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Statistical relationship between surface ozone and solar activity in a tropical rural coastal site, India

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Abstract

Surface ozone has been measured at Tranquabar (11°N, 79°9'E), a tropical rural site on the east coast of south India, during the years 1996 to 2004. The sunspot data were collected from Udaipur solar observatory during the same period. The relationship between annual mean smoothed sunspot number and annual mean surface ozone levels are studied by Pearson product moment correlation coefficient and that is found to be a high value 0.94. High positive rank correlation coefficients 0.76 and 0.62 obtained for the years 2000 and 2002 indicates the influence of higher solar activity over the surface ozone levels.

Keywords: Smoothed sunspot numbers, surface ozone, solar activity.

Introduction

Surface ozone is a highly efficient green house gas, its global warming potential is about 1200-2000 times that of CO_2 (Houghton *et al.,* 1990). The concentration of O_3 in troposphere are mainly contributed by two processes, one is downward distribution of stratospheric ozone and photochemical production ozone. In photo chemical production of ozone, the required atomic oxygen comes from the photo dissociation of NO_2 at shorter wavelengths (<420 nm) (Naja & Lal, 1997).

The upper atmosphere research satellite (UARS) data suggest changes of 20%, 8% and 3% near wavelength of 140, 200 and 250 nm respectively from solar maximum to solar minimum (Lean, 1997). When the solar activity is high both solar UV-C radiation and ozone concentrations are high. Measurements in the tropic suggest a change of ~ 6% of the total ozone column during the 11 year solar cycle form solar low to high. (Labitzke & Van loon, 1997). During the solar cycle 23 solar parameter had an increase from 1996 to 2000 (sun spot minimum) but the interval of 1998-2002 had short term fluctuations. Sunspot numbers had peaks in 1998, 1999, July 2000 (largest), October 2001 (second largest) and October 2002. Above about 25 km altitude at source region heights where production and loss processes are most important, one should be able to observe more easily the effects of changing solar activity on the O_3 concentration. From balloon observations, a strong positive correlation between sunspot number and ozone content in the altitude interval 20-30 km was observed. As the sunspot number increase from 10 to 180 the ozone content in this altitude range increases from 125 to 170 Dobson units

Fig. 1. Location map of the Tranquabar

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(Herman *et al.,* 1975). Dobson's *et al.* (1929) conducted, based on observation, that total ozone was enhanced during magnetically disturbed conditions which are associated with peak solar activity period. Willet (1962) result suggests that the ozone peak occurs 3 or 4 years before or after sunspot maximum.

Location and instrumentation

Tranquabar is situated on the eastern coast of India. There is no major industrial complex located in the town. March-May is the summer season. The weather at the site during summer is very hot due to intense solar radiation. The day time temperature reaches above 40°C and the night time above 30°C. the site receives heavy rainfall only during north east monsoon October – December which is the main rainy seasons (Singh & Sontakke, 1999). January – February is the winter season. June – September is the pre-monsoon seasons.

Method of estimation of O_3:

The O_3 concentration in parts per billion by volume (ppbv) was estimated by neutral buffered potassium Iodine (NBKI) method by bubbling a known volume of ambient air (Debaja, 2003). The NBKI method have been calibrated with UV photometric ozone analyzer (model 03 42M, environ. SA, May, 2002) by running them together by keeping averaging time interval of 30 min.

Result and discussion

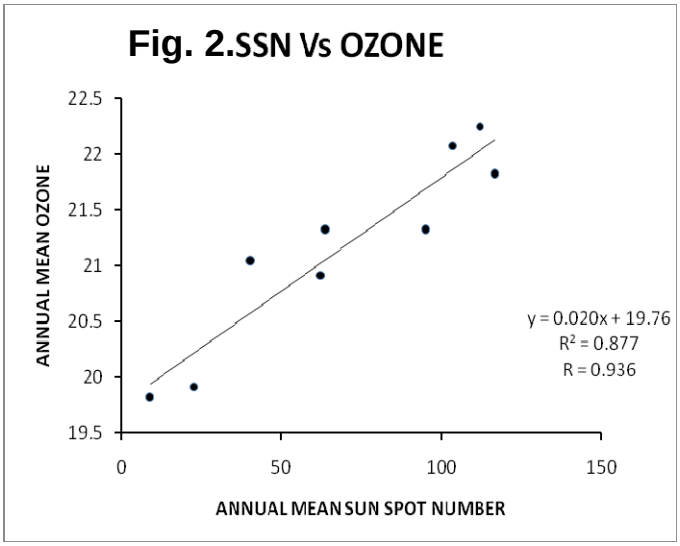
Table 1. Annual mean smoothed sunspot numbers & annual mean O_3

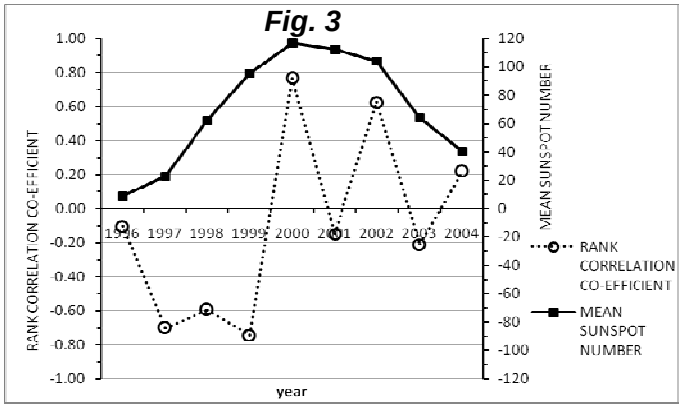
Year	SSN	Ozone
1996	9.1	19.83
1997	22.71	19.92
1998	62.42	20.92
1999	95.34	21.33
2000	116.83	21.83
2001	112.27	22.25
2002	103.76	22.08
2003	63.80	21.33
2004	40.47	21.05

Table 1 gives the values of annual mean smoothed sunspot numbers and annual mean surface ozone concentration in ppbv. The ozone concentration values during January 1996-December 2004 for Tranquabar are taken from Debaje (2003). The sunspot numbers are collected from Udaipur solar observatory which is similar to solar geophysical research data book and websites data to find the correlation coefficient between annual mean sunspot numbers and annual mean values of O_3 concentrations for the period 1996-2004. It is found from the Fig. 1 the graph drawn between the annual mean smoothed sunspot number and annual mean ozone levels are linear. The correlation coefficient becomes high positive value that is 0.94. Annual mean smoothed sunspot number and annual mean O_3 concentration for Tranquabar for the period 1996-2004 are illustrated in Fig. 2.

Table 2 gives the values of annual mean smoothed sunspot number and the Spearmen's rank correlation coefficient values between annual mean smoothed sunspot number and the annual mean ozone concentration. A graph is drawn between those two variables are given in the Fig. 3. We can see there are 2 strong peaks in the rank correlation values with high positive values 0.764 and 0.624 for the years 2000 and 2002. The annual mean sunspot numbers also maximum for those two years. But the rank correlation coefficient value for the year 2001 is – 0.148.

During the high number of sunspot more UV radiations will reach the ground it is quite natural that there will be increase in the ozone level. During periods of maximum sunspots the sun emits more energy (about 0.1% more) than during the periods of sunspot minima (Ahrens, 2000). Evidently the greater number of bright areas (faculae) around the sunspots radiates more energy which offsets the effects of the dark spots. However, most of this radiation is in ultraviolet wavelength which is absorbed by stratospheric ozone. But ozone concentration varies with the sunspot cycle reaching a maximum during sunspot maximum. The spectral composition of this variation in irradiance is such that much larger percentage changes takes place at ultraviolet wavelengths, with 19% of the increase taking place between the 200 and 300 nm region, although only





Indian Journal of Science and Technology Vol. 3 No. 7 (July 2010) ISSN: 0974- 6846

1.2% of the total irradiance is emitted in this wavelength region (Lean, 1989).

Since the Tranquabar a tropical rural coastal site is far away from the industrial and heavy traffic region the increase in the ozone level may be due to solar activity and not because of NO_X photo dissociation.

Table 2. Annual mean smoothed sunspot numbers & rank correlation coefficient between SSN & O_3

Year	Mean sunspot number	Rank correlation coefficient
1996	9.10	-0.1049
1997	22.71	-0.7028
1998	62.42	-0.5962
1999	95.34	-0.7448
2000	116.83	0.764
2001	112.27	-0.1486
2002	103.76	0.6241
2003	63.80	-0.2115
2004	40.47	0.2168

Conclusion

There exists a high positive correlation (+0.94) between the annual surface ozone concentration and annual smoothed sunspot number. Fig. 2 shows the variation between annual surface ozone concentration and annual smoothed sunspot number which is linear. Sunspots are maximum during the years 2000, 2001 and 2002. Annual mean surface ozone levels are also maximum in the corresponding years. Annual mean smoothed sunspot number and the Spearmen's rank correlation coefficient values between annual mean smoothed sunspot number and the annual mean ozone concentration are used to plot the curves in the Fig. 3. From the figure it can be seen that there are two strong peaks in the rank correlation values with high positive values 0.764 and 0.624 for the years 2000 and 2002. The annual mean sunspot numbers also maximum for those two years. But the rank correlation coefficient value for the year 2001 is – 0.148.

Generally ozone production depends on several factors such as temperature, solar activity, wind speed and direction. In this work the strong two peaks of rank correlation coefficient between annual mean smoothed sunspot number and the annual mean ozone concentration obtained in the years 2000 and 2002 represents the influence of solar activity.

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