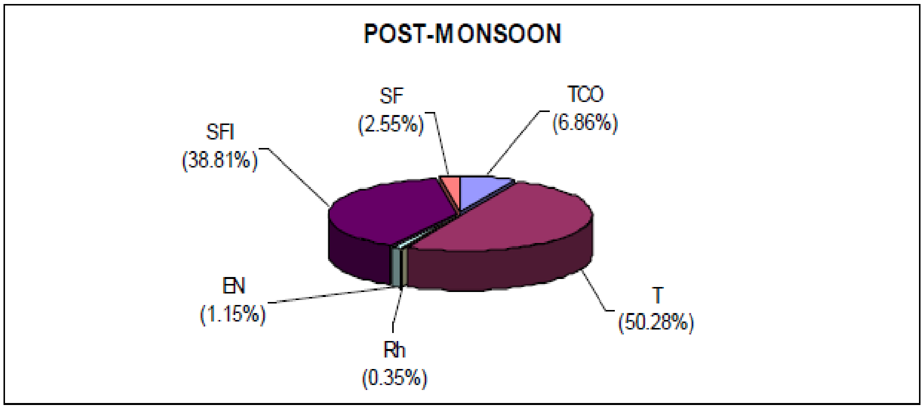

Figure 12: Percentage Dependence of the Parameters during Post-monsoon Season to Estimate Monsoon Rainfall over Gangetic, West Bengal.

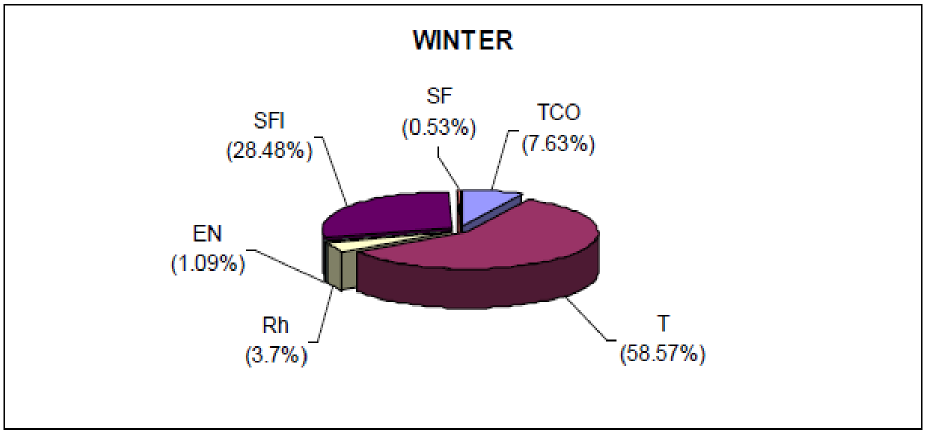

Figure 13: Percentage Dependence of the Parameters during Winter Season to Estimate Monsoon Rainfall over Gangetic, West Bengal.

It agrees fairly well with previous results as obtained by Midya *et al*., (2011b). During the rest other seasons, there is a strong inter-relation between El Nino Index and the Surface Temperature over Kolkata and in each season this Surface Temperature contributes the maximum percentage in estimating the Total summer monsoon rainfall over Gangetic West Bengal, India.

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