Relation between Total Ozone Content and Solar Ultra Violet Index Over India

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ABSTRACT

The ultraviolet (UV) region of electromagnetic radiation from sun occupies a section of wavelengths ranging from 400 to 10 nm. It is highly ionizing and activates many chemical processes on different types of materials and living beings. As a function of its effects on the biosphere, the UV radiation regions are arbitrarily called UV-A, UV-B and UV-C. A global scale called Solar Ultra Violet Index (UVI) is used to describe the level of UV radiation on the biosphere. The amount of UV radiation at different places on the earth depends on the position of the sun during the day and the season of the year. A decline in the amount of total ozone content (TOC) at a particular time also leads to an increase in UV radiation at that time. The present study has analyzed the variation of TOC and UVI over different Indian region using total ozone data from OMI and erythemal UV irradiance (converted to UV index) from TEMIS for the 2006-2010 period.

Keywords: Atmospheric Ozone, OMI, Total Ozone, TEMIS, UV Radiation, UV-Index,

I. INTRODUCTION

Characterisation and parameterization of the profiles of atmospheric trace gases are important for weather forecasting, climate modelling and environmental monitoring. Ozone plays particularly a significant role in the chemistry of the Earth's atmosphere, though in terms of abundance it is a 'trace species'[1]. Stratospheric ozone is naturally formed by chemical reactions involving ultraviolet sunlight and oxygen molecules. These reactions occur continually wherever ultraviolet sunlight is present. The production of stratospheric ozone is balanced by its destruction in chemical reactions. Ozone reacts continually with a variety of natural and anthropogenic chemicals in the stratosphere. In the lower atmosphere, ozone is produced by the chemical reactions between mainly nitrogen oxides and organic chemical pollutants produced by anthropogenic emissions. Several factors contribute to ozone's importance but perhaps the most important feature is the relationship between the absorption spectrum of ozone and the intensity of solar UV radiation. Although the Sun emits a large spectrum of radiation, the UV radiation constitutes a small part of it. The spectral distribution of solar UV radiation reaching the earth's surface depends on several factors: the radiation emitted by the sun, the earth-sun separation, the optical properties of the atmosphere, the solar elevation and the reflection properties of the surface. Regarding the biological effects of UV radiation, it can be divided in to three main ranges UV-A from 400 nm to 315 nm, UV-B from 315 nm to 280 nm and UV-C from 280 nm to 100 nm [2].

The absorption properties of the ozone molecule are strongly wavelength dependent. Even a strongly depleted ozone layer will completely absorb UV-C radiation. The absorption in the UV-B region is weaker. Approximately 90% of the UV-B is absorbed mainly by ozone and oxygen, only a fraction of this radiation reaches the earth's surface. UV-A radiation is almost unaffected by ozone variations. Therefore, the ultraviolet radiation reaching the Earth's surface is composed of mainly UV-A with a small UV-B component. Radiative transfer calculations show that for a cloud-free atmosphere with a sun vertically above and a 350 DU total ozone column amount and bare ground, the fraction of diffuse radiation amounts to 43% at 310 nm and 21 % at 380 nm. For a 35° solar elevation the corresponding percentages are 67% at 310 nm and 36% at 380 nm [3]. Therefore, the intensity of solar UV-B radiation on the surface depends on the ozone layer concentration and more Ozone should give less UV-B radiation at ground level and a decrease in the concentration of ozone in the atmosphere results in increased UV-B radiation at the surface of the earth. DNA and other biological macromolecules absorb UV-B and can be damaged in this process. The UV-B radiation has been reported to cause skin cancer and several other effects on human health as well as detrimental effects on animal and plants [4]. Many measurements have demonstrated the inverse relationship between total column ozone amount and UV radiation, and in a few cases long-term increases due to ozone decreases have been identified. At several sites, changes in UV differ from those expected from ozone changes alone, possibly as a result of long-term changes in aerosols, snow cover or clouds. This indicates a possible interaction between climate change and UV radiation. The present study is aimed to analyze the variation of Total Columnar Ozone (hereafter Total Ozone Content, TOC) and UV irradiance (converted to UV index) received by earth over India during 2006-2010 period. In order to cover the entire region of India seven locations are chosen.

II. UV INDEX

The UV index (UVI) is public oriented meteorological information that pretends to indicate, in quantitative simple way, the damaging ultraviolet radiation levels at the ground [5]. The UV index scale was proposed by World Health Organisation (WHO) and it is defined in terms of the erythemally weighted UV irradiance (*i.e.* "skin-reddening", or "sun burning" irradiance). The erythemal weighting function, which is applied to the spectrum, involves an arbitrary normalization to unity at wavelengths shorter than 298 nm, so erythemally weighted UV is not strictly defined in terms of an SI unit. Furthermore, when UV information was first provided to the public, another normalization (a multiplication by 40 $m^2 W^{-1}$) was applied to provide a number, called the UV Index [6]. With this normalization, the maximum UV Index is about 10 for normal ozone conditions [7] .

$$\text{UV Index} = 40 \int I(\lambda)\, w(\lambda)\, d\lambda,$$

Where

λ is the wavelength in nm,

$I(\lambda)$ is the irradiance in W m^{-2} nm^{-1}, and $w(\lambda)$ is the erythemal weighting function which is defined as:

$w(\lambda) = 1.0$ for $250 < \lambda \leq 298$ nm

$w(\lambda) = 10^{0.094(298 - \lambda)}$ for $298 < \lambda \leq 328$ nm

$w(\lambda) = 10^{0.015\,(139 - \lambda)}$ for $328 < \lambda \leq 400$ nm

$w(\lambda) = 0.0$ for $\lambda > 400$ nm.

Table 1.Solar Ultraviolet Index [6]

UVI	Exposure Level	Remarks
1-2	Low	Low danger from the sun's UV rays for the average person
3-5	Moderate	Moderate risk of harm from unprotected sun exposure. Need precautions.
6-7	High	High risk of harm from unprotected sun exposure. Hat and sun glasses are necessary to protect eyes and rotection against sunburn is needed.
8 -10	Very High	Very high risk of harm from unprotected sun exposure. Protective clothing and sunglasses to protect the eyes are necessary. Unprotected skin will be damaged and can burn quickly.
11+	Extreme	Extreme risk of harm from unprotected sun exposure. Unprotected skin can burn in minutes. White sand and other bright surfaces reflect UV and will increase UV exposure.

III. DATA

UVI data used in the study are obtained from Tropospheric Emission Monitoring Internet Service (TEMIS) [8] and the TOC data are obtained from NASA's Ozone Monitoring Instrument (OMI) site [9] . From the daily values monthly averages and annual averages are derived for different selected regions of India. The UV and Total ozone data are also available through international data archives such as the World Ozone and UV Data Centre (WOUDC). The descriptive statistics of the collected data is given in Table 2**.**

IV. DESCRIPTIVE STATISTICS

Table 2. Descriptive statistics of Total Ozone and UV index Data

Location	Latitude	Longitude	TOC (DU)					UVI				
			Min	Max	Mean	Range	Std	Min	Max	Mean	Range	Std
Chennai CHE	13.08	80.27	234	280	260.57	46	12.72	8.6	13.2	10.47	4.6	1.12
Hyderabad HYD	17.37	78.47	232	281	261.38	49	12.66	7.48	14.14	11.35	6.66	1.93
Mumbai MUM	19.08	72.87	237	283	264.37	46	12.30	6.85	13.65	10.82	6.80	2.12
Kolkata KOL	22.34	88.22	238	288	265.6	50	12.22	5.8	13.02	10.02	7.22	2.39
Ahmadabad AHA	23.09	72.56	242	286	267.62	44	12.58	5.67	13.35	9.85	7.68	2.50

Delhi DEL	29.01	77.38	249	300	275.87	51	11.68	3.9	12.52	8.40	8.62	2.93
Srinagar SRI	34.08	74.79	258	341	285.06	83	16.47	2.8	13.45	7.98	10.65	3.63

From Table 2 it is evident that the yearly average UV radiation decreases towards northern regions of India (high latitudes). This is due to the increase in both total ozone amount and solar zenith angle. The variation in total ozone and UVI for northern region are larger than southern region. The variation in total ozone and UVI for Srinagar is 83 DU and 10.65 respectively which is approximately twice as that of Chennai (46 DU, 4.6). However, over the entire region UV Index changes are consistent with changes in the total ozone amounts. For most of the locations, maximum values are reach in May and the lowest values in December or January, with the larger values in the southern parts, decreasing in general, towards high northern regions or high latitudes. All the stations show very similar monthly averages throughout the year despite their difference in latitude. The variations of the TOC and UVI for different regions of India for the period from 2006 to 2010 are graphically represented by the box plots in Figure 1(a) and 1(b).

Figure 2 clearly explains the relationship between total ozone content and UVI. Whenever the ozone content reaches its maximum value the UVI reaches its minimum value. For the Indian region the total ozone varies from 234 DU to 341 DU and the corresponding UVI varies from 13.2 to 2.8. The frequency distribution of TOC and UVI are expressed by the histograms which are shown in Figures 3(a) & 3(b) and the UVI values are summarized in Table 3.

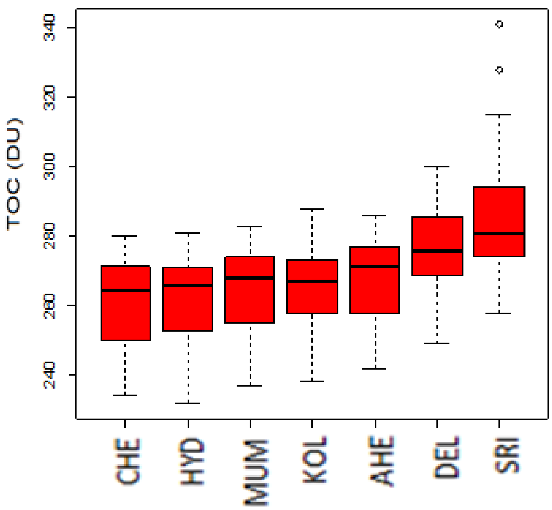

Figure 1 (a). Total Ozone

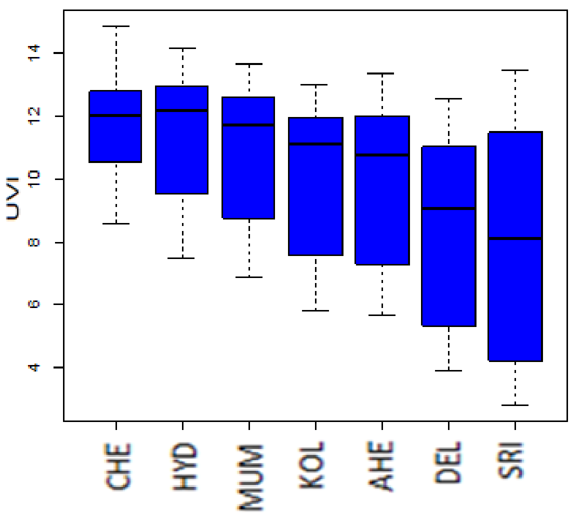

Figure 1 (b). UVI

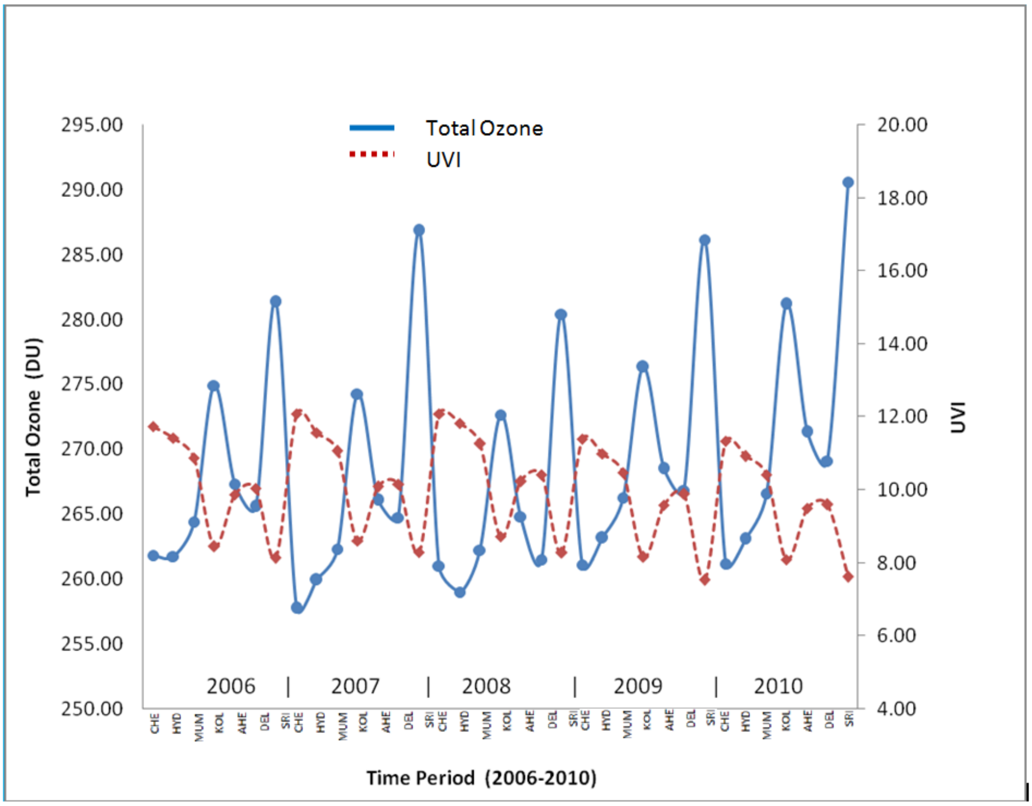

Figure 2 .Variation of Total ozone and UVI over India during the 2006-2010 period.

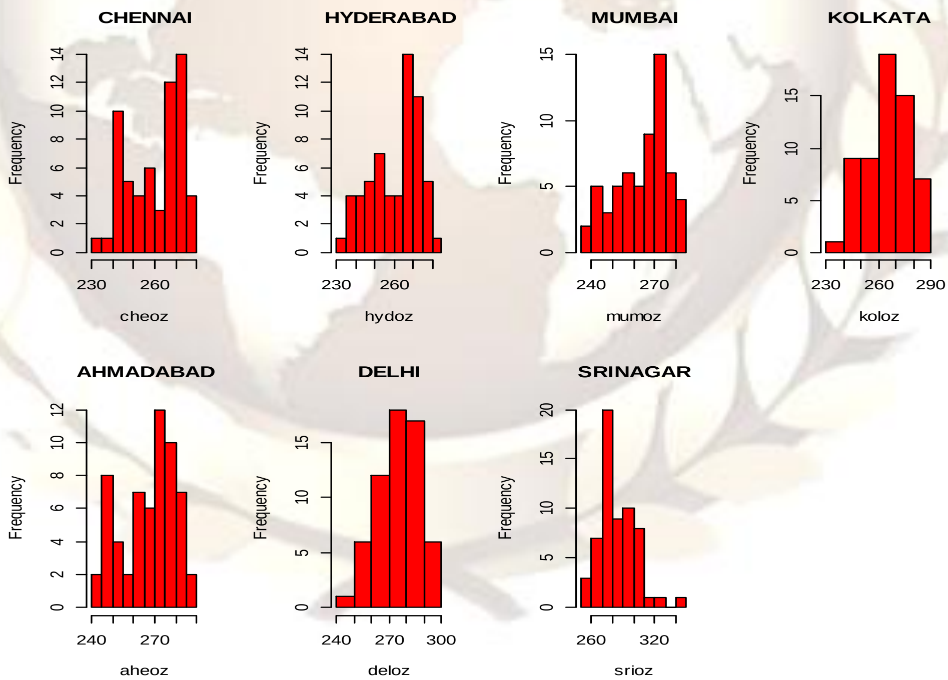

Figure 3 (a). Frequency Distribution of Total Ozone

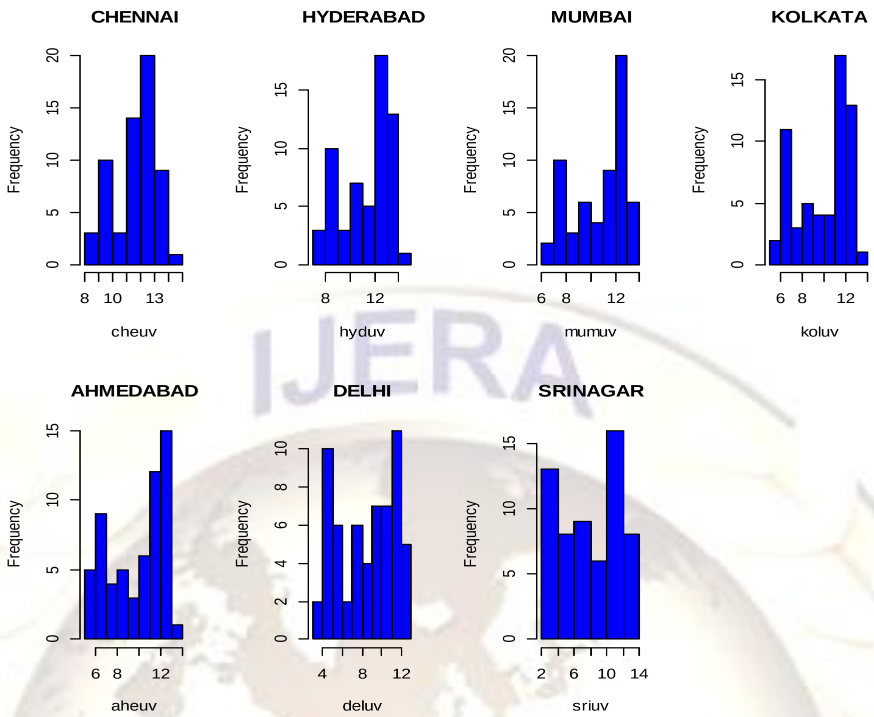

Figure 3 (b). Frequency distribution of UVI

Table 3. Frequency Distribution of UVI

Region	No. of Months				
	1-2	**3-5**	**6-7**	**8-10**	**11+**
Chennai	0	0	0	13	47
Hyderabad	0	0	3	13	44
Mumbai	0	0	2	19	39
Kolkata	0	2	12	12	34
Ahmadabad	0	5	9	12	24
Delhi	0	12	14	11	23
Srinagar	6	16	9	11	18

From Table 3 it is evident that Chennai and Hyderabad (low latitude regions of India) receives very high and Extreme UV radiation for most of the days because of the low ozone content over these regions. Chennai has only Very High and Extreme Index values during the entire period. On the other hand, because of high total ozone content over the northern regions of India, Ahmadabad, Delhi and Srinagar regions have received Moderate and Lower UV radiations.

V. CORRELATION BETWEEN TOC AND UVI

In order to establish and understand the relationship between total ozone content and UVI, correlation study is made. The correlogram is shown in Figure 4 and the results of the Pearson's correlation study are tabulated in Table 4.

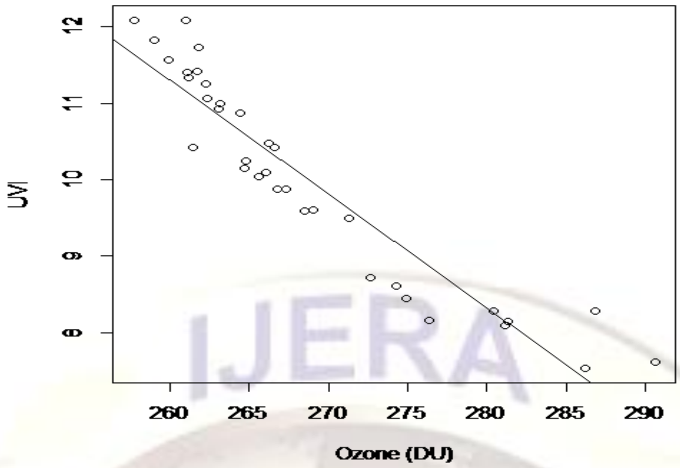

Figure 4. Correlogram of TOC Vs UVI

Table 4. Pearson's product-moment correlation between TOC and UVI

r	t	95 % confidence Interval		df	P
-0.9412	-16.0029	-0.9701536	-0.8857724	33	< 2.2e-16

The Pearson's correlation analysis shows that the overall correlation between TOC and UVI over the Indian region is r = -0.9412 with t value = 16.0029 and it is statistically significant at one per cent level of probability. The value of correlation coefficient indicates that there exist a very good inverse relationship between total ozone and UVI. Also the coefficient of determination r^2 =0.88 indicates that 88 percent of changes in total ozone alone is responsible for the changes in surface UV radiation variation. The rest of the variation in UVI may be explained by Clouds, Particulate matter, Aerosols and Air pollutants which absorb and scatter some of the ultraviolet radiation and thereby diminish the amount reaching the earth's surface.

VI. CONCLUSION

The relationship between UV-B radiation and Total ozone content over different regions of India has been analysed in the study. The results indicate that the variation in total ozone and UVI for northern region is larger than southern regions. The variation in total ozone and UVI for Srinagar is 83 DU and 10.65 respectively which is approximately twice as that of Chennai (46 DU, 4.6). It is found that the UVI very often rises above 10 in summer from March to May. The magnitude of correlation coefficient and the coefficient of determination clearly explain that at any particular location on the surface of the earth there is a direct inverse relationship between UV-B irradiation and the amount of ozone in the atmosphere.

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8 **TEMIS**. Tropospheric Emission MonitoringInternet Service. http://www.temis.nl/

9 **OMI**. Ozone Monitoring Instrument. http://aura.gsfc.nasa.gov/instruments/omi.html