International Journal of Multidisciplinary Research and Growth Evaluation.

Tropical ozone depletion and its correlation with relative sunspot numbers

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Article Info

ISSN (online): 2582-7138
Volume: 03
Issue: 04
July-August 2022
Received: 26-06-2022
Accepted: 13-07-2022
Page No: 200-204
DOI:
https://doi.org/10.54660/anfo.2022.3.4.10

Abstract
The paper presents yearly and seasonal variations of ozone concentrations from 1988 to 2005 at Srinagar ($34^{0}04^{/}$ N, $74^{0}29^{/}$E), which is an Tropical station. Yearly mean ozone values decreased gradually with different rates from 1988 to 2005. Oscillatory nature of variation ozone concentration with relative sunspot numbers denotes similar contribution of solar parameter and chemical processes in depletion of ozone

Keywords: Ozone depletion, tropical ozone, relative sunspot numbers, ozone variation

Introduction

Although ozone is a very minor constituent of atmosphere but it may act as a vital role in controlling the chemical kinetics of the atmosphere [1]. Recent ozone assessment confirms that the concentration of ozone had declined everywhere by a little amount [2]. But Farman *et al.* [3] first reported that dramatic decrease of ozone concentration took place at Antarctica during springtime. There are some theories that have been proposed by different researchers all over the world for the dramatic decrease of ozone at Antarctica [4, 5]. Chemical, dynamical and natural theories are mainly important [6].

According to chemical theory, different chemical reactions act as an important role in ozone depletion. The chemicals which catalyze the ozone destruction reactions are Ox [7], HOx [8, 9], Cl and ClOx [10, 11] etc. Ozone is not depleted rather it is redistributed in the stratosphere according to dynamical theory. As a result ozone hole is formed at Antarctica during spring time. Conventionally ozone hole [12] is created in a specific geographic place where its ozone abundance becomes ≤ 220 DU. Polar vortex is a small portion of the atmosphere isolated by the polar circulation during winter season in that region. The vortex formation is generally centered over eastern Antarctica in the South Polar Region. Antarctic polar vortex is more intense than its Arctic counterpart [13]. According to natural theory, volcanic eruption, solar UV- radiation variability, relative sunspot numbers, solar flare numbers, solar flare index etc. can play a vital role in ozone depletion. The effect of solar activity on ozone variation was first studied by Chakrabarty and Chakrabarty [14]. The variation of ozone with solar flare numbers and solar UV-radiation [15] for the period 1967-1987 and 1978-1984, respectively, clearly showed that Antarctic ozone, solar flare number and solar UV-fluxes were maintained by their October values mainly. The intense decrease in Antarctic ozone concentration was not dependent of solar UV- flux and solar flare number. Antarctic ozone depletion has a correlation with solar flux [16] Solar flare index and Relative sunspot numbers had a same type of effect on Antarctic ozone layer decline for the duration 1964-1985.The purpose of this paper is to verify the effect of relative sunspot numbers on the variation of tropical ozone for the later period.

Characteristics of variation of ozone

Yearly Variations

Ozone concentration of different stations has been obtained from internet website http//jwocky.gsfc.nasa.gov published from NASA, USA. Monthly mean ozone concentrations value has been obtained from the daily average value of ozone in Dobson Unit (DU) for the station Srinagar. The early mean ozone concentrations have been calculated from monthly average value of ozone in (DU).

The yearly mean ozone concentrations variations and monthly mean ozone concentrations for all months from 1988 to 2005 at Srinagar have been shown in Figure1. The nature of variations of ozone concentrations for every month of various years has been compared with yearly mean the variation of ozone concentrations. It has been observed that the variations of ozone concentrations for all months and variation of yearly mean ozone values followed nearly the same trend. The nature of variation of January ozone mean value from 1988 to 2005 was the most identical with the variation of yearly mean ozone values for the same period and the variation of May ozone mean values was the least identical with the variation of yearly mean ozone values from1988 to 2005 at Srinagar. It is also verified by the co-efficient of correlation value. The co-efficient of correlation between January ozone mean value with yearly mean values was the highest which was 0.82 and it was the minimum for February ozone mean values (0.56). At Srinagar the yearly mean concentration of ozone as well as the ozone concentrations for each month was gradually diminishing from 1988 to 2005 at different rates except in the month of July. The yearly mean ozone depletion rate was 0.3898 Du /year. And it was 0.4083 DU and 0.9749 DU per year for the months January and May respectively. In case of the month July, ozone concentration had increased by 0.0453 DU/year from the period 1988 to 2005.

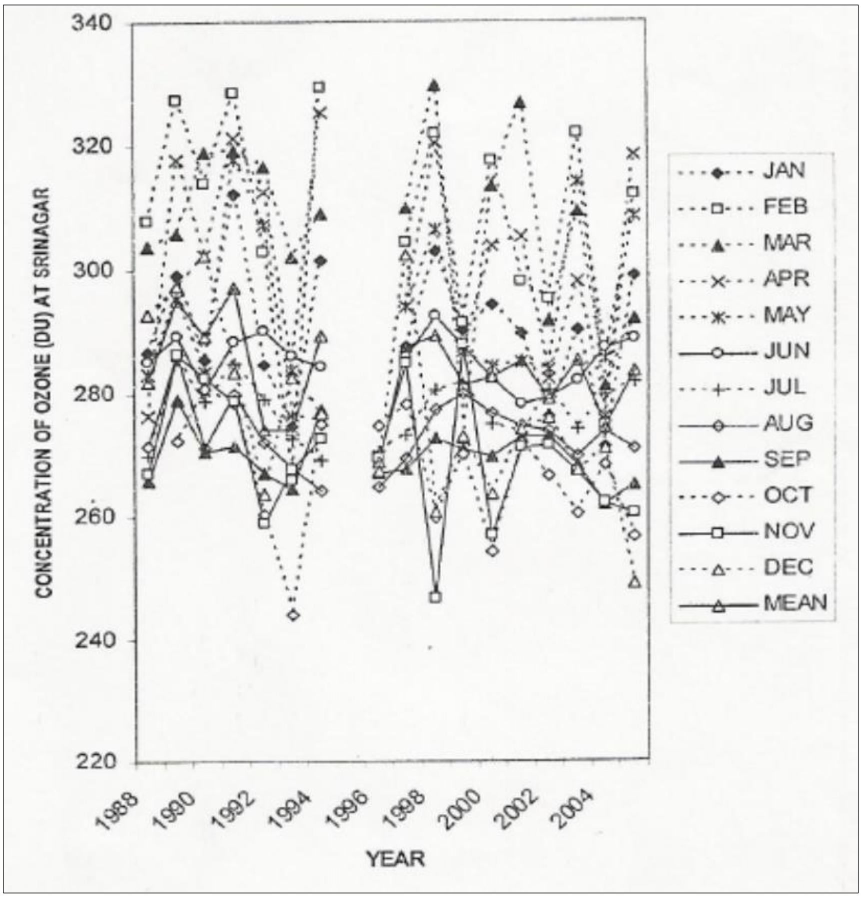

Fig 1

Seasonal Variation

Figure 2 reveals the seasonal variation of ozone concentrations for every year and their mean variation for the station Srinagar from 1988-2005. It has been found that seasonal variation in every 12 months and mean seasonal variation observed almost the equal trend. The nature of seasonal variation of ozone mean values for the year 1992 and 2004 among the years from 1988-2005 was the most identical with the mean seasonal variation and the seasonal variation for the year 1999 and 2002 among the years from 1988 to 2005 was the least identical with the mean seasonal variation respectively. It is verified with the help of co-efficient of correlation value also. The co-efficient of correlation between the seasonal variations of ozone mean values for the year 1992 and 2004 with the mean seasonal variation was the maximum (0.97 and 0.99). It was the minimum for the year 1999 and 2002 (0.44 and 0.73) respectively. Ozone concentration attained the maximum value for the months of January to March. The minimum ozone concentration occurred at the month of October. Ozone concentration gradually decreased from January, attained its minimum for the period of October and then gradually increased.

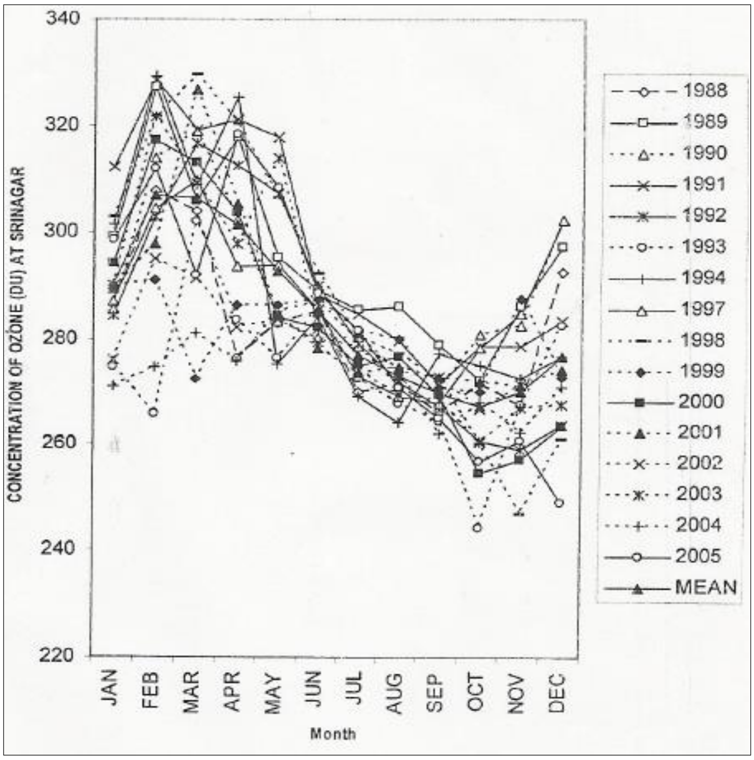

Fig.2

Nature of variation of relative sunspot numbers: Relative sunspot numbers are collected from the website ftp://ftp.ngdc.noaa.gov/stp/solar Data/sunspot Numbers Monthly. Variations of month to month mean relative sunspot numbers for various months and their mean variation from 1988 to 2005 have been depicted in Figure 3. The nature of variations of relative sunspot numbers for each month for different years has been compared with the variation of yearly mean relative sunspot numbers. It has been observed that the variations of relative sunspot numbers for all months and variation of yearly mean relative sunspot numbers followed nearly the same trend. The nature of variation of April relative sunspot numbers from 1988 to 2005 were the most identical with the variation of yearly mean relative sunspot numbers for the same period and the variation of February relative sunspot numbers was the least identical with the variation of yearly mean relative sunspot numbers for the same period . It has also been verified by the value of co-efficient of correlation. The co-efficient of correlation between April relative sunspot numbers with yearly mean values was the maximum (0.97). For the month of February relative sunspot numbers is minimum and which was 0.85. The yearly mean relative sunspot numbers as well as the relative sunspot numbers for all months was gradually decreasing from 1988 to 2005 at different rates. The rate of diminishing in relative sunspot numbers varied from 5.1315 to 1.6062 each year. The decreasing rate of yearly mean relative sunspot numbers was 0.7442 DU/year.

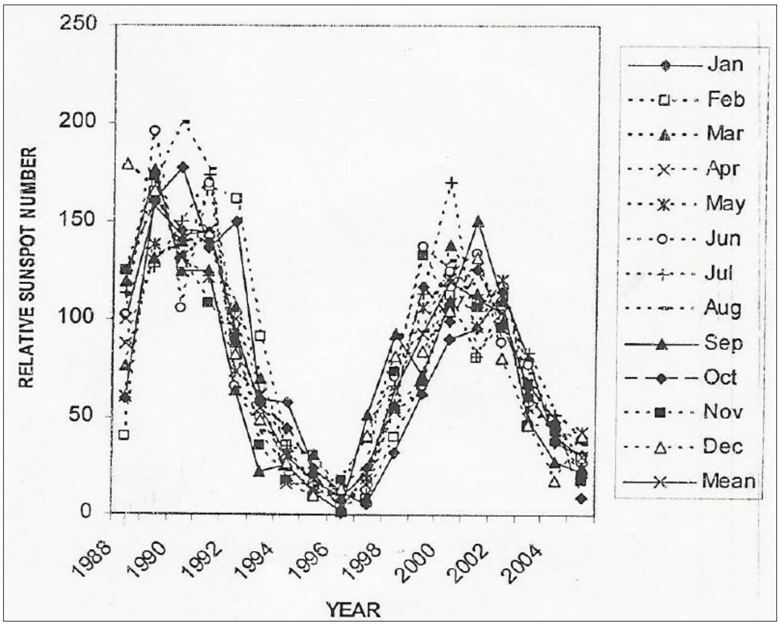

Fig 3

Seasonal variations of relative sunspot numbers for some different years and their mean variation from 1988 to 2005 have been presented in figure 4. The nature of seasonal variation of relative sunspot numbers for each year differs from each other. Mean seasonal variation clearly shows that from January to May relative sunspot numbers gradually decreased, thereafter increased to the month of August and then again gradually decreased. Minimum relative sunspot numbers occurred during the month of May and maximum in August. It has been observed that the seasonal variations of relative sunspot numbers in the year 1991 was the most identical with their mean variation and for the year 2002 was the least identical. It has also been verified by the value of co-efficient of correlation. The values of co-efficient of correlation between 1991 seasonal variations of relative sunspot numbers with mean seasonal variation were 0.67) and that for 2002 was -0.44. A decreasing trend in relative sunspot numbers has been observed from January to December for the years 1990 to 1995, 2000 and 2002 to 2005. The rate of decrease varied from 0.4567 to 5.867 per month. An increasing trend in relative sunspot numbers has been observed from January to December for the rest years. The rate of decrease varied from 1.987 to 9.6413 per month. The mean seasonal variation of relative sunspot numbers showed an increasing trend with 0.4447 per month.

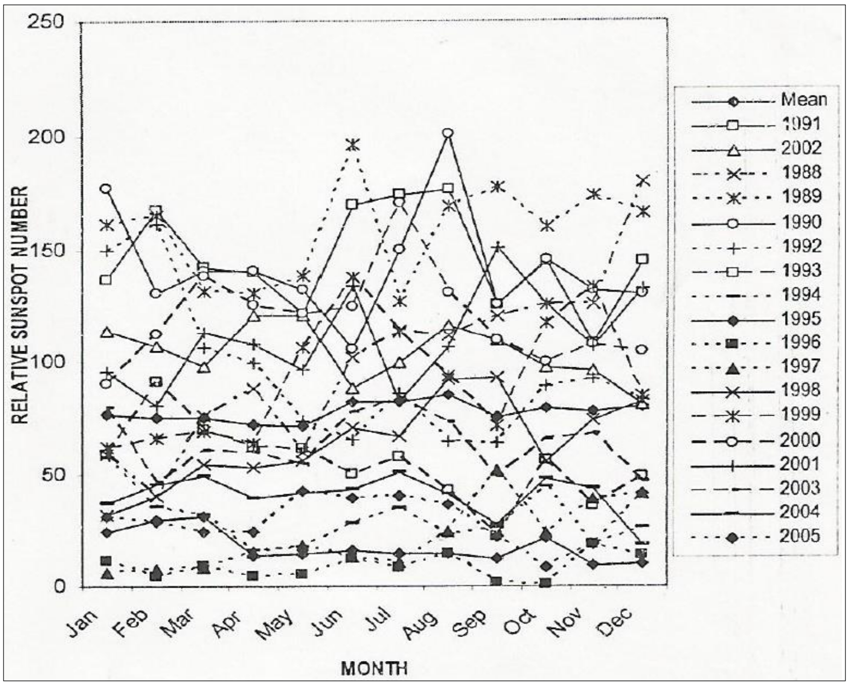

Fig 4

Effect of relative sunspot numbers on ozone variation

Figure 5 depicts the scattered diagram of variations of ozone concentration at Srinagar with relative sunspot numbers. This figure clearly reveals that the nature of ozone variation with relative sunspot numbers was oscillatory. The concentration of ozone had increased very slightly for above period with increase in relative sunspot numbers. But generally, ozone depletion should increase with increase of solar activity. It clearly indicates that some chemical processes play an important role to control the formation and destruction processes of ozone. Hence, the effect of solar parameters and chemical processes on ozone decline is comparable. So oscillatory nature is quite expected.

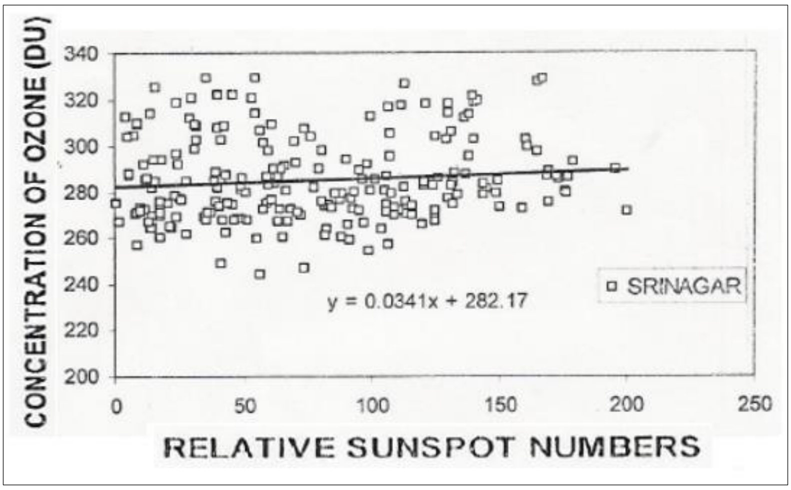

Fig 5

Conclusion

Yearly mean ozone concentration had decreased gradually at Srinagar with different rates from 1988 to 2005. The maximum and minimum ozone values occurred in the months of January to March and October, at Srinagar. The concentration of ozone gradually decreased from the month of January attained minimum in October and thereafter gradually increased. The nature of variation of relative sunspot numbers clearly depicts that yearly mean as well as monthly mean relative sunspot numbers had declined from 1998 to 2005. Scattered diagram shows the oscillatory nature of ozone variation with relative sunspot numbers which indicates that effect of solar parameters and chemical processes on ozone decline is comparable.

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