

## Association between surface ozone and solar activity

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### Abstract

The possible relationship between surface ozone and smoothed sunspot numbers (SSN) has been studied. The sunspot data were collected from Udaipur Solar Observatory for 1996-2004. Surface ozone has been measured at Tranquebar (11°N, 79.9°E), a tropical rural coastal site on the east coast of southeast India, during the same period. The measurements have shown that there exists a significant diurnal cycle/oscillation of average ozone with a maximum concentrations in the afternoon and average minimum ozone concentration at sunrise. Ozone measurements have also shown that the average higher concentrations [23 ± 9 ppbv] in May and lower concentration (17±7 ppbv) in October at this site. Further, the increase in surface ozone in association with increase in sunspot numbers is observed during May and October.

**Keywords:** Smoothed sunspot numbers; surface ozone; significant diurnal cycle.

### Introduction

Ozone belongs to the group of atmospheric trace gases. However, owing to its significant oxidizing ability and active interaction with solar ultraviolet radiation, ozone plays a significant part in ecology and radiation and dynamic processes in the atmosphere. For e.g., tropospheric photochemical processes with the participation of ozone and UV-B ultraviolet radiation can change the composition of the lower atmosphere. (Butukhanov & Lomukhin, 2008).

The ozone measurements recorded during the 19<sup>th</sup> century show that ozone concentration was about 10 Ppbv at mid latitudes over Europe and 5 Ppbv in tropical regions, with little variation through the year (Mickley *et al.*, 1999). It is an effective greenhouse gas responsible for climate change Northeast and Southeast Indian regions has high potential for ozone formation because of increasing oxides of nitrogen (Nox) and high solar radiation (Staudt AC., 2003).

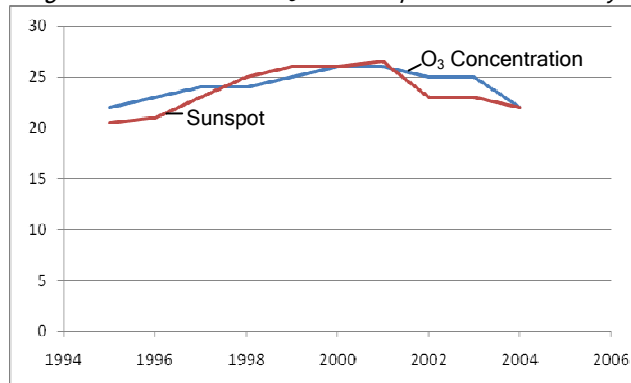
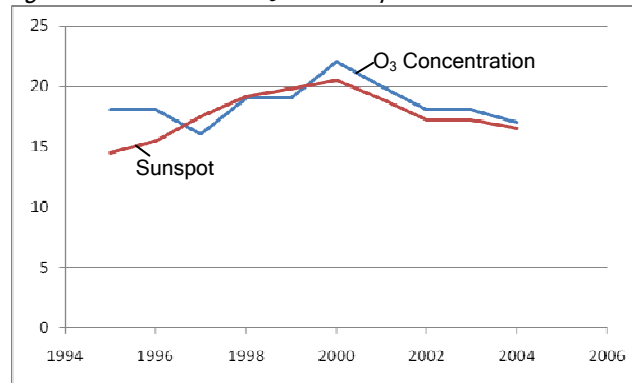
In this paper, we present ozone measurements which have been carried out for the first time in this region at Tranquebar, a remote rural and coastal site on the coromandal coasts of the Bay of Bengal, India.

### Location and instrumentation

Tranquebar is situated on the eastern coast of India. There is no major industrial complex located in the town. The month May is the representative for the summer season (March-May). The weather at the site during May is very hot due to intense solar radiation. The day time temperature reaches above 40°C and night time above 30°C. The site receives heavy rainfall only during northeast monsoon Oct- Dec which is the main rainy

season (Singh & Sontakke, 1999). The month January is the representative for the winter season (Jan- Feb). The month of July is the representative for the pre-monsoon season (Jun- Sep).

The ozone concentration in parts per billion by volume (ppbv) were estimated by neutral buffered potassium iodine (NBKI), (Ph = 6.8 ± 0.2) method, by bubbling a known volume of ambient air (2l/min for 30 min). This air is allowed to pass through the solutions containing KH<sub>2</sub>PO<sub>4</sub>, Na<sub>2</sub>HPO<sub>4</sub> and KI, followed by spectrophotometer measurement of I<sub>2</sub> at 352 nm wavelength. The ozone is estimated as 1 μl ozone ml<sup>-1</sup> = 4.09 × 10<sup>-6</sup> mol I<sub>2</sub> in 100 ml (Perry & Young, 1977). The ambient air sampling was carried out for collection of eight samples each times are given in Indian Standard Time (IST), which is ahead of the GMT by 5.5 h. The sample has been collected for 10 days continuously in a month of Jan, May, July and Oct from May 1996 to Oct 2004. As this method is intended for the manual determination of ozone concentration for 30 minutes time averaged, a sharp peaks (pulses) in ozone concentrations are not observable. The NBKI method have been calibrated with UV photometric ozone analyzer (Model ozone 42 M, Environment S.A. May 2002) by running them together by keeping averaging time interval of 30 min. Correction coefficient for ozone concentration above 1 ppbv for both the instruments is found to be 0.86. The UV ozone analyzer have minimum detectable limit of about 1 ppbv with response time 50 s. The daily surface meteorological parameters data are used from Indian Meteorological Department (IMD) for the above period at the nearest observatory Nagapattinam (10.8°N, 79.9°E, 9m).

Fig. 1. Plots of surface  $O_3$  and sunspot numbers for May.Fig. 2. Plots of surface  $O_3$  and sunspot numbers for October

### Results and discussion

It is known that ozone concentrations as well as solar flux in tropical region are more (Hingane, 1988). A number of studies have been reported on troposphere ozone behaviour and concentration from different parts of the world. One recent study about surface ozone concentration at rural, tropical state says that the average ozone concentration are higher ( $23 \pm 9$  ppbv) in May and lower ( $17 \pm 7$  ppbv) in Oct (Debaj *et al.*, 2003). Moreover, surface air temperature is highest (about  $36^\circ\text{C}$ ) during July whereas higher ozone concentration (23 ppbv) is observed during May instead of July (21 ppbv) due to more cloudiness during the month of July. Further rainfall and sky cover, which are higher during the month of Oct, shows negative correlation with temperature and ozone concentration.

Debaj *et al.* (2003) in their study indicated that ozone concentrations are higher in May and lie lower in Oct. But, in the same period (1996-2004) ozone concentration are a little bit higher in some particular years with increasing the sunspot numbers. This shows that there is some relation between surface ozone and sunspot numbers.

During periods of maximum sunspots, the sun emits more energy (about 0.1% more) than during the periods of sunspot minima (Donald Ahrens, 2000). Evidently, the greater number of bright areas (faculae) around the sunspots radiates more energy, which offsets the effects of the dark spot. However, most of this variation 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 take place at ultraviolet wavelengths, with 19% of the increase taking place between the 200 and 300 nm region, although only 1.2% of the total irradiance is emitted in this wavelength region (Lean, 1989).

The solar activity affects the earth's atmosphere, below the ionosphere. Because sunlight is required to produce ozone, concentrations of troposphere ozone are normally higher during the afternoons, during the summer months, and during the maximum solar activity.

### Conclusion

Ozone concentration increases with rising sunspot number. Generally, solar radiation plays a vital role in the surface ozone concentration. Fig. 1. gives the association between the solar radiation and ozone concentration. Ozone concentration in the month of May, which is the hottest month of the study site is increased with higher amount of solar radiation. Apart from this usual annual trend between ozone concentration and solar radiation, there are some peaks around the year 2001 and 2002. These years are having higher sunspot numbers.

The surface ozone concentration has also a clear diurnal cycle, with the higher values in day time and lower values at night. To determine the seasonal variation of surface ozone concentration, measurements were made for all the months of the year. In summer the surface ozone concentration was the highest compared to the other months. The surface ozone concentration was considerably higher next to May in the month of Oct. The surface ozone concentration is more or less same for all the other months. Variation in the seasonal surface ozone concentration is presented in the Fig. 1 and 2.

The surface ozone concentration depends on metrological conditions such as temperature, solar radiation, wind speed and direction. In this study this relation is not considered. Results of this research revealed that the surface ozone concentration is markedly correlated with sunspot numbers. The surface ozone concentration is higher in the month of May due to the greatest amount of solar radiation. The enhancement of surface ozone concentration has been observed in association with the increasing sunspot numbers. This feature is more significant in May than in Oct.

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Table 1. Ozone concentration and sunspot numbers for the period 1996-2004

Month	1996		1997		1998		1999		2000		2001		2002		2003		2004	
	O <sub>3</sub>	SSN	O <sub>3</sub>	SSN	O <sub>3</sub>	SSN	O <sub>3</sub>	SSN	O <sub>3</sub>	SSN	O <sub>3</sub>	SSN	O <sub>3</sub>	SSN	O <sub>3</sub>	SSN	O <sub>3</sub>	SSN
JAN	20	10.4	20	10.5	21	43.8	22	82.6	22	112.9	22	108.7	23	114.1	22	79.5	21	37.3
FEB	21	10.1	21	11	22	49	22	84.6	23	116.8	22	104	23	107.3	23	46.2	22	45.6
MAR	21	9.7	21	13.5	23	53.5	23	83.8	23	119.9	22	104.8	24	98.3	24	61.5	23	49.1
APR	22	8.4	22	16.5	23	56.6	23	85.5	24	120.8	23	107.5	25	120.7	25	60	23	39.3
MAY	22	8.0	23	18.5	24	59.4	24	90.5	25	119	26	108.6	26	120.8	25	55.2	22	41.5
JUN	21	8.5	21	20.4	23	62.5	22	93.1	23	118.7	24	109.8	23	84.3	23	77.4	23	43.2
JUL	19	8.4	19	22.7	23	65.5	21	94.3	23	119.8	24	111.7	22	99.6	20	85	22	51
AUG	18	8.3	19	25.1	20	67.8	20	97.5	20	118.6	23	113.6	21	116.4	19	72.7	21	40.9
SEP	19	8.4	19	28.4	19	69.5	20	102.3	21	116.3	20	114.1	21	109.5	19	48.8	19.6	27.7
OCT	18	8.8	18	31.9	16	70.5	19	107.8	19	114.5	22	125.7	20	97.5	18	65.6	17	48.4
NOV	18	9.8	17	35	17	73	19	111.0	18	112.7	20	106.5	19	95	18	67.2	18	43.7
DEC	19	10.4	19	39	20	77.9	21	111.12	21	112	19	132.2	18	81.6	20	46.5	21	17.9

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