

Dependence of Total Column Ozone on Different Solar Activity Features

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Received 19 June 2023; accepted 2 January 2024

In this study, a statistical study between three solar activity features (sunspot numbers (SN), solar flare (SF), and solar active prominence (SAP)) and total column ozone over five sites of India namely Srinagar (34° 5' N, 74° 47' E) (Jammu & Kashmir) from North, Kolkata (22° 34' N, 88° 21' E) (West Bengal) from East, Nagpur (21° 8' N, 79° 05' E) (Maharashtra) from centre, Ahmedabad (23° 2' N, 72° 35' E) (Gujrat) from west and Trivandrum (8° 31' N, 76° 56' E) (Kerla) from south for a duration of 33 years from 1986 to 2019 containing solar cycle 22, 23 and 24 are attempted. The TCO of considered sites are significantly correlated with different Solar activity features. The TCO's correlation coefficient is positive with SF for both the annual and seasonal periods and is negative with SN and SAP for the yearly and all-seasonal periods. According to this study the TCO concentration is dependent on sun intensity during the entire season. This statistical study enhanced understanding of the importance of solar activity features for the production of TCO in the Earth's atmosphere.

Keywords: Column Ozone; Solar Activity; Sunspot Numbers; Solar Flare

1 Introduction

The dynamics of upper atmosphere are strongly controlled by the intensity of solar extreme ultraviolet radiation. The solar chromosphere activity in the ultraviolet region is of great importance to our understanding of the solar influence on the Earth stratosphere and tropospheric chemistry.

There are many factors like solar activity, Quasi-biennial oscillation (QBO) and geomagnetic storms etc. impact the production and trend of TCO in the upper Earth atmosphere. It has been long suggested that the phase of the quasi-biennial oscillation (QBO), which when associated with other influencing factors such as solar activities in the stratosphere cause changes of ozone amount from the stratosphere to the troposphere. There has been possible links established between QBO and ozone variation in the upper-middle and polar region¹⁻⁴. Malliniemi *et al.*⁵ showed a positive relation at the 30 hPa easterly QBO phase throughout the whole twentieth century in the northern hemisphere between latitudes 20°N and 90°N. Furthermore, there is a probability that the atmospheric circulation variations could either be derived from within the troposphere due to radiative changes, or from the stratosphere through planetary wave interaction and also the propagation of zonal wind anomalies⁶⁻⁹.

India is a tropical country that gets a lot of ultraviolet (UV) light as a result, even a small variation in ozone concentration may have a big impact on the climate¹⁰. When magnetic conditions are disturbed, which are related to solar activity peaks, the total ozone was found to be significantly higher¹¹. There are some observations which support the increase in solar ultraviolet radiation with increase in sunspot number and hence, total ozone would be expected to vary more and less in phase with sunspot number¹²⁻¹⁴. Solar activity affects the variations of ozone concentrations and decrease in ozone level causes an increase of UV radiation at the earth's surface^{1,4,15-20}. Solar-induced ozone variations occur due to changes in solar UV irradiance that modifies the ozone production rate at low latitudes through molecular oxygen photolysis^{20,21-22}. Previous studies have shown a positive significant correlation between sunspot numbers and stratospheric ozone and a negative non-significant correlation between Manganese II core-to-wing ratio and ozone²²⁻²³. This suggests that the strength of effects depends on the type of individual solar index considered. Also, Selvaraj *et al.* (2010)²⁴ showed a significant positive correlation between solar activity and surface ozone in a tropical rural station on the east coast of South India (1996–2004). Labitzke *et al.*²⁵ reported that the ozone concentration in some cities in Nigeria from 1998 to 2005 shows positive correlation with sunspot number. In a 27-year investigation (1933–1959), the relative

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sunspot number and the global average of total atmospheric ozone were found to be significantly inversely correlated⁹. Bisht *et al.*¹⁹ presented a statistical study of TCO with different solar activity features (sunspot number, solar flare and solar active prominence) during 1986 to 2013 at two hill station of Uttarakhand (India) and found that solar activities are accountable for production of TCO.

In addition to the study of variation of TCO with different solar active features the analysis of long-term trend of ozone in different regions of the Earth has become an important aspect of atmospheric research. There has been an apparent downward trend of total column amount of ozone over mid latitude areas of Northern hemisphere in all seasons²⁶⁻²⁷. Lonthe *et al.*²⁸ analysed the abnormal behavior of ozone from 1981 to 1998 period in India. Harris²⁹ investigated the chemical and dynamic influence on the decadal ozone trend focusing on the northern hemisphere reported that the ozone variation in the tropic region all caused by the equatorial QBO in the zonal wind in the lower stratosphere during a solar cycle. Bhattacharya *et al.*² studied the trend of TCO at different stations of India and found that the concentration of TCO is high in northern India and it shows a symmetrical variation in TCO concentration. Potdara *et al.*⁴ analysed the variations in the trend of TCO concentration for recent three solar cycles 22,23 and 24 and found that TCO of different stations of India is more negative trend in solar cycle 22 as compared to other two cycle *i.e.*, solar cycle 23 and 24. The current study examines the impact of solar activity on the total column ozone at five Indian stations located in the country's northern, southern, eastern, and western regions. Additionally, the variation of TCO for yearly and seasonal months was investigated.

2 Data Observation

In the present study, we have considered five major stations of India based on their geographic location. They are Srinagar (34° 5' N, 74° 47' E) (Jammu & Kashmir) from North, Kolkata (22° 34' N, 88° 21' E) (West Bengal) from East, Nagpur (21° 8' N, 79° 05' E) (Maharashtra) from centre, Ahmedabad (23° 2' N, 72° 35' E) (Gujrat) from west and Trivandrum (8° 31' N, 76° 56' E) (Kerla) from south. We have taken the TCO data for a duration of 33 years from 1986 to 2019 containing solar cycle 22,23 and 24. The data of TCO and SN, SF, SAP are obtained from the following websites:

www.ozoneaq.gsfc.nasa.gov/ozone_overhead_all_v8.md
www.ngdc.noaa.gov/stp/space-weather/solar-data/solar-indices/sunspot-numbers/
www.ngdc.noaa.gov/stp/space-weather/solar-data/solar-indices/prominencefilaments/
www.ngdc.noaa.gov/stp/space-weather/solar-data/solar-features/solar-flare/

Five stations were taken into consideration, and Fig. 1 depicts the variance in TCO over the course of the investigation. The TCO of the northern station (Srinagar), the eastern station (Kolkata), the central station (Nagpur), the western station (Ahmedabad), and the southern station (Trivandrum) are each represented by a different color: cyan, red, black, green, and blue, respectively. The solar activity features' temporal variation is shown in Fig. 2 for the period 1986 to 2019. Black, green, and red colors represent the variations of SN, SF, and SAP respectively. The accompanying figures have their trend line drawn separately.

3 Statistical Study

Through the use of statistical methods, this part aims to comprehend how TCO is affected by different

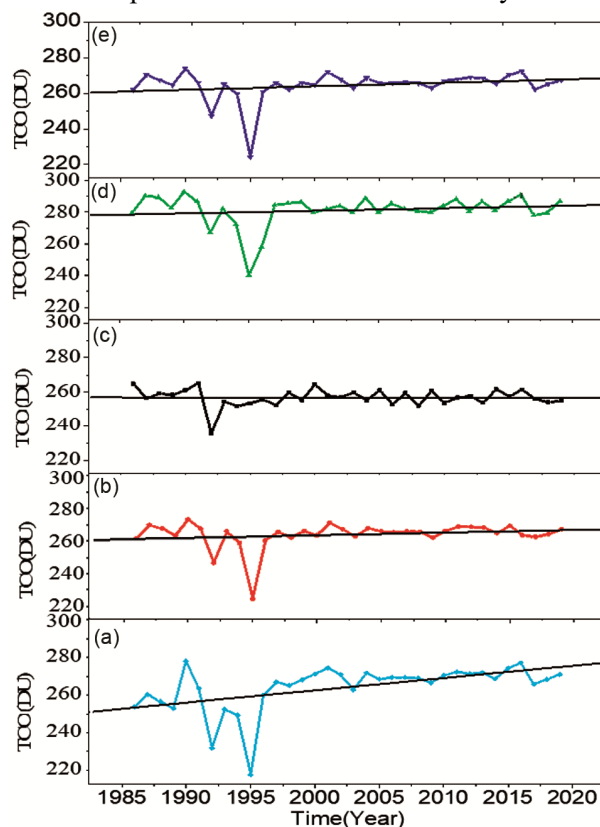


Fig 1 — The variation in total column ozone (TCO) of different stations of India over the entire period of consideration for (a) Srinagar (b) Kolkata (c) Nagpur (d) Ahmedabad (e) Trivandrum

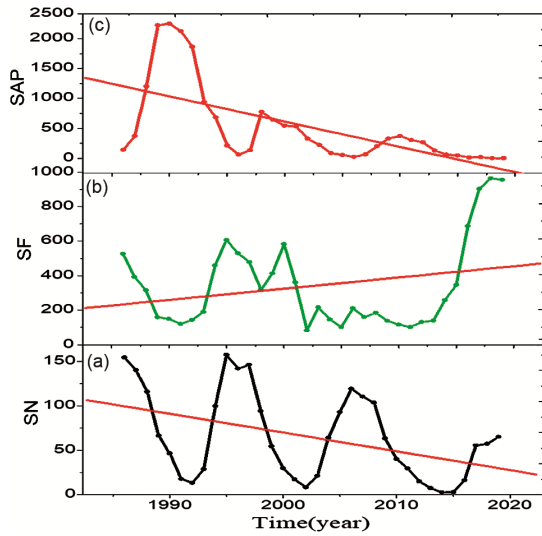


Fig 2 — The variation of (a) Sunspot number (SN) (b) Solar Flare (SF) (c) Solar active prominence during the consider time duration.

solar activity features. TCO scatter plots with SN, SF, and SAP have been created. At a 95% confidence level, linear fitting was applied to the plots. The figures have been annotated with the appropriate linear fitting equations and the correlation coefficient R. For seasonal analysis, the entire year is split into four seasons: winter (December, January, and February (DJF)), spring (March, April, and May (MAM)), summer (June, July, and August (JJA)) and autumn, which includes the months of September, October, and November (SON). The following formula is used to determine the correlation coefficient R:

$$\text{Coeff of Correlation } R = \frac{n(\sum o.s) - (\sum o)(\sum s)}{\sqrt{[n\sum o^2 - (\sum o)^2][n\sum s^2 - (\sum s)^2]}} \dots (1)$$

Where o indicate TCO , s means solar activity and n is total no. of data points.

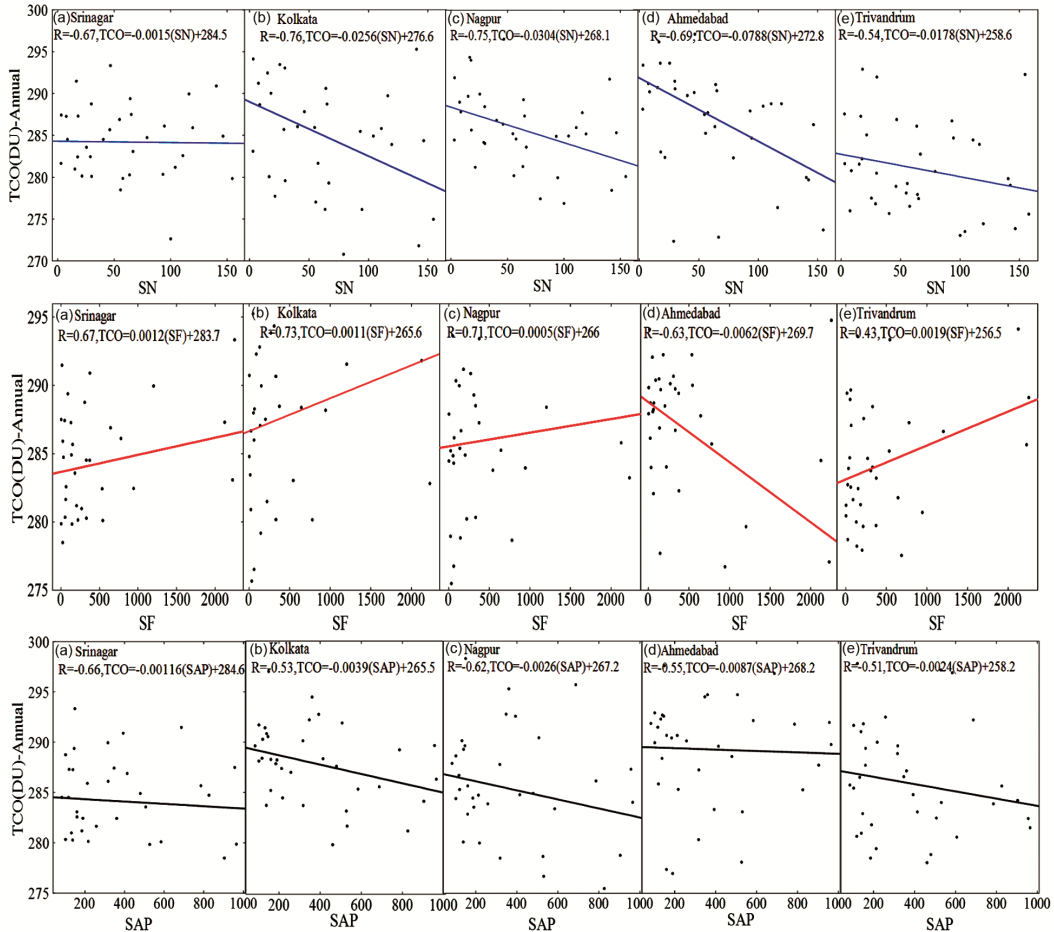


Fig. 3 — (i) Scatter plots of TCO (DU) with Sunspot number (SN) (a) Srinagar (b) Kolkata (c) Nagpur (d) Ahmedabad (e) Trivandrum in annual period. (ii) Scatter plots of TCO (DU) with Solar Flare (SF) (a) Srinagar (b) Kolkata (c) Nagpur (d) Ahmedabad (e) Trivandrum in annual period. (iii) Scatter plots of TCO (DU) with Solar active Prominence (SAP) (a) Srinagar (b) Kolkata (c) Nagpur (d) Ahmedabad (e) Trivandrum in annual period.

The TCO of considered stations with SN, SF, SAP from 1986 to 2019 have been analysed Statistically and their scatter plots have been drawn graphically. Fig. 3 (i-iii) indicates the scatter plots of TCO of (a) Srinagar (b) Kolkata (c) Nagpur (d) Ahmedabad and (e) Trivandrum with SN, SF, SAP for annual periods. The linear fit line equation and correlation coefficients R written in the corresponding figures. The correlation coefficient of TCO with SN is -0.67 for Srinagar, -0.76 for Kolkata, -0.75, for Nagpur, -0.69 for Ahmedabad and -0.54 for Trivandrum in annual period.

The correlation coefficient of TCO with SF is 0.67 for Srinagar, 0.73 for Kolkata, 0.71 for Nagpur, -0.63 for Ahmedabad and 0.43 for Trivandrum in annual period. The correlation coefficient of TCO with SAP

is -0.66 for Srinagar, -0.53 for Kolkata, -0.62, for Nagpur, -0.55 for Ahmedabad and -0.51 for Trivandrum in annual period.

Figure 4 (i-iii) displays the scatter plots of TCO with SN, SF, SAP (a) Srinagar (b) Kolkata (c) Nagpur (d) Ahmedabad and (e) Trivandrum for spring season. The linear fit line equation, correlation coefficients R written in the corresponding figures. The correlation coefficient of TCO with SN, SF, SAP are -0.68, 0.62, -0.61 for Srinagar, -0.72, 0.72, -0.51 for Kolkata, -0.68, 0.52, -0.54 for Nagpur, -0.69, -0.41, -0.60 for Ahmedabad and -0.63, 0.69, -0.61 for Trivandrum in spring seasons.

Figure 5 (i-iii) shows the scatter plots and linear fit of TCO with SN, SF, SAP (a) Srinagar (b) Kolkata (c) Nagpur (d) Ahmedabad and (e) Trivandrum for

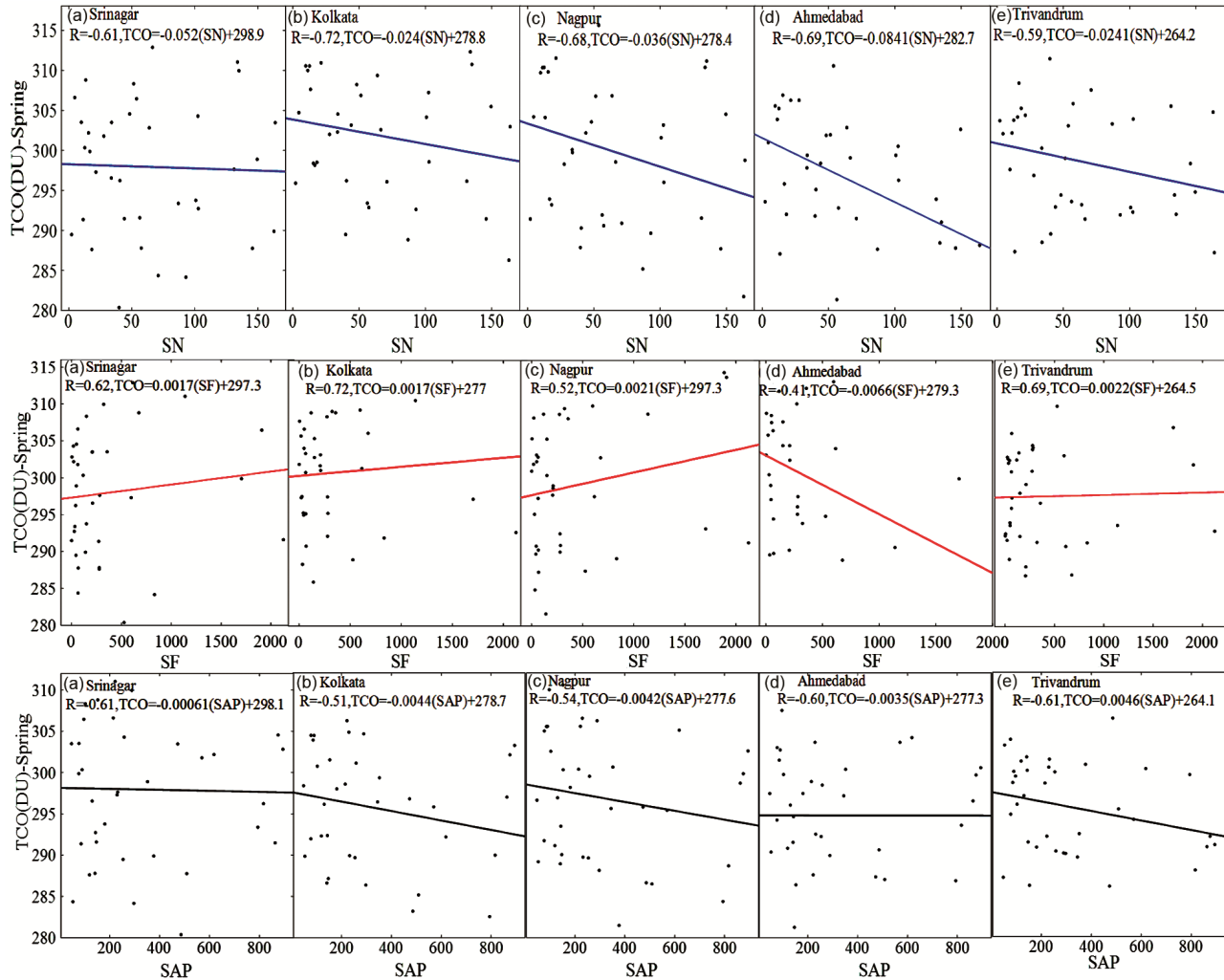


Fig 4 — (i) Scatter plots of TCO(DU) with Sunspot Number (SN) (a) Srinagar (b) Kolkata (c) Nagpur (d) Ahmedabad (e) Trivandrum in Spring. (ii) Scatter plots of TCO(DU) with Solar Flare (SF) (a) Srinagar (b) Kolkata (c) Nagpur (d) Ahmedabad (e) Trivandrum in Spring. (iii) Scatter plots of TCO(DU) with solar active Prominence (SAP) (a) Srinagar (b) Kolkata (c) Nagpur (d) Ahmedabad (e) Trivandrum in spring.

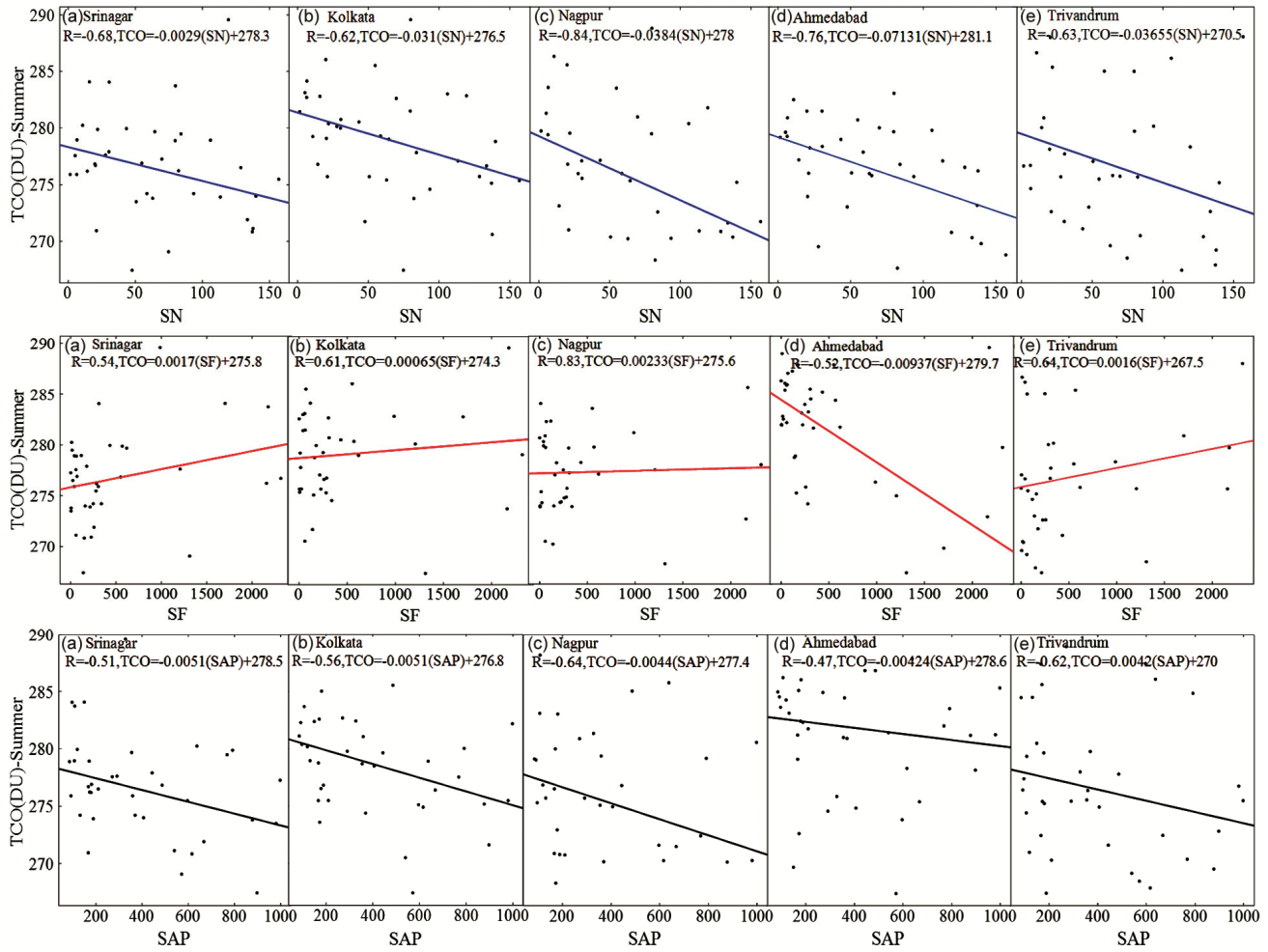


Fig 5 — (i) Scatter plots of TCO(DU) with sunspot number (Sn) (a) Srinagar(b) Kolkata (c) Nagpur (d) Ahmedabad (e) Trivandrum in Summer. (ii) Scatter plots of TCO(DU) with Solar Flare(SF) (a) Srinagar(b) Kolkata (c) Nagpur (d) Ahmedabad (e) Trivandrum in Summer. (iii) Scatter plots of TCO(DU) with Solar active Prominence (SAP) (a) Srinagar(b) Kolkata (c) Nagpur (d) Ahmedabad (e) Trivandrum in Summer.

summer season respectively. The correlation coefficient of TCO with SN, SF, SAP are -0.68, 0.54, -0.51 for Srinagar, -0.62, 0.61, -0.56 for Kolkata, -0.84, 0.83, -0.64 for Nagpur, -0.76, -0.52, -0.47 for Ahmedabad and -0.63, 0.64, -0.62 for Trivandrum.

Figure 6(i-iii) indicates the scatter plots of TCO with SN, SF, SAP (a) Srinagar (b) Kolkata (c) Nagpur (d) Ahmedabad and (e) Trivandrum. The correlation coefficient of TCO with SN, SF, SAP are -0.49, 0.79, -0.58 for Srinagar, -0.56, 0.74, -0.45 for Kolkata, -0.56, 0.64, -0.54 for Nagpur, -0.51, -0.49, -0.45 for Ahmedabad and -0.48, 0.66, -0.46 for Trivandrum in Autumn seasons. The linear fit equation added in corresponding figures.

Figure 7 (i-iii) presented the scatter plots and linear fit line of TCO with SN, SF, SAP (a) Srinagar

(b) Kolkata (c) Nagpur (d) Ahmedabad and (e) Trivandrum during winter season. The correlation coefficient of TCO with SN, SF, SAP are -0.53, 0.65, -0.54 for Srinagar, -0.54, 0.67, -0.47 for Kolkata, -0.59, 0.67, -0.49 for Nagpur, -0.52, -0.57, -0.55 for Ahmedabad and -0.46, 0.59, 0.58 for Trivandrum.

In order to assess the statistical significance of the correlation coefficient between TCO and solar activity features (SN, SF SAP), we use the students two tail t-test. We compute the significance of the Pearson correlation coefficient R at a 95 % confidence level (0.05 level) for both annual and seasonal months. There are 31(33-2) degrees of freedom. For both yearly and seasonal months, all values of the Pearson correlation coefficient (R) of TCO with SN, SF, and SAP are significant. The

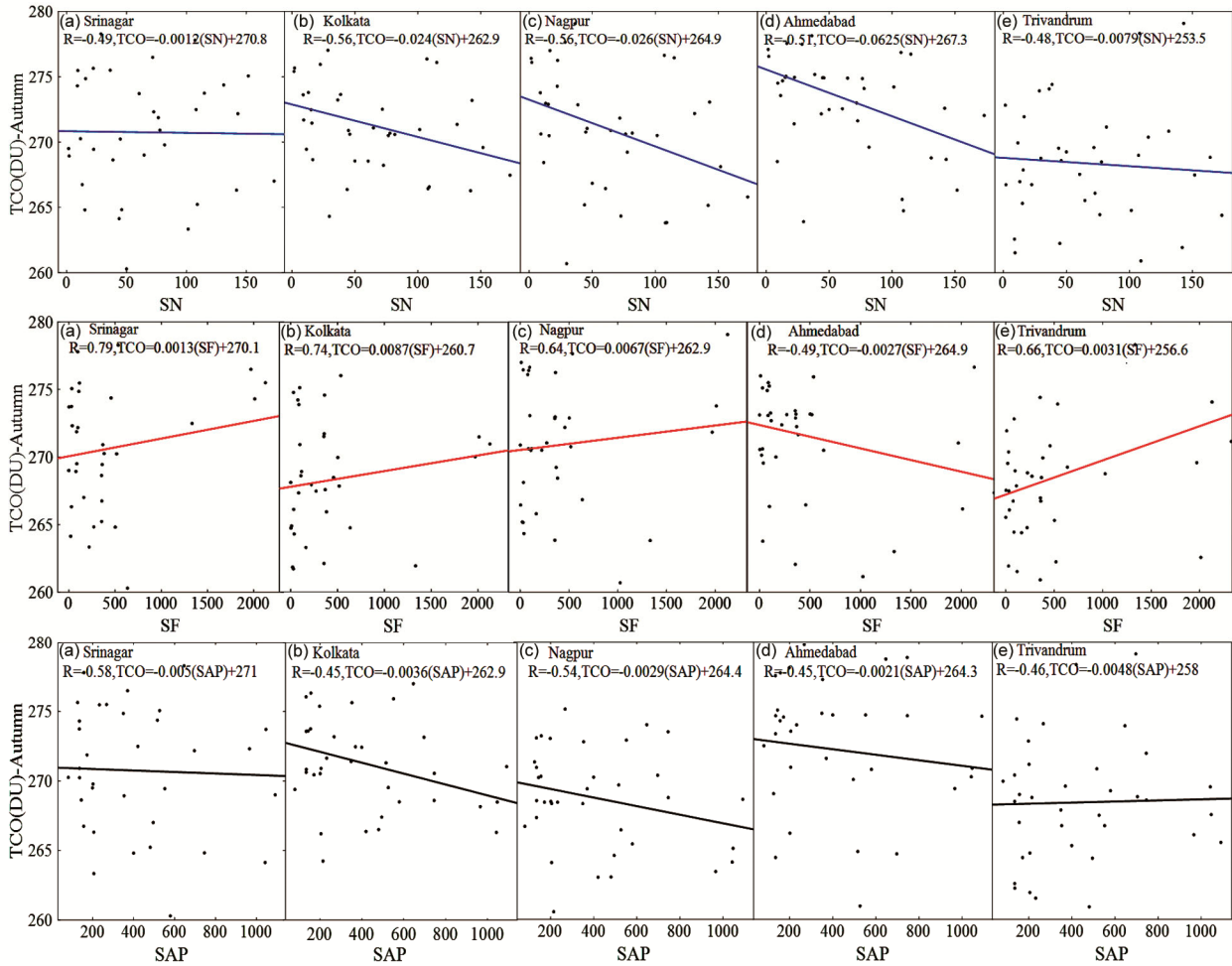


Fig 6 — (i) Scatter plots of TCO(DU) with Sunspot Number (SN) (a) Srinagar(b) Kolkata (c) Nagpur (d) Ahmedabad (e) Trivandrum in Autumn. (ii) Scatter plots of TCO(DU) with Sunspot Number (SN) (a) Srinagar(b) Kolkata (c) Nagpur (d) Ahmedabad (e) Trivandrum in Autumn. (iii) Scatter plots of TCO(DU) with solar active Prominence (SAP) (a) Srinagar(b) Kolkata (c) Nagpur (d) Ahmedabad (e) Trivandrum in Autumn.

t- value and p-value have been calculated for annual and seasonal periods. t-values calculated by following formula under 0.05 confidence level.

$$t = R \frac{\sqrt{n-2}}{\sqrt{1-R^2}} \quad \dots (2)$$

Where R is correlation coefficient, n is sample size.

The t and p value of TCO and solar activity features during corresponding periods mentions in Table 1-5. the p value for annual as well as seasonal periods are less than 0.05 (<0.05) for all considered stations over India. Hence the correlation between TCO and solar activity features is significant for annual and seasonal periods.

Figure 8 presents annual variation in TCO of different stations Srinagar red colour bar, Kolkata blue bar, Ahmedabad yellow colour, Nagpur green

Table 1 — Correlation coefficient R, and t-value and p-value for significance of R of TCO (DU) of Srinagar with SN, SF SAP for annual and seasonal period.

Seasons	Activity	Correlation coefficient R	t- value and p- value by two tail t-test for significance of R	
			t- value	p- value
Annual	SN	-0.67	5.03	0.00002
	SF	0.67	5.025	0.00002
	SAP	-0.66	4.89	0.00003
Spring	SN	-0.61	4.286	0.00016
	SF	0.63	4.399	0.00012
	SAP	-0.61	4.28	0.00017
Summer	SN	-0.68	5.16	0.00001
	SF	0.54	3.57	0.00119
	SAP	-0.51	3.30	0.00244
Autumn	SN	-0.49	3.12	0.00155
	SF	0.79	4.76	0.0004
	SAP	-0.58	3.96	0.00041
Winter	SN	-0.53	3.47	0.00155
	SF	0.65	4.76	0.0004
	SAP	-0.54	3.57	0.00119

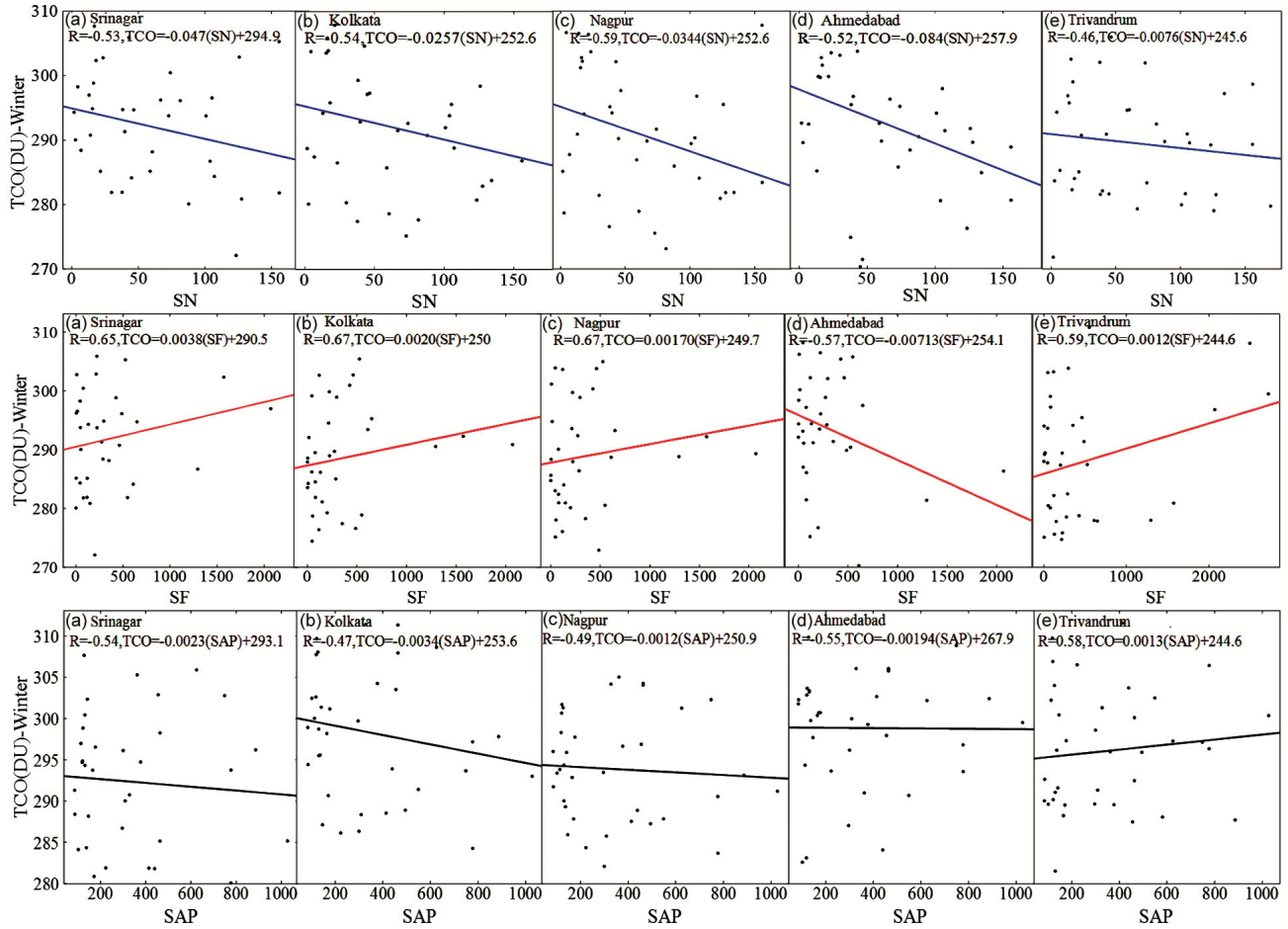


Fig 7 — (i) Scatter plots of TCO(DU) with solar active Prominence (SAP) (a) Srinagar(b) Kolkata (c) Nagpur (d) Ahmedabad (e) Trivandrum for annual period. (ii) Scatter plots of TCO(DU) with solar Flare (SF) (a) Srinagar(b) Kolkata (c) Nagpur (d) Ahmedabad (e) Trivandrum in Winter. (iii) Scatter plots of TCO(DU) with solar active Prominence (SAP) (a) Srinagar(b) Kolkata (c) Nagpur (d) Ahmedabad (e) Trivandrum in Winter.

Table 2 — Correlation coefficient R, and t-value and p-value for significance of R of TCO (DU) of Nagpur with SN, SF SAP for annual and seasonal period.

Seasons	Activity	Correlation coefficient R	t- value and p- value by two tail t-test for significance of R	
			t- value	p- value
Annual	SN	-0.75	6.31	0.00
	SF	0.71	5.61	0.00002
	SAP	-0.62	4.39	0.00012
Spring	SN	-0.68	5.1	0.00002
	SF	0.52	3.38	0.00197
	SAP	-0.54	3.572	0.00118
Summer	SN	-0.84	8.61	0.000
	SF	0.83	8.28	0.00
	SAP	-0.64	4.63	0.00006
Autumn	SN	-0.56	3.76	0.00071
	SF	0.64	4.63	0.00006
	SAP	-0.54	3.57	0.00119
Winter	SN	-0.59	4.06	0.00031
	SF	0.67	5.025	0.00002
	SAP	-0.49	3.12	0.00389

Table 3 — Correlation coefficient R, and t-value and p-value for significance of R TCO (DU) of Kolkata with SN, SF SAP for annual and seasonal period.

Seasons	Activity	Correlation coefficient R	t- value and p- value by two tail t-test for significance of R	
			t- value	p- value
Annual	SN	-0.76	5.9470	0.000
	SF	0.73	6.51	0.00
	SAP	-0.53	3.47	0.0015
Spring	SN	-0.72	5.77	0.000
	SF	0.72	5.77	0.000
	SAP	-0.51	3.301	0.00243
Summer	SN	-0.62	4.39	0.00012
	SF	0.61	4.28	0.00017
	SAP	-0.56	3.76	0.00071
Autumn	SN	-0.56	3.76	0.00071
	SF	0.74	6.12	0.000
	SAP	-0.45	2.80	0.000872
Winter	SN	-0.54	3.57	0.00119
	SF	0.67	5.02	0.00002
	SAP	-0.47	2.96	0.00585

Table 4 — Correlation coefficient R, and t-value and p-value for significance of R TCO (DU) of Ahmedabad with SN, SF SAP for annual and seasonal period.

Seasons	Activity	Correlation coefficient R	t- value and p- value by two tail t-test for significance of R	
			t- value	p- value
Annual	SN	-0.69	5.30	0.0019
	SF	-0.63	4.51	0.00009
	SAP	-0.55	3.66	0.00093
Spring	SN	-0.69	5.30	0.00001
	SF	-0.41	2.50	0.0183
	SAP	-0.60	4.175	0.00022
Summer	SN	-0.76	6.51	0.000
	SF	-0.52	3.38	0.00197
	SAP	-0.47	2.96	0.00585
Autumn	SN	-0.51	3.30	0.00244
	SF	-0.49	3.12	0.00389
	SAP	-0.45	2.80	0.00872
Winter	SN	-0.52	3.38	0.00197
	SF	-0.57	3.86	0.00054
	SAP	-0.55	3.66	0.00093

Table 5 — Correlation coefficient R, and t-value and p-value for significance of R TCO (DU) of Trivandrum with SN, SF SAP for annual and seasonal period.

Seasons	Activity	Correlation coefficient R	t- value and p- value by two tail t-test for significance of R at 0.05 level	
			t- value	p- value
Annual	SN	-0.54	3.57	0.0019
	SF	0.43	2.65	0.0125
	SAP	-0.51	3.30	0.0024
Spring	SN	-0.59	2.50	0.0183
	SF	0.69	5.30	0.0001
	SAP	-0.49	4.286	0.000016
Summer	SN	-0.63	4.52	0.00009
	SF	0.64	4.63	0.00006
	SAP	-0.62	4.39	0.00012
Autumn	SN	-0.48	3.04	0.00478
	SF	0.66	4.89	0.00003
	SAP	-0.46	2.88	0.00715
Winter	SN	-0.46	2.88	0.00715
	SF	0.59	4.06	0.00031
	SAP	0.44	2.72	0.0106

bar and Trivandrum brown colour bar. Fig. 9 represents annual and Seasonal periods TCO variation for all stations of India in which green colour bar shows the annual TCO bar of all stations, yellow colour for winter, red for spring, blue colour for summer and black indicate autumn of TCO of all stations. Fig. 10 displays the variation in TCO of all station with respected to latitude angle.

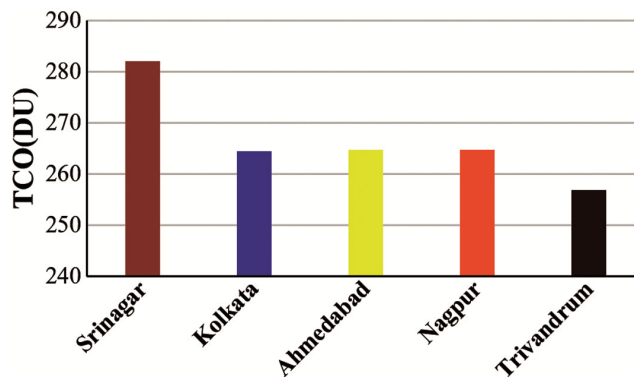


Fig. 8 — Variation in TCO of different stations Trivandrum, Kolkata, Srinagar, Ahmedabad and Nagpur of India.

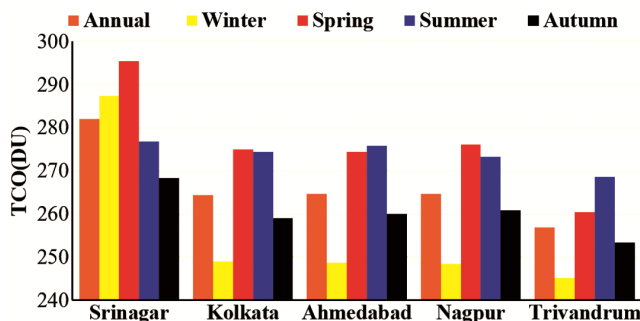


Fig. 9 — Variation in TCO of different stations Trivandrum, Kolkata, Srinagar, Ahmedabad, and Nagpur of India during annual and Seasonal periods.

4 Results and Discussion

Figure 1 demonstrates that all stations' TCOs follow the same pattern. A negative trend, where TCO declines during solar cycle 22 (1985 to 1996), is seen, but positive trends are seen for solar cycles 23 and 24. (1997 to 2019). Fig. 2 represents trend pattern of solar active features SN, SF and SAP. SN and SAP exhibit negative trend while SF indicate positive trend during consider solar cycle. In this statistical study, we have calculated correlation coefficient between TCO of considered stations of India with sunspot numbers (SN), solar flare (SF), solar active prominence (SAP) for annual and seasonal period. The correlation coefficient R and their test of significance t- value and p-values of all the stations are represented in Table 1-5 for annual as well as seasonal periods.

Figures (8-10), shows that concentrations of TCO is maximum in Srinagar and minimum in Trivandrum. In comparison to autumn and winter, the sun is more intense in the spring and summer. In the spring and summer, there is a substantial correlation between TCO and solar active features (SN, SF, SAP), but this correlation is weaker in the autumn and winter. As a result, spring and summer have a high level of TCO.

The Earth's atmosphere produces TCO in response to the solar active properties. which lead to the accumulation of TCO by increasing the exposure of Earth to UV radiation.

The latitude-longitude angle, the level of pollution and other factors specific to each location all had an impact on TCO concentration, which differs from place to place. Fig. 11 represents TCO with latitude angle of different station of India. From this figure, it is seen that TCO is maximum for north point Srinagar (34°.5' N , 74°.47' E) at 281.96 DU and minimum value for south points Trivandrum (8.31' N,76°.56' E) at 256.88 DU While for Ahmedabad (21°.8' N,79°.05' E), Nagpur (23°. 2' N,72°. 35' E) and Kolkata (22° 34' N,88° 21' E) TCO is respectively 264.73 DU, 264.66 DU and 264.38 DU which is approximately equal. At high altitudes, TCO concentration is greatest, whereas at low altitudes, it

is smallest. Trivandrum has the lowest concentration of TCO because to the hot circumstances, longitude location, or low height from sea level, whereas Srinagar has the highest concentration due to the winter season, high longitude, or high altitude from

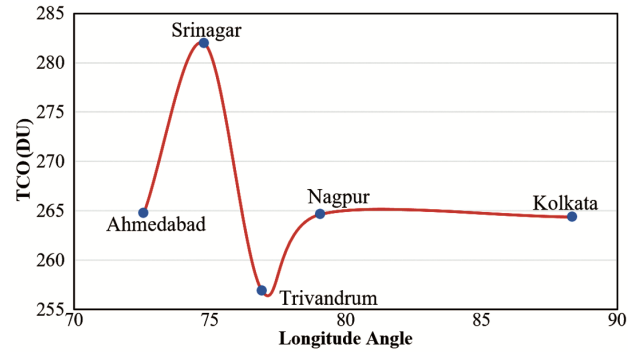


Fig. 10 — Variation in TCO with Longitude angle of different station of India

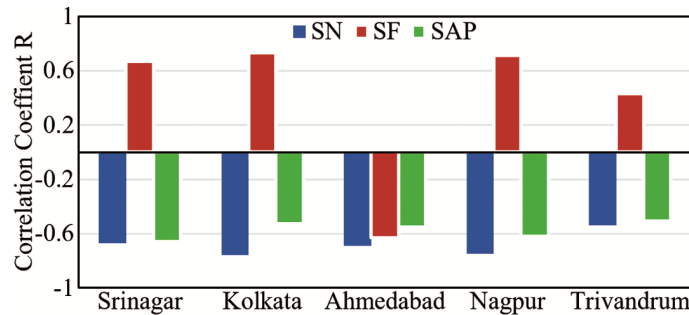


Fig. 11 — (i) The variation in correlation coefficient R in considered stations of India during Annual period

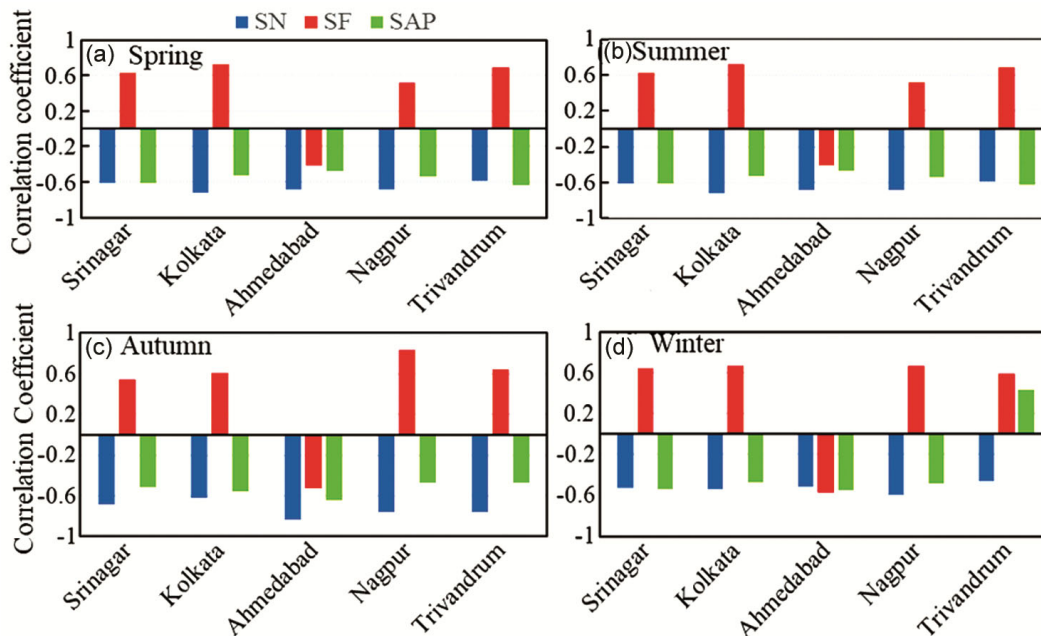


Fig. 11 — (ii) Variation in correlation coefficient of different stations during (a) Spring (b) Summer (c) Autumn (d) Winter

sea level. The other three stations are about in the same longitudinal location and at the same altitude. So, throughout both yearly and seasonal times, TCO concentration is the same for all three sites.

5 Conclusion

TCO of consider sites of India shows positive trend (increasing) for consider period while solar active features SN and SAP shows negative trend (decreasing) and SF shows positive trend (increasing). Since ultraviolet radiation coming from sun is used to the production of ozone in the upper atmosphere. TCO and SF shows positive trend that is increases the Ultraviolet approach in the upper Earth atmosphere while during the period 1990 to 1993 the less amount of ultraviolet radiation approaches to the upper earth atmosphere so that it shows negative trend (decreasing) of TCO and SF in this period.

Now, conclusion from our investigation that the TCO of every station is significantly correlated with solar activity features (SN, SF and SAP). The TCO of every station has been found to be negatively correlated with SN and SAP during both yearly and seasonal timeframes. The TCO of all studied stations exhibits strong correlation throughout the yearly, spring, and summer while displaying moderate correlation in the Autumn and poor correlation during the winter with SN and SAP. The correlation coefficient between the Trivandrum TCO and SAP is positive. With the exception of Ahmedabad, the TCO of the stations under consideration shows a substantial positive correlation with SF for both yearly and seasonal periods. SF and Ahmedabad's TCO have a negative correlation. The fluctuation in the correlation coefficient R for yearly and season months across the investigated length is depicted in Fig. 11(i-ii).

UV light entering the upper Earth's atmosphere is a need for TCO formation. Solar activity features in the solar atmosphere cause an increase in UV radiation. Bursts of energy are directed toward the Earth by SF. SF aids in accelerating UV radiation's approach to the Earth's atmosphere. The SF energy's UV radiation penetrates the Earth's stratosphere and amplifies the creation of TCO, allowing it to show a positive correlation with SF.

For Indian stations taken into consideration, TCO has a negative correlation with SN and SAP. According to the current study, TCO at the station under consideration falls when SN and SAP in the solar environment rise. We now draw the conclusion

that there is a significant connection between TCO and the solar activity features (SN, SF, and SAP) which have a considerable role to the production of TCO in the Earth atmosphere. UV radiations reach Earth's atmosphere as a result of solar activity features showing remarkable changes that is solar variability affects ozone through radiative heating in atmosphere.

Finally, we conclude that several solar activity parameters (SN, SF, SAP) are one factor which are useful to the production of TCO in the upper Earth atmosphere. there are some other factors in the Earth are latitude-longitude location, height from sea level and metrological seasons, affect the TCO concentration. The TCO concentration pattern are different in different places and in different time-period. This study shows the TCO concentration at several places around India, enabling us to predict temperature variation and climate change globally. Because the TCO concentration is higher than 220 DU at every site, there are no criteria for ozone depletion. The ozone layer's thickness, which changes seasonally and is normally thicker in the spring and summer and thinner in the autumn and winter, as well as air circulation patterns are taken into account in addition to solar intensity. With the help of this analysis, we may forecast the ozone depletion at the corresponding stations' TCO reliance on solar active characteristics, altitudes, and metrological seasons. Ozone is formed by the magnetic energy associated with solar active features in the form of UV radiation. Solar activity involves direct solar energy toward the Earth's atmosphere, which in turn drives space weather activity and causes variations in the accumulation of TCO levels in the atmosphere.

Acknowledgments

Mahesh Chandra Mathpal, one of the authors, expresses gratitude to UGC, New Delhi, India, for providing financial support via the RFSMS (Research Fellowship in Science for Meritorious Students) program. The several data centers from which we observed the total column ozone and solar active feature data are warmly acknowledged. Thanks to reviewers for their valuable reviews.

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